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BOOK OF ABSTRACTS

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Submission number: 2

ACCURATE MODELING OF QUANTUM TRANSPORT IN GRAPHENE GEOMETRIC DIODE FOR THZ RECTENNA APPLICATIONS

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Keywords: Modeling and Simulation; Nanoelectronics

Graphene geometric diodes could provide rectification at terahertz frequencies and present promising application in rectennas design for sensing and energy harvesting. This paper presents a multiphysics model for the simulation of rectennas, coupling quantum mechanics to simulate ballistic transport in the geometric diode and non linear electromagnetic simulation for the antenna rectification. The current-voltage characteristic, computed through a time-dependent Schrödinger equation approach, is then compared with experiments from the literature, providing a good matching. The diode has subsequently been used as a non linear element in the modelling of the rectenna device achieving a rectified voltage in the order of ten mV and a DC power conversion efficiency for different parallel resistive loads of few kiloohms in the range of 0.01%.

Submission number: 3

EXPLORING LEAD-FREE BISMUTH HALIDE PEROVSKITE NANOGENERATORS AND LITHIUM-ION BATTERIES FOR SELF-CHARGING POWER UNITS

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Keywords: Nano-Energy, Environment, and Safety

Halide perovskite, renowned for multifunctional properties, holds significant potential for realizing self-charging power systems, representing a pivotal advancement in sustainable energy technology. Herein, the potential application of a lead-free methylammonium bismuth iodide (MA3Bi2I9) perovskite for a self-charging power unit is demonstrated. This involves constructing a hybrid piezoelectric-triboelectric nanogenerator (HP-TENG) and utilizing MA3Bi2I9 for energy storage as a cathode in a lithium-ion battery (LIB). Initially, synthesized MA3Bi2I9 nanorods were composited with polystyrene-block-poly(ethylene-ran-butylene)-block-polysty rene (SEBS) polymer, and the dielectric and mechanical properties of composite films with perovskite loading content were investigated. The optimized HP-TENG exhibited superior performance, generating a voltage of 537 V, current density of 13.2 -956;A/cm² and maximum power density of 3.04 mW/cm2 attributed to the high piezoelectric coefficient of MA3Bi2I9 nanorods (-61566;20.6 pm/V). Moreover, MA3Bi2I9 thin films, serving as a cathode in LIB, demonstrated the highest specific capacity of 2378.9, mAhcm–3 with a capacity retention of -61566;87% for 150 cycles, underscoring its stable performance. Furthermore, HP-TENG was employed to charge the MA3Bi2I9-based LIB, showcasing the realization of a self-charging power unit for small-scale electronics. This study underscores the promising potential of perovskite materials in the development of high-performance nanogenerators and LIBs.

Submission number: 32

UNRAVELLING THE IMPACT OF RANDOM DOPANT FLUCTUATIONS ON SI-BASED 3NM NSFET: A NEGF ANALYSIS

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Keywords: Nanoelectronics; Modeling and Simulation; Nanofabrication

The utilization of Technology Computer-Aided Design (TCAD) tools for the simulation of both conventional and new electronic devices has become a crucial aspect within the semiconductor industry, as well as in academic research. This paper presents a comprehensive overview of our research investigating the impact of random dopant fluctuations on “3nm node” silicon nanosheet field effect transistors (NSFETs) fabricated. Our study employs NESS (Nano-Electronic Software Simulator), the in-house device simulator developed by the Device Modelling Group at the University of Glasgow. The first principle study was performed to calculate the electrical parameter of the material, and later a fully 3-D real Non-equilibrium Green’s function (NEGF) simulation was performed to capture the device characteristics.

Submission number: 33

SPECTRAL ENGINEERING OF A MICRO-CAVITY USING NANO-SCALE ASYMMETRY

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Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanoscale Communications; Modeling and Simulation

A nano-scale asymmetrical grating applied to the circumference of a micro-cavity is proposed, creating a simple asymmetric micro-gear structure with unique characteristics. We demonstrate the effect of this asymmetry on mode splitting by correlating its dimensions to the free spectral range. Additionally, mode-dependent emission behavior is observed, selectively radiating whispering gallery modes (WGM) out-of-plane. Due to asymmetry, clockwise and counterclockwise versions of the cavity exist, enhancing the probability of a certain rotational direction of the WGMs. This enables the generation of vertically emitted modes of non-zero orbital angular momentum with specific order and chirality.

Submission number: 34

NANOPARTICLE TOMOGRAPHY FOR VASCULAR ANEURYSM DETECTION

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Keywords: Nanosensors and Nanoactuators; Nanobiomedicine; Modeling and Simulation

A vascular aneurysm (VA) is an abnormal bulge or ballooning in the wall of a blood vessel, which results in a great risk of death after rupture. The best way to avoid VA rupture is to detect it at an early stage and take proper measures. However, there is no suitable method for early detection of VA. In this paper, we propose a novel nanoparticles (NPs) based sensing method for VA, namely, NP tomography (NPT). We first construct multiple blood vessel models in the forward problem by varying the location of VA and obtain the time-of-arrival (TOA) of NPs. In the inverse problem, we then infer the actual location of VA based on the recorded TOA of NPs, thereby enabling early VA sensing. The proposed methodology is validated through comprehensive COMSOL simulations. Numerical results demonstrate that the VA detection rate through NPT can be as high as 96%.

Submission number: 35

WSE2 NEGATIVE CAPACITANCE FIELD-EFFECT TRANSISTOR FOR GLUCOSE SENSING

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Keywords: Nanoelectronics; Nanobiomedicine; Nanofabrication

Field-effect transistor (FET) biosensors based on two-dimensional materials have been widely concerned in recent years because of their high sensitivity, label free, fast response and easy on-chip integration. However, constrained by the Boltzmann limit, the subthreshold swing (SS) of these sensors cannot fall below 60 mV/dec, posing challenges for further sensitivity enhancement. We present the biosensor based on a two-dimensional material WSe_2 negative capacitance field-effect transistor (NCFET) with graphene electrodes, which achieves ultra-steep subthreshold swing (SS<60 mV/dec) in aqueous solution, while demonstrating extremely high glucose sensing sensitivity. At room temperature, WSe_2 NCFET achieves a minimum subthreshold swing of 56 mV/dec in a liquid environment, and was used for the first time to detect glucose molecules with high sensitivity, wide detection range and specificity by enzymatic catalysis. The sensitivity of the WSe_2 NCFET biosensor could reach 4800 A/A in a glucose solution with a concentration of 5 mM. This work inspires further basic research and potential applications for highly sensitive biosensors.

Submission number: 36

COUPLING AEROSOL AND PLASMA PROCESS FOR THIN FILM DEPOSITION: FROM THE SYNTHESIS OF THE COLLOIDAL SOLUTION TO THE FINAL COATING

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Keywords: Nanomaterials; Emerging Plasma Nanotechnologies; Nanofabrication

Abstract— Plasma processes for thin film deposition generally involve continuous injections of gases or vapors in the reactor. However, it is difficult to inject slightly volatile liquids, as well as mixtures, liquid solutions with highly reactive molecules, or colloidal solutions. The direct injection of liquids as aerosols, i.e. droplets in a gas phase is a real opportunity.[1] It becomes possible to inject any liquid solutions regardless their composition. For nanocomposite thin film deposition, this involves injecting accurately defined, dispersed, and stable nanoparticles in a liquid solution containing the matrix precursor. It is therefore crucial to master the synthesis of nanoparticles including their stabilization to avoid their aggregation during the process [2]. Here, we are injecting pentane solutions containing ZnO nanoparticles. These latter are obtained in pentane through the hydrolysis of a highly reactive zinc precursor in the presence of two stabilizing agents namely, dodecylamine (DDA) and oleic acid (OA). These ligands form catanionic pairs surrounding the nanoparticles i.e. an ionic shell that efficiently prevents aggregation [3]. They also control the nanoparticles size and, consequently, their optical properties[4]. In addition, the aerosol formed from these solutions is highly controlled with droplets in the 10 µm size. Hence, it enables to plasma deposit nanocomposite thin films.

Submission number: 38

SIZE-DEPENDENT FORMATION OF AU-NPS MONOLAYER UNDER HIGH ELECTRIC FIELD

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Keywords: Nanofabrication; Nanomaterials; Nanopackaging

Nanoparticles (NPs) are considered functional materials due to their fundamental properties of high surface-to-volume ratio, high conductivity, and diversified surface functionalization. We conducted experiments on NPs of different sizes and calculated their UV-Vis absorption and zeta potential when they were suspended as a colloid solution of DI water with some traces of citrate. NPs are stabilized by citrate ions and rendered with a net negative surface potential, which can be confirmed by using a zeta-sizer for zeta potential measurement. Citrate ions acting as ligands form a coating on the surface of NPs and induce electrostatic repulsion due to their overall negative charges, whereas NP’s inner cores attract each other due to the van der Waals (vdW) force of attraction. The balance of repulsion and attraction keeps NPs stabilized in the aqueous solution for a prolonged period. Different sizes of NPs were subjected to an electric field to form the monolayer on a silicon substrate. The NPs of smaller sizes form an incomplete monolayer of disintegrated islands, due to their lower core: core attractions, these NPs fail to make a uniform and continuous monolayer. NPs of sizes greater than 40 nm show aggregation when placed in a high electric field environment due to their large core size and hence elevated core: core attraction. These large NPs aggregate irreversibly and form the clumps of NPs called nanoclusters. Interestingly, the optimal size of 20nm NPs leads to the formation of a perfectly hexagonally packed monolayer on the substrate when subjected to an electric field of <i>E -8776; 7.2 x 10^4 V/m.

Submission number: 39

STRETCHABLE JOULE HEATING ELECTRODE BASED ON HYBRID LAYERS OF SILVER NANOWIRES AND CARBON NANOTUBES

Pei, Qibing*

Keywords: Nanotechnology in Soft Electronics

Stretchable electrodes are an essential component in soft actuators and sensors. In particular, joule heating electrodes are required for thermal actuation systems. We present a highly compliant, patternable, and low-voltage operating joule heating electrode based on hybrid layers of silver nanowires and carbon nanotubes. The conductive layers were applied on a locally pre-strained bistable electroactive polymer (BSEP) membrane with a low resistance, and subsequently patterned by laser engraving. The resistance of the resulting electrode remains nearly almost unchanged up to 100% strain. A relatively low voltage applied to the electrode can heat up the BSEP membrane well above the polymer's phase transition temperature, thereby lowering its modulus. An electronic braille device based on the new joule heater was assembled. The electrode was patterned into individually addressable pixels according to the standard U.S. Braille cell format. Through joule heating of the pixels and local expansion of the BSEP membrane with a pneumatic pressure, the pixels deformed out of the plane to raise pins to display specific braille letters. The braille content can be refreshed.

Submission number: 41

DEMONSTRATION AND OPTIMIZATION OF MULTI-FIN DUAL SPACER FINFET FOR RELIABLE SUB-THZ FREQUENCY OPERATION

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Keywords: Modeling and Simulation; Nanoelectronics

This paper proposes a dual dielectric (DD) spacer multi-fin (MF) FinFET for sub-THz frequency operation. The placement of the DD spacers over the source/drain (S/D) extension regions offers additional capacitances, which are included in the modified small-signal model to predict the Y-parameter behavior accurately. The modeled Y-parameters are in good agreement with the TCAD-extracted data. Dual spacer capacitance increases the gate coupling and thus improves the DC performance. The optimized device shows the stable marginal frequency (fm) of 88.2 GHz, which is 21% higher than the baseline FinFET but at the cost of a diminished ratio of cut-off frequency to maximum oscillation frequency (fT/fmax) due to additional spacer capacitance. fT and fmax are obtained as 358 GHz and 579 GHz, respectively, for the optimal dual dielectric length. The paper thoroughly explores the behavior of capacitance and resistance modulation, transconductance, and intrinsic gain concerning the high--954; spacer length and the number of fins (n). A comprehensive analysis of various RF and stability figure-of-merits (FoMs) is conducted to determine the optimal operating conditions.

Submission number: 42

ON-THE-FLY DEFECT-AWARE DESIGN OF CIRCUITS BASED ON SILICON DANGLING BOND LOGIC

Drewniok, Jan*; Walter, Marcel; Ng, Samuel Sze Hang; Walus, Konrad; Wille, Robert

Keywords: Nanoelectronics; Quantum, Neuromorphic, and Unconventional Computing;

Modeling and Simulation

Silicon Dangling Bonds (SiDBs) have emerged as a promising post-CMOS technology for achieving ultra-low power dissipation, establishing themselves as a highly anticipated and environmentally friendly competitor in the realm beyond conventional CMOS. To support the SiDB logic framework, design automation approaches have rapidly evolved. However, at the atomic scale of SiDBs, material imperfections pose a significant roadblock in scaling these devices. Consequently, established design automation flows, which are defect-agnostic, are inadequate and have not kept pace with the latest experimental findings and advances in fabrication capabilities. A first attempt was recently proposed that extends established defect-agnostic physical design methods by rudimentary defect-aware capabilities. While promising at first glance, in this work, we show that this first attempt yields unsatisfactory results. Subsequently, we present a novel approach that automatically designs a tailored SiDB gate on-the-fly whenever an SiDB gate encounters atomic defects in its vicinity, thereby incorporating these atomic defects into its layout as an integral part. Our experimental evaluations confirm that the proposed approach is capable of designing SiDB circuits of significant complexity and size, even in the presence of atomic defects for the first time. Therefore, this work contributes to advancing this promising post-CMOS technology.

Submission number: 43

NONLINEAR OPTICAL SUSCEPTIBILITIES OF [100], [110] AND [111] SILICON NANOWIRES: A DFT STUDY

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Keywords: Modeling and Simulation; Nano-Optics, Nanophotonics, and

Nano-Optoelectronics; Nanomaterials

Using time-independent density functional theory (TIDFT), we demonstrate enhancement of the 2nd order optical susceptibilities of narrow (1 nm - 2 nm) unstrained Silicon Nanowires (SiNW) due to surface termination. It is shown that -967;(2) is enhanced up to 200 pm/V which promises a strong second harmonic generation (SHG) in SiNWs. For [100], [110] and [111] SiNWs, the yxx component of -967;(2) tensor is 81, 225 and 81 pm/V, respectively. These are in close agreement with values reported for strained silicon waveguides in experiments. For [110] and [100] nanowires, the 3rd order nonlinear optical susceptibility, -967;(3), is within the range of (0.1-12)×10-8722;18 m2/V2 which is close to the experimental values for bulk silicon. For [111] nanowires this is 100 times better than bulk silicon. This study shows methods of enhancing SHG in SiNWs through symmetry breaking via strain and/or surface termination and reconstruction. It also showcases the suitability of this fast DFT-based method in predicting the nonlinear optical susceptibilities of nano structures.

Submission number: 47

ADSORPTION DYNAMICS OF CO2 CONTAMINANT USING UNDOPED/DOPED ARGNR

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Keywords: Nanosensors and Nanoactuators; Modeling and Simulation; Nanomaterials

Carbon dioxide (CO2) plays a pivotal role in atmospheric composition and biological processes, but the increase in emissions resulting from fossil fuel combustion and deforestation requires urgent attention. The paramount goal is contributing to sensing CO2 emissions and developing effective strategies for preserving human health. This research employs an analytical study to scrutinize the sensitivity of doped and undoped armchair graphene nanoribbons (ArGNR) to CO2 contaminants. Using a linear combination of atomic orbital (LCAO) calculator, the various electronic properties like binding energy, adsorption energy, band structure, and density of states (DOS) of doped/undoped ArGNR are investigated. The results reveal that an undoped ArGNR exhibits limited sensitivity to CO2, while introducing dopants enhances its responsiveness. Notably, the BP (Boron-Phosphorus) and BAs (Boron-Arsenic) co-doped ArGNR-depict 6-11 times improved chemisorption and a higher CO2 response than the undoped ArGNR. Furthermore, it exhibits a-significantly reduced bandgap of approximately -17 % at the B site, indicating heightened conductivity and sensitivity.-Additionally, the DOS manifests substantial reactivity changes towards CO2 in the case of BAs' co-doped ArGNR compared to BP's co-doped ArGNR.

Submission number: 48

TOWARD DEVELOPMENT OF NANOSTRUCTURE SOLAR CELL: ROLE OF SI IN COPPER-ZINC–GERMANIUM–SULFIDE/SELENIDE

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Keywords: Nano-Energy, Environment, and Safety; Modeling and Simulation;

Nano-Optics, Nanophotonics, and Nano-Optoelectronics

Kesterite solar cells are quite popular these days which are used as photovoltaic applications. On the other hand, their efficiency rates are less than 12.6%. In kesterite solar cells, the utilization of nanostructure improves performance. In this work, the influence of the (BSF) back surface field layer on the performance of DQW (double quantum well) in copper_x0002_zinc-germanium-sulfide and selenide solar cells is investigated. An research of mathematical analysis such as recombination through different loss mechanisms, electrical properties such as IV Characteristics and optical properties such as IQE and EQE are explored. In a photovoltaic solar cell a novel structure CZGS/CZGSe DQW cell using Si as the BSF layer proposed, a remarkable efficiency of 24% without defect and with defect 19% is achieved

Submission number: 49

SPIKING NEURAL NETWORKS WITH NONIDEALITIES FROM MEMRISTIVE SILCON OXIDE DEVICES

Vu, Viet Cuong*

Keywords: Quantum, Neuromorphic, and Unconventional Computing; AI for Nanotechnology; Modeling and Simulation

Recent years have seen a rapid surge in the application of artificial neural networks in diverse cognitive settings. The augmented computational demands of these structures have led to an interest in new technologies and paradigms. Of all the artificial neural networks, the spiking neural network (SNN) is notable for its capability to imitate the energy-efficient signalling system in the brain. The memristor presents a promising potential for the integration of SNN into hardware, despite certain non-ideal device properties posing a challenge to its implementation. This study involves the simulation of a SNN model utilizing experimental data on silicon oxide. Particularly, it examines the impact of a non-linear weight update on SNN performance. SNNs were shown to possess tolerance for device non-linearity, while the network can simultaneously maintain a high degree of accuracy. These results provide valuable prior information for future implementation of silicon oxide device-based neuromorphic hardware.

Submission number: 50

TECHNOLOGY MAPPING FOR BEYOND-CMOS CIRCUITRY WITH UNCONVENTIONAL COST FUNCTIONS

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Keywords: Quantum, Neuromorphic, and Unconventional Computing; Nanoelectronics; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

With beyond-CMOS circuit technologies emerging from scientific endeavors in an effort to outperform transistor-based logic in feature size, operation speed, and energy dissipation, it has become apparent that besides their differences in physical implementations, their design automation techniques also have to evolve past established norms. While conventional logic synthesis aggressively optimizes the number of nodes in logic networks (as a proxy criterion for area, delay, and power improvements), this trope does not incorporate the additional costs caused by inverters and interconnects in the form of wire segments, signal splitters, and cross-over cells as imposed onto novel circuit implementations such as photonic crystals and field-coupled nanotechnologies. In this work, we propose a novel scalable technology mapping algorithm that captures these unconventional costs by utilizing subcircuit databases that are obtained by applying technology-aware exact physical design techniques. This overcomes the substantial quality loss that previously inevitably occurred when generating beyond-CMOS circuit layouts from conventionally optimized logic networks. Our method achieves average improvements of 84.5%, 74.5%, and 65.2% for the number of buffers, the number of crossings, and the critical path length, respectively, as compared to a state-of-the-art physical design algorithm for FCN circuits.

Submission number: 52

UNLOCKING FLEXIBLE SILICON DANGLING BOND LOGIC DESIGNS ON ALTERNATIVE SILICON ORIENTATIONS

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Keywords: Nanoelectronics; Quantum, Neuromorphic, and Unconventional Computing; Modeling and Simulation

With the impending plateau of Moore’s Law, the search for novel computational paradigms has intensified. Silicon dangling bond (SiDB) logic emerges as a promising avenue in this quest, leveraging the quantum-dot-like properties of SiDBs and atomically precise fabrication techniques to realize logic functions at the nanometer scale. Advances in computer-aided design (CAD) tools specialized for SiDB logic exploration have also opened the door to novel logic research from the gate- to application-level. This paper introduces a lattice vector formulation for SiDB logic designs on alternative silicon lattice orientations, enabling the exploration of logic gates on arbitrary lattice orientations and addressing the limitations of previous SiDB logic research confined to the H-Si(100)-2×1 surface. A comprehensive workflow for designing standard tile libraries compatible with design automation frameworks is proposed, facilitating the scaling of SiDB layouts to large-scale systems implementation on multiple lattice orientations. We demonstrate the proposed lattice vector representation and the library design workflow through a case study on the H-Si(111)-1×1 surface, showcasing the first logic gates designed for this orientation. This advancement opens new avenues for SiDB logic research, enabling rigorous evaluations of various lattice orientations for future logic design studies and experimental investigations.

Submission number: 54

IMPACT OF OLEYLAMINE-COATED ZNO NPS AND ZNO-GERANIOL NANOCAPSULES ON THE CONTROL OF THE HERBIVORE TUTA ABSOLUTA IN TOMATO PLANTS

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Keywords: Nanomaterials; Hydrophobic, Oleophobic and/or Icephobic nanostructured surfaces; Nanobiomedicine

Abstract— Among the new horizons that nanomaterials open, nano-agrochemicals are able to improve agricultural production by increasing the efficiency of inputs and minimizing relevant losses. In the present study, primary hydrophobic ZnO NPs coated with oleylamine have been prepared, physicochemically characterized and used as building moieties in combination with the insect repellent, geraniol, in 1:2 mass ratio respectively, for the formation of the secondary nanocapsules. Multiple important biological activities are known for the essential oil geraniol. The prepared nanosystems ZnO@OAm NPs, ZnO@-927;-913;m@Ger NCaps as well as geraniol nanoemulsions (GNEs) were tested for their insecticidal activity against the herbivore Tuta absoluta in tomato plants. The LC50 value for the ZnO@OAm NPs was calculated at 29.11mg/L while the NCaps and GNEs exhibited almost the same and much higher LC50 values at about 286 mg/L. The significantly different insecticidal behavior, up to now, is attributed to nanosize effects as well as to the hydrophobicity/hydrophilicity balance of the studied nanosystems.

Submission number: 57

ENDING THE TYRANNY OF THE CLOCK: SAT-BASED CLOCK NUMBER ASSIGNMENT FOR FIELD-COUPLED NANOTECHNOLOGIES

Walter, Marcel*; Drewniok, Jan; Wille, Robert

Keywords: Nanoelectronics

This paper presents an algorithm for clock number assignment in the physical design process of Field-coupled Nanocomputing (FCN), a set of promising beyond-CMOS technologies that manipulate physical fields instead of electrical currents for computation and information transmission. Clocking has traditionally been a significant obstacle to the scalability of FCN physical design algorithms, requiring pre-defined clocking schemes that limit the quality of circuit layouts and add complexity to the design process. Our proposed method utilizes Boolean Satisfiability (SAT) solving to facilitate the assignment of clock numbers without the need for predefined clocking, while ensuring compliance with technological constraints on information flow and synchronization.-Via an experimental evaluation, we confirm the proposed algorithm's versatility to reconstruct clock assignments for diverse clocking schemes in reasonable runtime, and its scalability up to layouts with a half-million tiles. Thereby, we are potentially paving the way for a new era of physical design algorithms that are not constrained by the limitations of predefined clocking schemes. This research suggests a move towards physical design strategies adapted from conventional design automation, potentially mitigating one of the major challenges to FCN's further development.

Submission number: 59

WIGNER TRANSPORT IN LINEAR MAGNETIC FIELDS: THE QUANTUM MAGNETIC TERM EFFECT

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Keywords: Modeling and Simulation; Nanoelectronics

Modeling the single electron dynamics under the influence of an electromagnetic field is important for next-generation electronic solid-state quantum systems for electron quantum optics and nanoelectronics. To that end, we focus on the gauge-invariant Wigner equation, which explicitly depends on the kinetic momentum of the electron. However, the obtained equation is complex and multidimensional, which poses significant numerical challenges. Therefore, simplifying assumptions are needed to gain first experiences with this new theoretical description. Recent advancements allow for the setting of an electron in a linear magnetic field. The high-order mixed derivative term, caused by the linearity of the field, leads to quantum effects of the electron evolution. Here, we study this so-called quantum magnetic term effect by analyzing its interplay with the single-electron dynamics of a snake state type of evolution. We observe a redistribution of the density while the main path of the electron is preserved, which is supported by the Ehrenfest theorem.

Submission number: 60

A* IS BORN: EFFICIENT AND SCALABLE PHYSICAL DESIGN FOR FIELD-COUPLED NANOCOMPUTING

Hofmann, Simon*; Walter, Marcel; Wille, Robert

Keywords: Nanoelectronics; Quantum, Neuromorphic, and Unconventional Computing

Field-coupled Nanocomputing (FCN) has emerged as a promising alternative to traditional CMOS technology, driven by recent advancements in atomic-scale logic gate fabrication and simulation. However, the efficient placement and routing of logic functions remain significant challenges, with existing algorithms lacking scalability or quality. In this paper, we present a novel method aimed at addressing these challenges by focusing on the generation of layouts with outstanding quality in a fraction of the time compared to existing approaches. Through extensive experimentation, we demonstrate that our method significantly reduces area overhead, outperforming two state-of-the-art heuristics by more than 70% and 24%, respectively, while achieving these results at a remarkable 460 times faster pace compared to the latter. Furthermore, we contribute to open science by releasing our algorithm as an open-source implementation, fostering collaboration and further advancements in the field of FCN.

Submission number: 61

FABRICATION OF TAPERED AND CYLINDRICAL GAN NANOWIRES USING NANOSPHERE LITHOGRAPHY

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Keywords: Nanofabrication; Nanomaterials

Nanowires fabricated using the top-down method can offer high uniformity and precise morphology. However, achieving well-controlled dry and wet etching processes is essential to produce large-area uniform nanowires. It is also interesting to have control on their shape, since tapered structures can have favorable light extraction properties, whereas cylindrical shapes are preference for electronics or photodetection. This paper presents a comprehensive study on the fabrication of GaN nanowires using a top-down approach facilitated by nanosphere lithography. We focus on optimizing both dry and wet etching processes to achieve high-aspect-ratio nanowires with controlled shapes. The final wet etching step, critical for shaping the nanowires, was performed with a crystallography-selective method, resulting in nanowires with vertical m-plane facets or tapered structures, depending on the initial diameter of the spheres. This demonstrates the process's adaptability to control nanowire geometry.

Submission number: 62

UNIFYING FIGURES OF MERIT: A VERSATILE COST FUNCTION FOR SILICON DANGLING BOND LOGIC

Drewniok, Jan*; Walter, Marcel; Ng, Samuel Sze Hang; Walus, Konrad; Wille, Robert

Keywords: Modeling and Simulation; Nanoelectronics

As Silicon Dangling Bond (SiDB) logic emerges as a promising beyond-CMOS technology, Figures of Merit (FoMs) to assess gate performance become crucial in implementing devices that are robust against environmental variations. Constructing robust SiDB logic involves designing gates that excel across multiple FoMs. However, there exist no clear guidelines on the ideal ranges for FoM values, nor a systematic approach to designing SiDB gates that optimize across multiple FoMs. Motivated by this, this work focuses on addressing the following key objectives: 1) Introduction of a new FoM, called Band Bending Resilience. 2) Determination, presentation, and detailed discussion on the best achievable values for each FoM for all 2-input Boolean functions. 3) Presentation of the versatile cost function -967;, unifying multiple FoMs tailored to specific application requirements and priorities. 4) Implementation of the optimization strategy using the cost function -967;, which aims at designing SiDB logic with minimal cost, ensuring an optimal balance between all FoMs. Overall, this research contributes significantly to the understanding of SiDB logic, establishing a basis for future progress in the field.

Submission number: 64

ELECTRICAL MODELING OF ACTIVE LAYER ALTERATIONS IN RESPONSE TO THE APPLIED MECHANICAL STRAIN IN ORGANIC SOLAR CELLS

Ghorab, Mahya; Wagner, Veit; Joodaki, Mojtaba*

Keywords: Nanoelectronics; Modeling and Simulation; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

This study encompasses the first attempt at the electrical modeling of the active layer alterations in response to applied mechanical strain in organic solar cells (OSCs). The effects of applied tensile strain are modeled by the variations in biomolecular recombination and the effective band gap of the complex system in the active layer. A conventional bulk heterojunction (BHJ) OSC with a P3HT:PCBM mixture for its active layer is considered. 2-dimensional (2-D) drift-diffusion equations are solved by employing the finite element method in COMSOL Multiphysics.

Submission number: 65

CHIP-SCALE NANOPHOTONIC TECHNOLOGIES AND APPLICATIONS

FAINMAN, YESHAIAHU*

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics; AI for Nanotechnology

Dense photonic integration requires miniaturization of materials, devices, circuits and systems, including passive components (e.g., engineered composite metamaterials, filters, etc.), active components (e.g., modulators and nonlinear wave mixers) and integrated circuits (Fourier transform spectrometer, programmable phase modulator of free space modes, linear algebra processors, etc.).

Submission number: 66

TRAJECTORY OF PARTICLES ACROSS A TILTED-ANGLE WASHBOARD FIELD

Wang, Wei*; Liu, Qilu

Keywords: Modeling and Simulation; Nano-Acoustic Devices, Processes, and Materials;

Nanosensors and Nanoactuators

There has been a markedly increased interest in applying a washboard-like periodic potential in microfluidic systems for microscopic operations, which are often realized by intervening a standing surface acoustic wave (SSAW) at a random angle to the flow direction. Particles exposed to such a potential normally exhibit two distinct behaviors: a drift mode (following the flow stream with a certain degree of lateral deviation) and a locked mode (migrating along the equipotential line). However, even though there are attempts to describe the function of such systems, the physical basis of the particle behavior remains not yet understood. This work analyzes the behavior of particles in a washboard-like potential that is introduced at a random angle -952; to the flow direction, both numerically and analytically. Depending on the potential to drag force ratio -949;, we identified an explicit transition threshold |-949;|=|cos-8289;-952; | between two distinct regimes of particle motion: the drift mode and the locked mode. The oscillating trajectory in the drift mode is revealed fundamentally nonlinear, whose slope S is -(-949;^2 tan-8289;-952;)-8725;2, while the slope of the straight path in locked mode is presented by -1-8725;tan-8289;-952;. The formula shows a good agreement with numerical calculations and previously published experimental data with only a moderate deviation in the transition regime. The expression could also be easily promoted to several scalar potentials, including electrophoresis, dielectrophoresis, and optical trapping. It helps in understanding particle behavior in a washboard potential and provides a reliable approach to evaluate the choice of structural and operating parameters for the best performance of the microsystem aiming at a variety of applications.

Submission number: 67

DEALING WITH CONTROL ERRORS IN SPIN QUBIT ARRAYS

Heinz, Irina*; Burkard, Guido

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Modeling and Simulation; Spintronics

In recent advancements of quantum computing utilizing spin qubits, impressive quantum gate fidelities exceeding 99.5% have been demonstrated [1-5]. However, as efforts move towards scaling qubit arrays, the impact of various sources of errors and decoherence such as crosstalk, residual exchange interactions, or heating effects becomes a critical consideration. Analyzing the impact of crosstalk arising from nearby and near-resonant driving on neighboring qubits during single-qubit and two-qubit operations using a Heisenberg model reveals synchronization conditions for Rabi oscillations and appropriate control protocols to evade crosstalk [6-8]. Additionally, a finite on-off ratio of the exchange interaction between spin qubits limits the quantum gate fidelity in spin-qubit architectures [9]. Dynamical decoupling sequences can be used to mitigate the effect of residual exchange interaction in double quantum dots, whereas in larger qubit arrays a driving scheme using multiple steps can increase the fidelity while increasing the gate time. Our findings emphasize the significance of accounting for error sources when scaling up spin qubit devices and highlight the tradeoff between the effects of coherent errors and increased gate times used for mitigation techniques to remain with fidelities above the error correction thresholds.

Submission number: 68

SELECTIVE RESONANT DEVICE FOR CONTINUOUS FREQUENCY SWEEPING APPLIED TO MAGNETIC SUSPENSIONS

Ruiz Nievas, Javier; Rodriguez Barroso, Alejandro*; Martinez Cano, Oscar; Ruiz Pelegrina, Carlos; Camacho, Guillermo; De Vicente, Juan

Keywords: Nanomagnetics; Nanostructures for extreme environments; Nanomaterials

Non-stationary magnetic fields are capable to promote the formation of far-from-equilibrium structures in magnetic particle suspensions. A governing parameter during self-assembly is the Mason number that measures the relative importance of hydrodynamic over magnetostatic forces in quiescent state. Under high Mason number particles experience averaged interactions and aggregate to form quasistatic structures. A particularly interesting example is that of high frequency perturbating magnetic fields. In this manuscript we show that it is possible to gradually increase the field frequency (and therefore the Mason number) using a variable inductance coil. Structures are visualized and the generated torque measured in a customized torsional rheometer. Torque measurements are compared with similar frequency sweeps using a capacitor resonance bank. Using the inductance approach a smooth continuous variation of the torque is measured in striking contrast to the capacitance approach.

Submission number: 69

GATED BP/MOS2 HETEROSTRUCTURE WITH TEMPERATURE ENHANCED PHOTOCURRENT

Di Bartolomeo, Antonio*; Durante, Ofelia; Viscardi, Loredana; Truda, Lidia; Martucciello, Nadia; Osamah, Kharsah; Daniel, Leon; Sleziona, Stephan; Schleberger, Marika

Keywords: Nanoelectronics; Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanomaterials

Two-dimensional van der Waals heterostructures offer versatile platforms for multifunctional optoelectronic devices. In this work, we study the electrical transport and the photoresponse in BP/MoS2 heterostructures made of multi-layer black phosphorus (BP) exfoliated over CVD-grown monolayer molybdenum disulfide (MoS2) with Cr contacts. The heterostructures show good rectification and a dominant n-type behavior under a back-gate voltage. The exposure to light reveals a high photoresponse with photocurrent enhanced by the rising temperature. The BP/MoS2 devices can be operated over a wide range of temperatures, either below or above room temperature. An energy band model that considers a type II BP/MoS2 heterojunction between two back-to-back Schottky junctions, at the Cr/BP and Cr/MoS2 interfaces, is proposed to explain the experimental results.

Submission number: 70

ENHANCEMENT OF A STOCHASTIC-COMPUTING MORPHOLOGICAL NEURAL NETWORK THROUGH APPROXIMATE ADDERS

Frasser, Christian; Zhang, Tingting; Liu, Bowen; Font-Rossello, Joan; Crespi, Lluc;

Moran, Alejandro; Canals, Vincent; Roca, Miquel; Han, Jie; RossellO Sanz, Josep Lluis*

Keywords: Quantum, Neuromorphic, and Unconventional Computing; AI for Nanotechnology

Stochastic Computing has proven to be an extremely suitable hardware design approach for Morphological Neural Networks (MNNs) due to its ease of implementing maxima, minima, and products using simple logic gates that perform bitwise operations. This study enhances the design of MNNs by incorporating stochastic and approximate computing techniques. This approach results in a significant reduction in the required hardware resources for adders, which are the most area-consuming components of MNNs. Experimental results demonstrate a minimal decrease in accuracy, along with reductions in hardware resources, and improvements in speed and energy efficiency compared to previous studies. The proposed methodology is validated through implementation on a field-programmable gate array.

Submission number: 71

NANO (AND MICRO) TECHNOLOGIES AS PILLARS OF EDGE INTELLIGENCE IN THE EMERGING PARADIGMS OF 6G, FUTURE NETWORKS AND SUPER-IOT [FULL ABSTRACT]

Iannacci, Jacopo*

Keywords: Nanoscale Communications; Nanosensors and Nanoactuators;

Nanotechnology in Soft Electronics

Planning for future communication networks, like 6G and Future Networks (FN), is pushing the boundaries of hardware technology. This paper explores how tiny sensors and actuators, based on Nano and Micro Electro-Mechanical Systems (NEMS/MEMS), can play a crucial role, especially at the network edge. First, key concepts to understand the needs of these future networks and how NEMS/MEMS can address them, are going to be defined. Then, existing research examples in NEMS/MEMS materials, devices, and systems, all relevant to the development of 6G and FN, will be reported.

Submission number: 72

SCALING TOWARDS HIGH POWER HIGH SPEED PHOTONIC CRYSTAL SURFACE EMITTING LASERS

Zhou, Weidong*; Gautam, Chhabindra; Pan, Mingsen

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics

Photonic Crystal Surface Emitting Lasers (PCSELs) have emerged as a third-generation diode laser technology for high power high brightness high speed lasers with applications in LiDAR and 3D sensing, datacom and lasercom, photonic and quantum integrated circuits. In this talk, we report PCSEL performance trade-offs and challenges in power scaling, modal competition, and charge injection control. We will report the impact of charge injection control, the design towards high speed high power lasers, and coherent coupled PCSEL arrays. Perspectives on the future directions will also be discussed.

Submission number: 73

LOW-TEMPERATURE (CRYOGENIC) TRANSPORT IN GATE-ALL-AROUND (GAA) SILICON NANOWIRE FIELD-EFFECT TRANSISTOR

Verma, Amit*; Nekovei, Reza; Shiri, Daryoush

Keywords: Nanoelectronics; Modeling and Simulation; Nanomaterials

This work explores the temperature dependency of the performance of an ultra-thin silicon nanowire (SiNW) gate-all-around field-effect transistor (GAA-FET). The nanowire is assumed coaxially aligned with an ideal cylindrical gate-all-around device. The nanowire is [110] axially aligned with a diameter of 1.3 nm. Electron transport is modeled using Ensemble Monte Carlo (EMC) simulations coupled self-consistently with an electrostatic solver that solves Gauss Law in integral form. Electron scattering mechanisms include bulk silicon longitudinal acoustic and optical phonons. A wide range of temperatures is considered – from 4 K to 150 K to understand the effects of temperature on device performance under both steady-state and device switching conditions. The device is seen to work appropriately for the temperature range considered. The differences in device currents for different temperatures is attributed to the differences in the electron scattering rates for the various temperatures.

Submission number: 74

5-BIT SIGNED SRAM-BASED IN-MEMORY COMPUTING CELL

Karimpour, Faranak*; Pardo, Fernando; Garcia Lesta, Daniel

Keywords: AI for Nanotechnology; Modeling and Simulation; Quantum, Neuromorphic, and Unconventional Computing

Hardware accelerators are critical in providing real-time processing for edge computing applications, particularly in the context of convolutional neural networks. A crucial challenge in this context is achieving low power consumption while maintaining an appropriate performance in terms of accuracy. This work delves into a thorough analysis of prospective architectures for the core cell of the multiply-and-accumulate function, monitoring each structure's crucial benefits and drawbacks. It includes electrical simulations comparing their performance in a 180 nm process node for 1.8 V and 3.3 V. Moreover, a process corner simulation is proposed to identify on-chip process variations in the voltage error of the proposed design under different input voltages. Notably, the minimum corner errors observed at +15 and -7 sign bits are 0.45% and 0.63%, respectively. The significant outcome highlights that the single-switch implementation achieves optimal performance, displaying the lowest error value of 0.14%, specifically at the +15 sign bit and operating at 1.8 V.

Submission number: 75

BIO-INTEGRATED SOFT ELECTRONICS BASED ON BIOMIMETIC 3D NANOFIBER NETWORKS

Xu, Lizhi*

Keywords: Nanomaterials; Nanofabrication

Nanofiber networks are essential structures in natural biological tissues, which exhibit a combination of mechanical flexibility, fracture resistance, and mass permeability to enable many important physiological functions. Inspired by natural soft tissues, we exploit biomimetic nanofiber networks as building blocks for the construction of a variety of bio-integrated soft devices. A key component in these materials and devices is aramid nanofiber (ANF). With appropriate solvent-based processing steps, the ANFs self-organize into hyperconnective networks, which capture some of the key features of load-bearing soft tissues. They also exhibit tissue-mimetic physical properties and microstructural reconfigurability, which are beneficial for device applications. The composites can be functionalized with bioactive molecules or soft electronic components for interfacing with cells and tissues. In this presentation, I will introduce some of our recent works ranging from electroconductive hydrogels and wearable devices to theoretical modeling and meso-structural designs. These works address the fundamental physical mismatches between biomedical devices and biological soft tissues, paving the way for the development of advanced wearable human-machine interfaces, implantable electronics, tissue engineering platforms, and other biomedical systems.

Submission number: 76

FLEXIBLE OXIDE ELECTRONICS FOR EXTREME GEOMETRIES AND MECHANICAL DEFORMATIONS

Münzenrieder, Niko*; de Souza Oliveira, Hugo; Catania, Federica; Saeedzadeh Khaanghah, Niloofar; Lanthaler, Albert Heinrich; Corsino, Dianne; Cantarella, Giuseppe

Keywords: Nanostructures for extreme environments; Nanotechnology in Soft Electronics; Nanoelectronics

Electronics is moving away from a one-solution-fits-all approach based on traditional semiconductor technologies. This is because an ecosystem for biocompatible, large-area, environmentally friendly, wearable, and high-performance electronics based on a variety of materials and technologies can provide bespoke solutions for specific application scenarios. An important aspect of this development is represented by soft and flexible systems that can bend and stretch. Here we present our flexible electronics technology which is based on thin films and oxide semiconductors. Transistors, sensors and circuits fabricated on polymer substrates exhibit carrier mobilities around 16.5 cm2/Vs, transit frequencies exceeding 100 MHz, and voltage gains up to 19 dB while being bend to millimeter radii or stretched by more than 200 %.

Submission number: 77

ADSORPTION OF ACETONE THROUGH A GERMANIUM MONOLAYER FOR A POTENTIAL DIABETES DIAGNOSIS

Barranco, Alejandro*; De Santiago, Francisco; Miranda, Alvaro; Trejo, Alejandro; Salazar, Fernando; Cruz-Irisson, Miguel

Keywords: Nanomaterials; Nanosensors and Nanoactuators; Nanobiomedicine

One key aspect of the successful treatment of diabetes, a global issue, is early detection. Acetone is a waste product of fat metabolism, which occurs when the body substitutes fat for sugar to generate energy. Individuals with diabetes produce excess acetone when there is insufficient insulin to transport glucose into cells; hence, acetone serves as a reliable indicator of diabetes. Since the discovery of graphene, two-dimensional nanostructures, such as phosphorene, stanene, silicene, and germanene, have attracted significant interest in the scientific community. Their novel and unique properties, including high surface-to-volume ratio, flexibility, and sensitivity, make them ideal materials for the adsorption and detection of chemical agents through a variety of mechanisms. In this study, a monolayer of undoped and doped germanium with B, Al, and Ga impurities was proposed as the base material for acetone molecule detection and potential diabetes diagnosis. A first-principles method was used to determine the molecular adsorption geometries, adsorption energies, and electronic properties. The results suggest that the acetone molecule undergoes chemisorption when interacting with the germanium monolayer, achieving adsorption energies ranging from 0.57 eV to 1.19 eV. Additionally, the desorption time of the nanostructure was estimated at different temperatures, along with the modulation of the material's work function upon acetone molecule adsorption. This research can offer valuable insights for the development of biosensing devices based on germanium nanostructures.

Submission number: 78

ON THE IMPACT OF SOFT ERRORS ON TRANSFORMERS EMBEDDINGS

Gao, Zhen*; Liu, Shuang; Reviriego, Pedro; Liu, Shanshan; Lombardi, Fabrizio

Keywords: Modeling and Simulation

Transformers are widely utilized in Natural Language Processing (NLP) and computer vision (CV) with remarkable success. For pre-trained Transformer models involving text processing, embedding representations are indispensable parameters, and occupy a large volume of memory. Soft errors on embedding vectors can lead to incorrect inputs to Transformers, which may further result in a loss of model performance. This paper takes Contrastive Language–Image Pre-training model (CLIP) for image classification as a case study to examine the impact of soft errors on embedding vectors that are represented by half-precision floating point values. Two error models are used for the injection experiments; the first model is a one-time injection with specific error rates, and the second model considers the accumulated errors with multiple injections. Simulation results show that for one-time error injection, only the first two exponent bits are critical such that errors on them would cause an obvious performance loss; the third exponent bit becomes critical for accumulated errors. These results are valuable for the efficient protection and design of a memory for the embedding vectors.

Submission number: 79

ATOMISTIC MODELING OF [W18O54(SEO3)2]4-8722; POLYOXOMETALATES (POM) MOLECULES IN THE PRESENCE OF COUNTER-CATIONS FOR MEMORY DEVICE APPLICATIONS

Jacobs, Jake; Vila-Nadal, Laia; Georgiev, Vihar*

Keywords: Modeling and Simulation; Nanoelectronics; Spintronics

Polyoxometalates (POMs) are versatile molecular metal oxides explored for various applications. This case study focuses on [W18O54(SeO3)2]4-8722;, a POM with potential for integration with molecular memory devices. The impact of counter-cations on its properties is investigated using Density Functional Theory (DFT). The study delves into the computational details of [W18O54(SeO3)2]4-8722; optimization using DFT, considering counter-cations and solvents. Theoretical models reveal the significant influence of counter-cations on frontier orbital energies, especially in vacuum. Interestingly, the Continuum Solvent Model (COSMO) demonstrates that explicit counter-cations have a minor impact when solvents are considered. This finding has implications for computational efficiency in future POM studies. The study concludes by highlighting the importance of counter-cations in DFT modelling and proposes avenues for further research, including expanding the range of POMs and exploring POM-cation-surface interactions.

Submission number: 80

MULTILAYER MAGNETIC DOMAIN WALL MTJ-BASED SPIKING NEURAL NETWORK

LONE, AIJAZ*; Rahimi, Daniel N.; Fariborzi, Hossein; Setti, Gianlcua

Keywords: Spintronics; Quantum, Neuromorphic, and Unconventional Computing;

Nanomagnetics

Spintronic devices, especially the magnetic tunnel junction and magnetic domain wall-based devices, hold significant promise for applications in energy-efficient data storage and Unconventional computing architectures. We present a novel multilayer spintronic neuromorphic device based on spin-orbit torque-driven domain wall dynamics. The typical leaky integrate and fire LIF neuron-like characteristics are realized using the combination of SOT and demagnetization energy effects. The device characteristics are modelled as the modified LIF model. We test the spiking neuron model for the classification of the MNIST dataset by emulating a 3- layer spiking neural network SNN -based on the DW-MTJ LIF neuron model. The network achieves classification accuracy above 96% thus the proposed device can be integrated with the CMOS for energy efficient neuromorphic computing.

Submission number: 81

TUNING ELECTRONIC QUANTUM TRANSPORT IN CARBON-BASED 2D NANOARCHITECTURES

Garcia-Lekue, Aran*

Keywords: Modeling and Simulation; Nanoelectronics; Nanomaterials

Recent experimental advances have demonstrated that graphene nanoribbons (GNRs) can be laterally coupled with atomic precision to obtain a nanoporous graphene (NPG) structure with highly anisotropic electronic properties.[1] Moreover, simulations have shown that the lateral coupling of GNRs leads to-sizable interribbon transmission giving rise to intriguing interference patterns,[2,3] and that such interribbon-transmission can be switched on/off by the chemical modification of the coupling bridges.[4,5] Using density functional theory (DFT) and a multiscale transport method based on DFT combined with-nonequilibrium Green's functions (NEGF), we have carried out electronic structure and current simulations-for different NPG-based systems. First, in collaboration with our experimental colleagues, we have explored-a new NPG that, provided by specifically designed coupling bridges, shows additional degrees of freedom to-control the in-plane current.[6] Besides, we have investigated a bilayer composed of NPG and graphene,-concluding that the interlayer current can be tuned by changing their relative twist angle.[7] Our results-showcase the versatility of NPG based low-dimensional systems for nanoelectronic applications and carbon-nanocircuitry.

References

[1] Moreno et al., Science 360, 199 (2018)-
[2] Calogero et al., Nanoscale 11, 6153 (2019)
[3] Calogero et al., Nano Lett. 19, 576 (2019)
[4] Calogero et al., JACS 141, 13081 (2019)
[5] AlcOn et al., Adv. Funct. Mater. 31, 2104031 (2021)
[6] Moreno et al., JACS 145, 8988 (2023)
[7] Diaz de Cerio et al., in preparation

Submission number: 82

FROM FUNDAMENTALS OF CRYSTALLIZATION FOULING ON NANOMATERIALS TO RATIONAL DESIGN OF SCALEPHOBIC SURFACES

Schutzius, Thomas*

Keywords: Hydrophobic, Oleophobic and/or Icephobic nanostructured surfaces;

Nano-Energy, Environment, and Safety

Crystallization fouling, a process where scale forms on surfaces, is pervasive in nature and technology, negatively impacting the energy conversion and water treatment industries. Despite significant efforts, rationally designed materials that are intrinsically resistant to crystallization fouling without the use of active methods like antiscalant additives remain elusive. This is because antiscalant surfaces are constructed today without sufficient reliance on an intricate but necessary science-base, of how interweaved interfacial thermofluidics, nucleation thermodynamics, and surface nanoengineering control the onset of nucleation and adhesion of frequently encountered scaling salts like calcium carbonate and calcium sulfate. Such scaling salts are common components of fouling deposits in industrial heat exchangers and membranes, which significantly inhibit heat transfer and flow performance. I will present my recent work on the development of innovative materials and systems addressing these challenges. I will focus on our findings related to understanding the fundamentals of scale nucleation and adhesion and how we use this to rationally engineering intrinsically scalephobic surfaces based on the collaborative action of their composition and topography.

Submission number: 83

SPIN QUBITS, VARIABILITY AND SCALABILITY

Martinez Diaz, Biel*; Niquet, Yann-Michel

Keywords: Modeling and Simulation; Quantum, Neuromorphic, and Unconventional

Computing; Nanofabrication

Semiconductor spin qubits are among the most promising platforms for quantum computation, and remarkable advances in the last years have largely demonstrated their great potential. Nonetheless, the realization of a large-scale quantum processor still remains an important technological challenge. The design and fabrication of large-scale devices is already challenging given the nanometric size of the qubit objects. Moreover, the operation of such arrays is likely to require very homogeneous spin qubits, which imposes strong constraints in terms of materials quality and disorder. Several platforms are being studied- Si MOS spin qubits, with either electrons or holes as carriers, benefit from their similarities with classical transistors and from the long-lasting experience on microelectronics to be fabricated with existing standardized procedures in industrial facilities. Nonetheless, in these devices the qubits are hosted at the interface between Silicon and SiO2, which is an amorphous oxide prone to be defective. These defects generate undesired fluctuations in the electrical environment of the qubits that can induce an undesired qubit-to-qubit variability. [1] In the last years, epitaxial-heterostructure-based spin qubits have become the platform of reference, partly thanks to their low level of disorder in the vicinities of the qubits. Yet, existing experiments still show sizable inhomogeneities between the qubits, which can compromise scalability.-In this talk, we will review the strengths and weaknesses of Si MOS and Ge/SiGe spin qubits in terms of qubit-to-qubit variability and the subsequent implications for scalability. Device simulations including realistic levels of disorder have allowed us to quantify the expected levels of variability in the relevant qubit properties, and evaluate the impact on the performance of an eventual large-scale quantum processor. [1,2] These results highlight the importance of taking into account variability during the design of large-scale architectures.-

References:-1.--Phys. Rev. Applied 17, 024022, (2022) 2.--arXiv:2402.18991 (2024)

Submission number: 84

A NUMERICAL STUDY OF THE RF HYPERTHERMIA TREATMENT OF BRAIN TUMORS USING NOVEL SPIO-MICELLES

Lodi, Matteo Bruno*; Corda, Eleonora Matilde Angela; Assawapanumat, Wirat; Chabert, Gian Luca; Fanti, Alessandro; Mazzarella, Giuseppe; Saba, Luca; Perra, Andrea; Nasongkla, Norased

Keywords: Nanomagnetics; Modeling and Simulation; Nanobiomedicine

Brain tumors are deep-seated neoplasms that are difficult to treat with conventional strategies, so new solutions are needed. Magnetic hyperthermia is a treatment strategy against brain tumors. However, administering magnetic nanoparticles to target brain tumors and perform a radiofrequency hyperthermia treatment is not a trivial task. Recently, micelles that can overcome blood-brain barrier have been proposed as cargo to concentrate superparamagnetic nanoparticles in the target tumor volume. In this work the synthesis and preliminary characterization of novel superparamagnetic iron oxide (SPIO) micelles for brain tumor hyperthermia is presented. A numerical multiphysics model, that couples the mass transfer problem with the radiofrequency heating equations, is proposed to study what key SPIO-micelles magnetic features and the extrinsic treatment parameters are needed to plan a successful treatment. The computational analysis is performed using patient-specific geometries derived from magnetic resonance images and considering a parametrized tumor geometry. We successfully identified the SPIO-micelles concentration and the working conditions needed to perform the hyperthermia treatment on the brain tumor.

Submission number: 85

REDUCING WIRE CROSSINGS IN FIELD-COUPLED NANOTECHNOLOGIES

Hien, Benjamin*; Walter, Marcel; Wille, Robert

Keywords: Nanoelectronics

In the realm of circuit design, emerging technologies such as Field-Coupled Nanotechnologies (FCN) provide unique opportunities compared to conventional transistor-based logic. However, FCN also introduces a critical concern: the substantial impact of wire crossings on circuit robustness. These crossings are either unrealizable or can severely degrade signal integrity, posing significant obstacles to efficient circuit design. To address this challenge, we propose a novel approach focused on reducing wire crossings in FCN circuits. Our methodology introduces a combination of LUT mapping and decomposition aimed at producing advantageous network structures during logic synthesis to minimize wire crossings. This new optimization metric is prioritized over node count and critical path length to effectively tackle this challenge. Through empirical evaluations, we demonstrate the effectiveness of the proposed approach in reducing a first approximation for wire crossings by 41.69%. This research significantly contributes to advancing wire crossing optimization strategies in emerging circuit technologies, paving the way for more reliable and efficient designs in the post-CMOS logic era.

Submission number: 86

ANALYSIS, DESIGN AND EVALUATION OF HIGH-PERFORMANCE STOCHASTIC MULTILAYER PERCEPTRON: FROM MINI-BATCH TRAINING TO INFERENCE

Wang, Ziheng; Niknia, Farzad; Liu, Shanshan*; Reviriego, Pedro; Gao, Zhen; Lombardi, Fabrizio

Keywords: Quantum, Neuromorphic, and Unconventional Computing; AI for Nanotechnology; Modeling and Simulation

Stochastic computing (SC) is a novel computing paradigm for implementing Multilayer Perceptrons (MLPs), which can mitigate the burden of power dissipation in advanced nanoscale systems. SC MLP has been studied to perform efficient and reliable training/inference in energy-constrained platforms. The mini-batch technique, known for its efficiency in training neural networks with conventional arithmetic, has rarely been explored within the context of SC implementations. Through theoretical analysis and simulation, this paper deals with the impact of the mini-batch technique on SC MLPs. The comparison reveals a unique pattern: SC MLPs experience a linear speed-up, surpassing the sublinear trend observed in traditional MLPs. These results indicate that SC MLPs could benefit substantially from the mini-batch technique. A hardware implementation is then provided in this paper. Initially, the setup for an SC MLP with mini-batch training is outlined, followed by a detailed pipeline design for forward propagation. It achieves an operating frequency of 1 GHz, outperforming existing designs found in the technical literature while requiring less energy dissipation than a conventional MLP. The comprehensive analysis, design, and evaluation demonstrate that SC MLPs are well-positioned to benefit from the mini-batch technique and effective hardware implementations across both training and inference.

Submission number: 87

NANOENGINEERED BIO-INTERFACES TO INTERROGATE & CONTROL BIOLOGICAL EVENTS ON MATERIAL INTERFACES

Krishnamoorthy, Sivashankar*

Keywords: Nanofabrication; Nanobiomedicine; Nanosensors and Nanoactuators

The outcome of the interaction of biological medium with material interfaces has significant implications for a range of biodevices/bio-interfaces with the goal of interrogating or controlling the response of biomolecules or biological cells. Control over the material interface properties is thus the key to driving the desired biological end outcomes.- A fine degree of control over the material interface is achievable if one could engineer the material structure and functionality down to length scales of the order of biomolecules, viz., few nanometers to few tens of nanometers. 'Engineering' the material interface at these length scales would however demand both (a) an ability to fabricate well-defined nanoarrays with desired structure/functionality, (b) with ability to make systematic and fine changes to the structure/functionality to establish structure <=> activity correlations, and (c) 'eyes' to assess the impact of the material interface variables on the biological outcomes.- The talk would focus on the use of molecular tools to engineer the structure/functionality at the molecular level. The talk would also focus on unique and first-time tools that can provide real-time, label-free feedback of nano-bio interactions.

Submission number: 88

IN VIVO COMPUTATIONAL STRATEGY FOR TUMOR TARGETING IN NOISY SCENARIOS

Jiang, Zhaoyang; Shi, Shaolong; CHEN, YIFAN*; Chen, Zan

Keywords: Nanobiomedicine; Quantum, Neuromorphic, and Unconventional Computing; Nanorobotics and Nanomanufacturing

Because of the inefficiency of conventional medical imaging techniques for early tumor detection, we proposed the framework of in vivo computation in the previous work. Tumor tissue induces the generation of biological gradient field (BGF), and an external magnetic field is utilized to guide nanoswimmers in the search space to find the location of the tumor. Since various kinds of noise are generated in the process of tumor targeting, it is necessary to perform some measures to minimize the impact of noise. Thus, we propose a resampling strategy for in vivo computation and verify its effectiveness through some simulation experiments. The results show that the in vivo computational resampling strategy has significant noise filtering effects in almost all cases.

Submission number: 89

NANOSTRUCTURED SILICON FOR HIGH-EFFICIENT AND COST-EFFECTIVE HEAT RECOVERY THROUGH THERMOELECTRIC CONVERSION

Ragazzo Capello, Carlotta*; Masci, Antonella; Dimaggio, Elisabetta; Pennelli, Giovanni

Keywords: Nanomaterials; Nanoelectronics; Nanofabrication

— Nanostructuring is very effective in enhancing the thermal to electrical energy conversion efficiency of most materials, including in particular silicon which presents a perfect trade-off between technical potentialities and environmental/political/social issues. Heat sources, that nowadays are exploited only in a small fraction, could become key players in energy production thanks to thermoelectric device based on nanostructured silicon. Successful strategies, including on-chip devices for micro-harvesting and cost-effective large-area vertical nanowire forests for macro-harvesting will be presented. An estimation of the efficiency will be reported, highlighting the competitiveness of these devices with respect to conventional techniques.

Submission number: 90

WEARABLE TEXTILE ANTENNAS THROUGH GREEN APPROACH SOLUTION AND SCALABLE PRINTING PROCESSES

Tavares, Joana*; Loss, Caroline; Pinho, Pedro; Alves, Helena

Keywords: Nano-Energy, Environment, and Safety; Nanoelectronics; Nanotechnology in Soft Electronics

Flexible textile antennas play a fundamental role in enabling wireless communication among the expanding domains of 5G and the Internet of Things (IoT), allowing seamless integration into everyday objects [1]. On the other hand, attaining such functionalities in textiles presents challenges due to constraints in electronic performance and the requirement for scalable fabrication processes [1, 2]. This work presents two flexible textile antennas suitable for both wearable and non-wearable devices, designed to operate within the 5G technology using highly conductive silver nanoparticle inks. These antennas are implemented on two distinct textile substrates, that also serve as the dielectric component: a 3D polyester and a natural fabric, burel. The fabrication processes employed are both cost-effective and scalable, with the antennas optimized to function within the 3–3.5 GHz frequency range. These antennas keep their return loss performance even when exposed to bending deformation and washing cycles. Additionally, through the integration of these optimized devices into clothing and wall coverings, a comprehensive analysis including experimental measurements of the textile-based antennas across different circumstances is presented. Their return loss performance is preserved, both when worn off the body and when worn on or near the body. This research underlines the suitability of these antennas for wearable applications while aligning with the principles of green wireless technologies, therefore contributing to the advancement of sustainable wireless communication systems [3].-Acknowledgements The authors also acknowledge funding supported by FCT/MCTES, co-financed by the operational program NextGenerationEU – PRR, and by national funds, under contracts C632491900-00467021, PCIF/SSO/0163/2019 (https://doi.org/10.54499/PCIF/SSO/0163/2019), UIDB/05367/2020-UIDP/05367/2020 (https://doi.org/10.54499/UIDB/05367/2020), UIDB/00195/2020, UIDB/50008/2020-UIDP/50008/2020, and DFA/BD/4411/2020.

References

[1]--G. Martins, P. Pinho, C. Loss. IEEE. (2022) 1-4.
[2]--D. H. Werner, and H. J. Zhi. John Wiley & Sons. (2016).
[3]--J. Tavares, C. Loss, P. Pinho, H. Alves. Advanced Materials Technologies. (2024) 2301499.

Submission number: 91

FLEXIBLE GRAPHENE/PEDOT: PSS FREE-STANDING INFRARED PHOTODETECTOR

Lu, Guanxuan; Zhou, Rui; Wang, Jiaqi; Xie, Zhemiao; Yuan, Yifei; Yeow, John T.W.*

Keywords: Nanomaterials; Nanotechnology in Soft Electronics

The combination of polymers and nanomaterials has improved the diversity and compatibility of signal detection. The main challenge that researches face is related to the stability, the response rate, and the final signal detection of the fabricated detectors. Graphene as a traditional two-dimensional material has been applied to improve the internal carriers transport and enhance the final detected signal. By mixing the graphene material with poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT: PSS) polymer and forming the corresponding composites, synergistic effects have been demonstrated based on the final experiment results. To move further, one free-standing infrared detection (IR) detector has been fabricated with no substrate supported. The results for the infrared wave radiation have been collected and compared with different graphene loadings. Overall, these discoveries offer valuable understanding for promoting the graphene related composited in the field of infrared detection.

Submission number: 92

A PHYSICS-BASED ANALYTICAL MODEL FOR BALLISTIC INSE NANOTRANSISTORS

de Souza, Adelcio; Celino, Daniel; Ragi, Regiane; Romero, Murilo*

Keywords: Modeling and Simulation; Nanoelectronics

This paper presents a physics-based model for ballistic field-effect nanotransistors, focusing on devices based on a two-dimensional indium selenide (InSe) channel. Through an analytical solution of the Poisson equation and making use of the Landauer formalism, we derive concise expressions for current-voltage (I–V) and capacitance-voltage (C–V) characteristics. Validation of the resulting curves is performed against numerical simulations and experimental data, demonstrating an excellent agreement

Submission number: 93

MICROMAGNETIC STUDY OF THE FREQUENCY RESPONSE OF SKYRMIONS IN MAGNETIC MULTILAYERS

Raimondo, Eleonora; Darwin, Emily; Rodrigues, Davi; Giordano, Anna; Carpentieri, Mario; Finocchio, Giovanni; Tomasello, Riccardo*

Keywords: Spintronics; Modeling and Simulation

Magnetic skyrmions are localized magnetization entities with a particle-like feature due to the topological stability. Often considered as promising information carriers, they can exhibit a variety of dynamics beyond the rigid translational motion, such as breathing mode and gyration. These modes are at the key ingredient for skyrmion-based oscillators and detectors. These modes become even more interesting when considering skyrmions in magnetic multilayers. Here, we analyze, within a micromagnetic framework, the frequency response of skyrmions in different magnetic multilayers, as a function of the number of ferromagnetic repetitions and/or number of skyrmions. We observe the presence of a main frequency peak related to the breathing mode, as well as the emergence of additional peaks linked to the number of repetitions and skyrmions. Our achievement can be useful for the design of the next generation of microwave devices based on skyrmions.

Submission number: 94

PHASE-BINARIZED DIPOLE-COUPLED SPIN HALL NANO OSCILLATORS (SHNOS) AS ISING MACHINES

Garg, Neha; Singhal, Sanyam; Sadashiva, Aniket; Muduli, Pranaba; Bhowmik, Debanjan*

Keywords: Spintronics; Quantum, Neuromorphic, and Unconventional Computing;

Nanomagnetics

Dipole-coupled uniform-mode spin Hall nano oscillators (SHNOs) are modeled here using coupled Landau Lifschitz Gilbert Slonczweski (LLGS) equations and shown to exhibit phase binarization (an essential criterion for Ising machines) upon the application of RF magnetic field, which is consistent with the dynamics predicted by the physics-agnostic Kuramoto model. Next, it is shown that such phase binarized dipole-coupled SHNOs can be used to solve the Max-Cut problem on different complete weighted graphs, with weights dependent on the distances between the SHNOs.

Submission number: 95

TI3C2TX MXENE-INTEGRATED LOG-PERIODIC ANTENNA DESIGN FOR ENHANCED TERAHERTZ RADIATION DETECTION

Zhou, Rui; Lu, Guanxuan; Wang, Jiaqi; Xie, Zhemiao; Yuan, Yifei; Yeow, John T.W.*

Keywords: Nanosensors and Nanoactuators; Nanoelectronics

This study introduces a novel antenna configuration, integrating $Ti_3C_2T_x$ MXene into a log-periodic design, specifically for advancing terahertz (THz) detection. The incorporation of MXene material enhances THz detection, merging the high electrical conductivity and exceptional absorption properties of MXene with the broad frequency response of the log-periodic design. The outcome is a compact and high-performance antenna with improved absorption, bandwidth and directionality, setting a new benchmark for THz applications. This innovative design paves the way for miniaturization without compromising the antenna's effectiveness, ideal for THz imaging and non-destructive testing. Our investigation articulates the harmonious convergence of materials science innovation with sophisticated antenna design, redefining the potential of THz detection systems.

Submission number: 96

NANOROBOTIC BIOSENSING: ULTRA-PRECISION, PROGRAMMABLE, AND ENHANCED EFFICIENCY

Fan, Donglei*

Keywords: Nanorobotics and Nanomanufacturing; Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanobiomedicine

Recent advancements in micro/nanorobotics have led to the development of innovative techniques for the manipulation and detection of biomolecules with unprecedented precision and efficiency. In this talk, I will discuss our recent invention on precise electrokinetic control of nanowire bioprobes and the accelerated enrichment and detection of biomolecules using magnetic rotary opto-plasmonic microsensors to address challenges in sensitive, high-speed, low-concentration bioanalysis. We invented a novel electrokinetic approach that enables the precise two-dimensional positioning and three-dimensional orientation control of untethered nanowires in solution, overcoming Brownian-motion effects. The technique achieves a positioning accuracy of 20 nm and orientation precision of 0.5°, facilitating the active transport and synchronous alignment of nanoprobes for complex trajectory navigation and subcellular probing.[1] Leveraging magnetic effects, we demonstrate how controlled mechanical rotation of opto-plasmonic microsensors significantly enhances the capture and detection speed of DNA molecules, achieving at least a 4-fold increase in efficiency and the underlying working mechanism. [2] The efforts permit a rational approach towards the high-precision, robotic, high-speed sensing of biomolecules, paving the way for advanced nanorobotic tools in bioanalysis, assembly, and micromanipulation with subcellular resolution.- Acknowledgements We thank National Science Foundation and Welch Foundation for supporting the research.

References

[1]--Huaizhi Li, Daniel Teal, Zexi Liang, Hyunah Kwon, David Huo, Alison Jin, Peer Fischer, and Donglei (Emma) Fan, Nature Nanotechnology, 18, 1213–1221 (2023).
[2]--Jianhe Guo, Zexi Liang, Yun Huang, Kwanoh Kim, Peter Vandeventer, and Donglei (Emma) Fan, ACS Nano, 14, 15204–15215 (2020).

Submission number: 97

MAGNETIC IRON-CHELATING NANOBUBBLES FOR BOOSTING THERAPIES EFFECTIVENESS IN THE CNS

Rizzo, Sebastiano Antonio; Stura, Ilaria*; Ficiara, Eleonora; Scomparin, Anna; D'Agata, Federico; Cavalli, Roberta; Guiot, Caterina

Keywords: Nanobiomedicine; Nanomagnetics; Nanomaterials

Brain iron overload is a hallmark of many neurodegenerative diseases. Local chelating therapy poses many challenges due to the presence of very selective membranes and requires carriers of nanometric dimensions pushed by physical forces. Provided the carriers exhibit magnetic properties, magnetic fields already used in clinics, e.g. TMS, may drive them properly. The present study proposes the manufacturing of theranostic iron-chelating nanobubbles conjugated with SPIONs modulating their concentration to optimize initial driving and preserving the surface for effective chelation.

Submission number: 98

ENHANCEMENT IN DIELECTRIC AND THERMAL PROPERTIES OF NANOFLUIDS FOR TRANSFORMERS APPLICATION

Khan, Asfar Ali; Saleem, Aliya; Khan, Suhaib Ahmad*

Keywords: Nanomaterials; Nanofabrication; Nano-Energy, Environment, and Safety

In this work, we have demonstrated the efficacy and capabilities of dielectric fluid, i.e., “transformer oil,” due to their growing demand for the production of good insulation. Dielectric insulating fluids perform critical tasks such as electrical insulation and cooling functions in power system equipment. Improving the dielectric and thermal properties of insulating fluids extends the service life and ensures the reliability of power equipment for a safe electricity supply. For this purpose, the nanofluids were prepared using a two-step method. Therefore, enhancing the thermal and electrical properties of dielectric fluids using different types of novel nanoparticles, namely aluminum oxide (Al2O3), titanium oxide(TiO2), and zirconium sulphate (Zr(SO4)2) with different concentrations of NPs of 0.0125wt%, 0.025wt%, and 0.0375wt% have been used to investigate the dielectric and thermal properties.

Submission number: 99

DESIGNING ENERGY-EFFICIENT PATH-BASED DECISION TREE MEMRISTOR CROSSBAR CIRCUITS

Sinha, Pranav*; Chavan, Akash; Raj, Sunny

Keywords: AI for Nanotechnology; Nano-Energy, Environment, and Safety;

Nanoelectronics

We propose an approach to designing energy-efficient in-memory decision tree (DT) machine-learning circuits using memristors and PATH-based computing. DT machine learning (ML) algorithms are computationally simple, and they require fewer data to train compared to other ML algorithms, making them an attractive option for edge computing. Existing work on creating energy-efficient DT circuits has utilized FLOW-based computing. However, these approaches require costly write operations before every inference, leading to high energy utilization. In this paper, we propose an algorithm to generate PATH-based DT in-memory crossbar circuit designs that only require a write during circuit synthesis and not before every inference, leading to highly energy-efficient inference. We test the performance of our PATH-based design on multiple standard machine learning datasets and demonstrate that our approach achieves a 47% reduction in energy consumption, on average, compared to the state-of-the-art.

Submission number: 100

PREPARATION AND CHARACTERIZATION OF TANNASE IMMOBILIZED TITANIUM DIOXIDE NANOPARTICLES

Vu Phuong, Dong; Yoo, Hoon*

Keywords: Nanobiomedicine; Nanomaterials

Tannase-immobilized titanium dioxide nanoparticles (TITNP) was prepared by amino-functionalization and glutaraldehyde crosslinking on the surface of titanium dioxide nanoparticles (TNP) in anatase. The catalytic activity, thermal stability and reusability of immobilized tannases at various temperature or pH conditions were estimated by the tannase activity assay, which quantitates the gallic acid (GA) released after tannase-catalyzed hydrolysis reaction of tannic acid (TA) by capillary electrophoresis system. The amino_x0002_functionalized TNP intermediate was confirmed by the characteristic changes in Fourier-Transform infrared (FT-IR) spectrum, zeta potential and sedimentation behavior. Immobilized tannases retained its catalytic activity more than 60 % at temperature range of 30 to 60 °C and pH range of 3 to 6 with the optimum activity at 40 °C and pH 5. In addition, immobilized tannases were thermally stable which retained 43 % of tannase activity at 70 °C during the incubation for 60 min. Furthermore, TITNP showed strong reusability maintaining 60 % of initial enzyme activity even after 20 cycles of repeats. Thus, characteristic properties of TITNP might be useful for industrial application in food or medicine fields.

References

[1] K. Singh, A. Mishra, D. Sharma, K. Singh, Current Nanoscience, 15(2019) 234

Submission number: 101

ULTRASENSITIVE DETECTION OF PB2+ IONS IN WATER USING WS2 NANOFLOWERS

Chaudhary, Sumit; Patel, Chandrabhan; Mahapatra, Brahmadutta; Jyoti, Kumari; Dubey, Mayank; Yadav, Saurabh; Mukherjee, Shaibal*

Keywords: Nanosensors and Nanoactuators; Nanomaterials

The swift and accurate detection of waterborne pollutants is crucial due to the significant risks they pose to both human health and the environment. Lead and its compounds are highly toxic and can cause various illnesses. However, current lead detection systems face several limitations, including slow response times, high costs, and limited mobility. In this investigation, we have successfully engineered a sensor capable of detecting trace levels of toxic Pb2+ ions with excellent sensitivity, remarkable selectivity, and rapid transient performance. The developed sensor comprised of CTAB-WS2 as a sensing layer drop-casted on interdigitated electrodes (IDEs) device, sensing layer synthesized through a facile hydrothermal method. Surface morphological, crystal structure and elemental composition of the synthesized CTAB-WS2 is investigated via FESEM, XRD and EDX analysis. Moreover, sensing performance of the developed sensor display outstanding selectivity towards Pb2+ ions in the presence of other heavy metal ions. With a sensitivity of 418 -956;A/ppb and a remarkable detection limit of 89.9 ppt, the sensor demonstrated exceptional performance. Moreover, its rapid response time of less than 5 seconds makes it suitable for real-time detection applications. These superior attributes position CTAB-WS2-based sensors as a promising candidates for deployment in real-time environmental quality monitoring and toxic metal detection endeavors.

Submission number: 102

USING ANALOGIES IN ELECTRIC CIRCUITS AND SIGNAL PROCESSING TO TEACH PHYSICS OF NANOMATERIALS

Shiri, Daryoush*

Keywords: Modeling and Simulation; Nanoelectronics; Nanomaterials

The graduate nanoelectronics and nano-device physics courses rely heavily on understanding fundamental solid-state physics concepts, such as band structure, bandgap, Brillouin Zone (BZ), and direct vs. indirect bandgap materials. The majority of electrical engineering students do not take a solid-state physics course. They find the above concepts challenging to grasp in the first year of their graduate nanotechnology studies. For example, they often complain of difficulty in understanding, imagining, and interpreting 3D solid (bulk) band structure plots and points of high symmetry in BZ. On the other hand, they are well-trained in circuit and signal processing courses. In this presentation, I will show how circuit and signal processing concepts can be used pedagogically to teach the physics of phonons and electrons in nanostructures to electrical engineering students.

Submission number: 103

INVERTED T-SHAPED TUNNEL FIELD-EFFECT TRANSISTORS FOR EXTREMELY LOW POWER CHIP APPLICATIONS

suman, saket*; Srivastava, Dr. Asutosh; KUMAR, RAKESH

Keywords: Nanoelectronics; Modeling and Simulation

In this paper, we are exploring a novel inverted T-shaped Tunnel Field Effect Transistor (IT-TFET) structure for extremely low power applications. In this study, we use Sentaurus TCAD tool to simulate and analyse the electrical characteristics of proposed novel IT-TFET Structure. The inverted T-shaped TFET structure offers enhanced electrostatic control, reduced ambipolar behaviour and device performance. In this study we analyze the device characteristics and performance metrics of Inverted T-Shaped structure. The result shows significant improvements in ON current with value of ION 0.51×10-4A/-956;m, improvement in Subthreshold Swing (SS) with a value of (10.9mV/dec) and ambipolar behaviour with value of order 2.2×10-18 A/-956;m. The optimized IT-TFET structure offers improved ION/IOFF ratio with a value of 1014. So our new transistor design has great electrical characteristics, making it promising candidate for extremely low power chip applications.

Submission number: 105

BILAYER MOS2 BASED MEMRISTIVE CROSSBAR ARRAY FOR NEUROMORPHIC APPLICATIONS

Yadav, Saurabh; Patel, Chandrabhan; Chaudhary, Sumit; Paul, Animesh; Ghodke, Shruti; Mukherjee, Shaibal*

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Nanofabrication; Nanoelectronics

Memristors offer considerable potential to further biological synapse modeling and are frequently utilized to simulate biological synapses due to their typical neuron-synapse-like metal–insulator–metal (MIM) sandwich structure. However, the memristor's poor stability and high switching voltage limit its wider application to the biological synapse mimicking. High-density and highly efficient neuromorphic computing capabilities is required for the realization of multi-functional neuromorphic computing integrated with 3D RRAM technology. Therefore, in this study, we have successfully fabricated a bilayer MoS_2-based Memristive Crossbar Array (MCA) using Au/MoS_2/Au configuration. This work not only exhibits non-volatile bipolar resistive switching characteristics with an impressive endurance of 240 cycles and a remarkable retention time of up to 3×104 seconds, but also showed excellent operational uniformity with a coefficient of variation limited to 4.57 % and 2.52 % for RESET and SET voltages, respectively.

Submission number: 106

MAGNETIC VECTOR IMAGING OF QUASI-2D MAGNETIC SYSTEMS AT THE SOFT X-RAY TRANSMISSION MICROSCOPE OF THE MISTRAL BEAMLINE

Herguedas-Alonso, A.Estela*; Fernandez, Victoria Vega; Jurczyk, Jakub Mateusz;

Andrea, Sorrentino; Pereiro, Eva; Martin, Jose Ignacio; Velez, Maria; Ferrer, Salvador;

Hierro-Rodriguez, Aurelio

Keywords: Nanomagnetics

The ability to characterize the 3D vector magnetization configuration at the nanoscale is an unvaluable experimental asset for the nanomagnetism community to better understand and utilize magnetization phenomena. In the present contribution, we explain and demonstrate the capabilities of the Soft X-ray Transmission Microscope of the MISTRAL beamline at the ALBA Synchrotron, for the characterization of inhomogeneous three-dimensional magnetic textures within weak magnetic signal heterostructures. Different systems of NdCo5/Ni80Fe20 and NdCo5/Ni80Fe20/NdCo5 have been fabricated to evaluate the sensitivity limits of the experimental setup. We have reconstructed the 3D magnetization of structures with an effective Fe thickness as thin as 0.4 nm. The presented results are a sound basis of the potential of the method for the 3D vector magnetic characterization of mono/few-layer 2D Van der Waals magnets and/or ultra-thin Spintronic devices at the nanoscale.

Submission number: 108

ILLUMINATING THE FUTURE: LUMINESCENT ORGANIC MATERIALS AND PEROVSKITE QUANTUM DOTS FOR RARE-EARTH-FREE HUMAN-CENTRIC LIGHTING

Menendez-Velazquez, Amador*; Garcia-Delgado, Ana Belen; Morales Sabugal, Maria Dolores

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanomaterials; Nano-Energy, Environment, and Safety

In pursuit of efficient lighting solutions, scientists and engineers have long relied on rare-earth elements to create the vibrant LED displays and bright LED lights that power our devices and illuminate our homes. However, the environmental impact and scarcity of these materials have prompted a search for alternatives. Against this backdrop, luminescent organic materials and perovskite quantum dots emerge as a groundbreaking development poised to revolutionize the world of white light-emitting diodes (WLEDs). This study introduces an innovative hybrid approach for the fabrication of high-quality, rare-earth-free WLEDs. By synergizing organic materials with perovskite quantum dots, we have developed WLEDs that not only bypass the need for rare-earth elements but also offer a customizable light spectrum and tunable correlated color temperature (CCT), making them ideal for human-centric lighting (HCL) applications. Moreover, they maintain high color rendering index (CRI) values. Specifically, our WLEDs achieve CCT values ranging from 3705 K to 8238 K, with CRI values exceeding 85 in optimal configurations. To our knowledge, this is the first demonstration of such a hybrid methodology's potential and advantages, marking a significant step forward in the development of sustainable, rare-earth-free human-centric lighting solutions.

Submission number: 109

EFFECT OF SILICON ATOM DOPING IN SINX RESISTIVE SWITCHING FILMS

Mavropoulis, Alexandros Eleftherios*; Vasileiadis, Nikolaos; Bonafos, Caroline; Normand, Pascal; Ioannou-Sougleridis, Vassilios; Sirakoulis, Georgios; Dimitrakis, Panagiotis

Keywords: Nanoelectronics; Nanofabrication; Quantum, Neuromorphic, and Unconventional Computing

Doping stoichiometric SiNx layers (x=[N]/[Si]=1.33) with Si atoms by ultra-low energy ion implantation (ULE-II) and annealing them at different temperatures can significantly impact the switching characteristics. Electrical characterization and dielectric breakdown measurements are used to identify the main switching properties and performance of the fabricated devices and the effect that the Si dopants and annealing temperature have. In addition, impedance spectroscopy measurements revealed the dielectric properties of the silicon nitride films, as well as the ac conductance, which is utilized to identify the conduction mechanisms.

Submission number: 110

UNVEILING OPTOELECTRONIC TRAITS IN CHALCOGENIDE NANO-FILMS FOR PHOTOVOLTAICS APPLICATIONS

Dubey, Mayank; Yadav, Saurabh; Chaudhary, Sumit; Patel, Chandrabhan; Mukherjee, Shaibal*

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanoelectronics

This report presents a comprehensive analysis of dual ion beam sputtered (DIBS) Cu2(In,Ga)Se3 (CIGSe) nano-films, with a focus on their optical, compositional, and morphological properties. An innovative Al/Ga:ZnO/ZnO/CIGSe/Mo structure is proposed and evaluated using a Solar Cell Capacitance Simulator (SCAPS) tool, integrating experimental parameters to assess its suitability for photovoltaic applications. The primary objective of this analysis is to enhance device efficiency using cost-effective materials while eliminating the use of toxic CdS and substituting it with environmentally friendly and sustainable alternatives. X-ray Diffraction analysis demonstrates a strong tetragonal orientation in the CIGSe film. Spectroscopic ellipsometry reveals a band-gap of 1.57 eV and a notable absorption coefficient of approximately 104 cm-1. Integrating these experimental findings into SCAPS under standard illumination (AM 1.5), yields promising results with a photocurrent density (Jsc) of 34.03 mA/cm2, open-circuit voltage (Voc) of 0.612 V, fill factor (FF) of 80.25%, and an impressive solar cell efficiency of 16.73%.

Submission number: 111

ACOUSTIC CHIP FOR RAPID LABEL-FREE EARLY-STAGE DETECTION OF RARE LEUKEMIC CELLS

matarese, bruno*; Flewitt, Andrew J; Huntly, Brian

Keywords: Nanobiomedicine; Nano-Acoustic Devices, Processes, and Materials;

Nanosensors and Nanoactuators

We present a promising approach for detecting as few as 1% of rare leukemia cells during the early stages of blood cancers. This study demonstrates a novel microfluidic chip utilizing a bulk piezoelectric ceramic device to manipulate cells with sound waves. By analyzing the movement patterns of normal mononuclear cells (MNCs) and abnormal THP-1 acute myeloid leukemia (AML) cells within an acoustic field, we observed distinct behaviors. Our findings suggest a label-free, non-targeted approach for sensitive detection of rare abnormal cells within a mixed population. This method, based on acoustophoresis principles, holds promise for analyzing biophysical properties of individual cells for early cancer diagnosis, potentially leading to earlier intervention and improved patient outcomes for leukemia. While this study focuses on microscopic analysis, we also discuss the potential for developing large-scale acoustophoresis-based methods for high-throughput rare cell detection using high-resolution nanofabrication techniques.

Submission number: 112

FABRICATION AND CHARACTERIZATION OF ALUMINA BASED RESISTIVE RAM FOR SPACE APPLICATIONS

PANDAY, DHARMENDRA KUMAR; suman, saket*; Khan, Saif Khan; Srivastava, Dr. Asutosh

Keywords: Nanoelectronics; Nanofabrication; Nanomaterials

In this paper, we have studied resistive random access memory which inherits excellent properties as a non-volatile memories in terms of higher speed, lower cost, higher storage density and scalability applications in various fields. The memristor is a basic circuit element that results in the new type of non-volatile memory like ReRAM. The critical feature of memristor is the ability to retain its state without power, thus promising as a substitute for non-volatile memories in VLSI systems. We have explored the material properties, and studied electrical characteristics including resistance switching mechanism for the fabrication of non-volatile memory RRAM. We have fabricated the MIM (Metal-Insulator-Metal) structure of ReRAM in the form of Au/Al2O3/Pt-Si. The insulator layer (Al2O3) was deposited on the platinized Si-Wafer by Atomic Layer Deposition technique. The top electrode was fabricated as Au dots using thermal Evaporator. Various characterization techniques such as XRD, AFM and SEM of the deposited layers techniques were carried out to study the morphology of the dielectric layer. Pre-radiation VI – Characteristics of the fabricated ReRAM was determined and the results have been studied. Our I-V characteristics show a typical bipolar switching for Au/Al2O3/Pt-Si ReRAM configuration. Post radiation studies would be carried out to determine the radiation hardness of ReRAM as a non volatile memory for space applications.

Submission number: 114

RAPID AND LOW-COST FABRICATION OF GRAPHENE FROM PENCIL LEAD

Jiwarawat, Natchanon; Leukulwatanachai, Thapan; Subhakornphichan, Kunbhass; Limwathanagura, Siwagorn; Wanotayan, Sittinadh; Pungetmongkol, Porpin*

Keywords: Nanomaterials; Nanofabrication

A fast, simple and cost-effective electrochemical exfoliation of graphene using pencil lead has been reported. The synthesized graphene was characterized using a field-emission scanning electron microscopy (FE-SEM), atomic force microscope (AFM), and Raman spectroscopy to validate physical properties. The graphene exhibited a few-layered structure with small number of defects was produced, with an ID/IG ratio of 0.19. The layer graphene was then deposited onto the SPCE, where electrical properties were also determined. The findings of this study suggests that an alternative low-cost graphite precursor can potentially be applied to produce high-quality graphene, increasing the availability of the precursor, and preparing towards commercialization.

Submission number: 115

X-RAY TRANSMISSION MICROSCOPY OF DIPOLAR-COUPLED BILAYERS WITH CROSSED ANISOTROPIES FOR RECONFIGURABLE SPIN WAVE TRANSPORT

Herguedas-Alonso, A.Estela; Javier, Hermosa; Hierro-Rodriguez, Aurelio; QuirOs, Carlos; Diaz, Javier; Velez, Maria; Finizio, Smone; Tacchi, Silvia; alvarez-Prado, Luis Manuel*

Keywords: Nanomagnetics; Spintronics; Modeling and Simulation

Scanning transmission X-ray magnetic resonant microscopy (STXMRM) is used to study the magnetization reversal mechanisms of its stripe domains in dipolar-coupled layers (Py/Al/NdCo7) used for reconfigurable spin wave transport. The element specificity of X-ray permitted to observe the evolution of the stripe-domains as a function of the external magnetic field in each layer and determine the correlations between layers. This is key for the understanding of the hysteretic behavior observed in the spin wave transmission of the permalloy (Py) when it is dipolar coupled to the stripe domain textured NdCo7 layer. The images obtained show that the stripe domain imprinting on the Py layer is undetected in the range of fields where hysteretic properties in the dynamics of the Py magnetic moments are present, indicating that they should be induced by the stray field of the NdCo7 layer.

Submission number: 116

CURRENT RECTIFICATION VIA PHOTOSYSTEM I MONOLAYERS INDUCED BY THEIR ORIENTATION ON HYDROPHILIC SELF-ASSEMBLED MONOLAYERS ON TITANIUM NITRIDE

Rojas, Jonathan*; Wang, Zhe; Liu, Feng; Fereiro, Jerry A.; Chryssikos, Domenikos; Dittrich, Thomas; Leister, Dario; Cahen, David; Tornow, Marc

Keywords: Nanotechnology in Soft Electronics; Nanoelectronics; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

Photosystem I (PSI) is a photosynthetic protein which evolved to efficiently transfer electrons through the thylakoid membrane. This remarkable process attracted the attention of the biomolecular electronics community, which aims to study and understand the underlying electronic transport through these proteins by contacting ensembles of PSI with solid-state metallic contacts. This paper extends published work of immobilizing monolayers of PSI with a specific orientation, by using organophosphonate self-assembled molecules with hydrophilic heads on ultra-flat titanium nitride. Electrical measurements carried out with eutectic GaIn top contacts showed current rectification ratios of up to ~200. The previously proposed rectification mechanism, relying on the protein's internal electric dipole, was inquired by measuring shifts in the work function. Our straightforward bottom-up fabrication method may allow for further experimental studies on PSI molecules, such as embedding them in solid-state, transparent top contact schemes for optoelectronic measurements.

Submission number: 117

SYNTHESIS AND CHARACTERIZATION OF A BIOCOMPATIBLE, POLYMER MATRIX NANOCOMPOSITE FOR PHOTOACOUSTIC APPLICATIONS

Patterson, Alexandra*; Song, Hyunwoo; Kang, Jeeun; Boctor, Emad; Spicer, James B.

Keywords: Nano-Acoustic Devices, Processes, and Materials

Polymer matrix nanocomposites hold promise for being used as biocompatible, photoacoustic emitting materials. Such a combination of material capabilities has potential in the application of minimally invasive epiretinal implants that can be used to deliver a vision-like experience to patients with macular degenerative vision loss. A method based on chemical vapor deposition is used for in-situ growth of palladium nanoparticles in a polydimethylsiloxane matrix. This scalable method is shown to prevent nanoparticle agglomeration that is typically seen with other commonly used nanocomposite synthesis methods. This method can be iterated multiple times on the same sample to increase nanoparticle diameters. In this work, we report characterization results on samples created with this process obtained using UV-Vis-NIR spectrometry, x-ray diffraction (XRD), and transmission electron microscopy (TEM). Results are also reported for the photoacoustic response of these materials obtained using a pulsed laser ultrasonic transmitter and a hydrophone receiver. These results will assist in the design of epiretinal implants that can be used as part of a prosthetic system to provide a vision-like experience for users.

Submission number: 118

DETERMINATION OF DIRECTION OF SINGLE ELECTRON CHARGING IN AN ISOLATED METAL DOUBLE-DOT SYSTEM USING RF REFLECTOMETRY

Rahaman, Mohammad Istiaque*; Orlov, Alexei; Snider, Gregory

Keywords: Nanosensors and Nanoactuators; Nanofabrication; Nanoelectronics

Charge sensing plays a crucial role in quantum computing systems, often involving Single Electron Transistors (SETs). However, fabrication of SETs involves additional processing steps and demands improved SET yield. In this work, we have demonstrated a single-port radio frequency gate reflectometry setup for single charge sensing without SETs. By strategically placing a restricted set of gates around a structure composed of two nanoscale metal separated by a tunnel barrier, we showcased single electron charge transfer and detection within a sub-20nm space. In our approach, a single gate serves as both a charge manipulator and a detector. The change in complex admittance associated with a single electron tunneling event is detected in the reflected RF signal. Our proposed system holds potential for sensing the charge of topological qubits.

Submission number: 119

ALGINATE FILMS EMBEDDING ELECTROSYNTHESIZED ZNO NANOSTRUCTURES FOR FOOD PACKAGING APPLICATIONS

MONTEFUSCO, ANTONICA VALERIA*; Izzi, Margherita; CALIA, DOMENICO; PUGLIESE, ANNA; SPORTELLI, MARIA CHIARA; CIOFFI, NICOLA; Picca, Rosaria Anna

Keywords: Nanopackaging; Nanomaterials

Even today, many products intended for food, though well cultivated, unfortunately undergo deterioration due to contamination by pathogenic microorganisms causing a considerable economic burden. Hence, new solutions are explored to improve food preservation. Biodegradable coatings with antimicrobial properties can prolong product shelf-life thus limiting pathogen growth and/or biofilm formation. In this work we propose cross-linked films based on alginate, a biodegradable polysaccharide biopolymer, modified with zinc oxide nanostructures (ZnO NSs). The nanomaterial was prepared through a green electrochemical-thermal method, using a sacrificial zinc anode corroded in a slightly alkaline bath in the presence of sodium dodecyl sulfate, as a stabilizer. A suitable protocol for fabricating self-supported ZnO NSs/alginate films was developed. Morphological and spectroscopic characterizations were performed on NSs to evaluate their composition and morphology. Films were characterized in terms of composition and water uptake, showing that the addition of ZnO NSs improves significantly their resistance, and supporting their potential application in food packaging studies.

Submission number: 120

NANOPOROUS AL2O3 ASSISTED ANODIZING OF WTI ALLOY

Hoha, Aliaksandr; Turavets, Ulyana; Poznyak, Alexander; Pligovka, Andrei*

Keywords: Nanofabrication; Nanomaterials; Nano-Optics, Nanophotonics, and

Nano-Optoelectronics

Abstract— Nanoporous Al_2O_3 assisted 125 and 180 nm WTi alloy in 0.1, 0.4 M oxalic and 0.2, 0.4, 0.6 M tartaric acid solution were galvanostatically and potentiostatically anodized, in boric acid solution were galvanostatically reanodized. Time-current and time-voltage, morphology and composition, chemical etching and planarization features were investigated. Features of anodizing, chemical etching and morphology are presented.

Submission number: 121

SENSING PERFORMANCE OF VISIBLE LIGHT-ACTIVATED SNO2 FUNCTIONALIZED WITH CUINS2@ZNS QDS FOR HYDROGEN DETECTION

Orlando, Antonio*; Gaiardo, Andrea; Valt, Matteo; Trentini, Guglielmo; Magoni, Marco; Tosato, Pietro; Lugli, Paolo; Krik, Soufiane; Petti, Luisa

Keywords: Nanomaterials; Nanosensors and Nanoactuators; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

In recent years, the detection of air pollution has gained an increasing interest due to the impact that this has on human health and the environment. In this context, one of the key challenges is the real-time and selective monitoring of the air quality. To this aim, chemiresistive gas sensors represent one of the most widely used technologies, due to their low cost, fast response, and portability. Nowadays, chemiresistive gas sensors based on semiconducting metal oxides (SMOX) are the most widely used thanks to their reliability and high sensitivity. However, despite the important advantages, there are two main drawbacks associated with their use, namely the low selectivity of SMOX-based gas sensors and the high power consumption associated to the need of high temperatures for thermal activation of the sensing film. To address these drawbacks, there is an urgent need for novel approaches. One interesting strategy to decrease energy consumption involves the use of light radiation for sensor activation instead of the traditional heating methods. However, a significant limitation is the low absorption of visible radiation by many sensing materials, notably SMOX. To overcome this issue, an effective strategy involves functionalizing SMOX with antenna molecules capable of absorbing visible light and facilitating electron transfer to the conduction band of the SMOX. Quantum dots (QDs) have emerged as a promising class of molecules for this purpose. In this study, an innovative composite material composed of SnO_2 nanoparticles functionalized with $CuInS_2$@ZnS (ZCIS) QDs acting as an antenna for blue light activation was investigated. The experimental results showed a significant change in sensor resistance under blue light illumination (464 nm), yielding a notable response value of 43.18. Leveraging this illumination, hydrogen (H_2) detection at concentrations of 30, 60, 150, and 300 ppm was tested, yielding responses of 1.05%, 1.35%, 2.89%, and 4.07%, respectively. Another significant outcome of the study is the recovery time of the sensor. It was observed a consistent recovery time of approximately 2 hours across all tested H_2 concentrations.

Submission number: 122

FABRICATION, DEPOSITION, MORPHOLOGY AND COMPOSITION OF PEROVSKITE CSPB(BR1-XIX)3

Turavets, Ulyana*; Poznyak, Alexander; Hoha, Aliaksandr; Pligovka, Andrei

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanomaterials;

Nanofabrication

In this work, $CsPb(Br_{1-x}I_x)_3$ perovskite crystals with simple and affordable deposition technique under ambient condition is proposed to be formed. Thus, synthesis of safe inorganic perovskites on glass substrates and bilayer anodic Al/WTi system films was developed by Ligand-Assisted Reprecipitation method immediately on target substrates. Their composition, morphology and photoluminescent characteristics have been studied. Photoluminescence peaks $CsPbBr_2I$ and $CsPbI_3$ are 535 and 550 nm respectively and X-ray diffraction analysis show the resulting crystals have an orthorhombic phase. Scanning electron microscopy showed the rod structure of perovskite.

Submission number: 123

THIN FILM MICROWAVE ABSORBER–COLUMN-LIKE THERMISTOR COUPLE FABRICATED VIA ANODIZING OF AL/WTI FOR RECTANGLE WAVEGUIDE CALORIMETER SENSOR

Hoha, Aliaksandr*; Turavets, Ulyana; Poznyak, Alexander; Pligovka, Andrei

Keywords: Nanosensors and Nanoactuators; Nanomaterials; Nanofabrication

Absorber–thermistor couple was formed by combine barrier anodizing WTi layer and anodizing two-layer system Al/WTi on single pieces of glass substrate. The use of thin film couple can reduce the heat capacity of the calorimetric sensor. Thermistor was formed by anodizing of magnetron sputter-deposited Al/WTi in 0.4 M oxalic acid aqueous solution at constant current density 6 mA-8729;cm–2, reanodizing in an electrolyte containing 0.5 M boric acid and 0.05 M sodium tetraborate in a potentiodynamic mode by raising the voltage to 380 V, and chemical etching. Thin film microwave absorber was formed by anodizing of magnetron sputter-deposited Al/WTi in 1 % citric acid aqueous solution and chemical etching. The column-like thermistor morphology by scanning electron microscopy on formation conditions were investigated. The dependence of sheet resistance on the barrier anodizing voltage of metal WTi thin film has been investigated. Thin film microwave absorber with sheet resistance above 100 Ohms•-9633;–1 was obtained. The calculated temperature coefficient of resistance in the temperature range 20 to 55 °C appeared to be negative and rather low –8.4•10–3•K–1 for the column-like thermistor. The design of absorber – thermistor couple for rectangle microwave calorimeter and experimental sample have been developed.

Submission number: 124

AN EFFICIENT QUANTUM-INSPIRED COMPUTING APPROACH FOR INTRUSION DETECTION SYSTEM

Shen, Jyun-Yi; Wu, Ching-Hsuan; Hua, Cheng-Yen; Chang, Ming-Ho; Kuo, Shu-Yu*;

Chou, Yao-Hsin; Kuo, Sy-Yen

Keywords: Quantum, Neuromorphic, and Unconventional Computing; AI for Nanotechnology

Quantum-inspired computing (QIC) algorithms simulate the principles of quantum mechanics to enable an efficient search for optimal solutions and substantial reductions in computational costs. This study marks the first attempt to propose a QIC algorithm designed for constructing an intrusion detection system (IDS). With the rapid advancement of technology comes a surge in malicious activities. The IDS is an important defense against internet attacks, which is crucial for efficiently identifying anomalous network traffic and preventing detrimental consequences such as data breaches. The proposed system introduces a new encoding method for IDS on QIC, complemented by a novel technique: a voting mechanism. This mechanism enhances accuracy and reliability in the decision-making process by aggregating multiple inputs or opinions, thereby reducing the rate of false negatives and false positives. The results demonstrate that the QIC-based IDS effectively distinguishes between normal network traffic and malicious activities, achieving high accuracy on two well-known benchmarks with lower floating-point operations (FLOPs). This lightweight design and high efficiency offer significant advantages for real-time systems and various industries.

Submission number: 125

NANO DETECTION OF MIR-155 FOR EARLY LUNG CANCER DIAGNOSIS VIA SURFACE-ENHANCED RAMAN SPECTROSCOPY

Quin, Christina*; McClelland, Arthur; Zeng, Tingying Helen

Keywords: Nanomaterials; Emerging Plasma Nanotechnologies; Nanobiomedicine

Lung cancer remains the preeminent cause of cancer-related mortality worldwide, necessitating advancements in early detection methods to improve patient prognosis. Traditional diagnostic tools, such as CT scans and sputum cytology, are hindered by high false-positive rates, prompting the need for more accurate and non-invasive diagnostic techniques. This study delves into the innovative integration of miR-155, a microRNA implicated in lung carcinogenesis, with Surface Enhanced Raman Spectroscopy (SERS) facilitated by silver nanoparticles for the early detection of lung cancer in ex vivo samples. Through a meticulously designed series of experiments, the sensitivity and specificity of SERS in detecting miR-155 at physiologically relevant concentrations were examined. The constructed methodology capitalized on the unique plasmonic effect achieved via the use of silver nanoparticles to enhance the Raman signal of miR-155, enabling the detection of this biomarker at concentrations indicative of early-stage non-small cell lung cancer (NSCLC). The results revealed a significant enhancement in the Raman signal intensity of miR-155 in the presence of silver nanoparticles, demonstrating the potential of SERS as a powerful tool for the early diagnosis of lung cancer in controlled laboratory settings. The application of this technology represents a paradigm shift towards non-invasive, accurate, and cost-effective lung cancer diagnostics, with the potential to substantially improve early detection rates and patient survival outcomes. However, further validation in clinical settings is necessary. This research underscores the promise of nanotechnology and bioanalytical methods in cancer diagnostics, paving the way for future studies to validate these findings in clinical settings and explore the integration of SERS with existing diagnostic protocols for a more comprehensive approach to lung cancer detection.

Submission number: 126

DEMONSTRATION OF A NAND-LIKE SOT-MRAM MULTI-LEVEL CELL WITH TWO OPERATIONAL MODES

Wang, Chenyi; Yan, Zhengjie; Wang, Min; Wang, Zhaohao*

Keywords: Spintronics; Nanofabrication

Multi-level cell (MLC) schemes have demonstrated effectiveness in scenarios such as neural network acceleration and multi-task optimization. Leveraging several advantages, particularly its compatibility with complementary metal oxide semiconductor (CMOS) processes, the MLC scheme of MRAM has been widely researched. In this study, we propose an MLC-MRAM architecture based on spin-orbit torque (SOT) and voltage-controlled magnetic anisotropy (VCMA) within a NAND-like structure, featuring two operational modes. One mode involves a one-step writing operation, enabling deterministic writing of four data states. It effectively addresses the previous annealing challenge associated with the MLC device and achieves reliable switching within a single step. The other mode combines SOT and VCMA effects in the two-step operation which facilitates multi-level storage. The experimental results confirm the existence of multiple resistance states, characterized by the minimal variation (a standard deviation of less than 6%). Our work verifies that the NAND-like SOT-MRAM MLC based on canted devices with in-plane magnetic anisotropy, achieves multi-level storage while satisfying the fundamental requirements for in-memory computing.

Submission number: 127

MULTI-FUNCTIONAL DESIGN FOR MEMORY AND STRONG PHYSICAL UNCLONABLE FUNCTIONS BASED ON NAND-LIKE SOT ARRAYS

Wang, Min; Hou, Zhengyi; Wang, Bi; Wang, Zhaohao*

Keywords: Spintronics; Modeling and Simulation

MRAM-based physical unclonable function (PUF) design has become a hot research topic in academia and industry. The spin-orbit torque-based PUFs (SOT-PUFs) have the advantages of non-volatility, substantial miniaturization, and low energy consumption. However, existing MRAM PUFs share a common issue: PUF and memory functions cannot coexist simultaneously in the same array. Meanwhile, most of the memory-based PUFs are weak PUFs. The proposed multifunctional design further improves these issues with memory and strong PUF functionality where NAND-like SOT devices further reduce cell area. The uniformity and uniqueness are estimated to be 0.4986 and 0.4997, respectively. Our work validates the multi-functionality of the proposed design and paves the way for SOT-based applications.

Submission number: 129

LOW TOXICITY PROFILE OF CHITOSAN/ZINC OXIDE NANOCOMPOSITE IN EARLY ZEBRAFISH DEVELOPMENTAL STAGES

younes, salma; younes, nadin; Gheyath, Nasrallah*

Keywords: Nano-Energy, Environment, and Safety; Nanomaterials

Marine biofouling presents a significant challenge to the global maritime industry, with traditional biocidal agents used to mitigate this issue posing considerable toxicity risks to aquatic ecosystems. In response to these concerns, the adoption of chitosan/zinc oxide nanoparticle (CZNC) composites as a sustainable biocidal solution has garnered interest, primarily due to chitosan's environmentally benign characteristics. This potential suggests that CZNCs could lead to the development of less harmful antifouling surfaces. Given the increasing reliance on zebrafish as a model organism in ecotoxicological research, this study seeks to conduct a thorough assessment of the acute, cardiovascular, neurological, and hepatotoxic effects of CZNC exposure in zebrafish embryos. The study's findings, derived from acute toxicity assays, indicate that zebrafish embryos showed no acute toxicity symptoms or mortality. Furthermore, exposure to CZNCs did not result in cardiotoxic or neurotoxic effects. However, a slight hepatotoxic response was observed in the embryos, which did not impact their survival, even after an extended exposure period of 10 days. These results contribute meaningful insights into the toxicity profile of chitosan/metal oxide nanocomposites. It is anticipated that this research will offer novel perspectives on the creation of environmentally friendly antifouling coatings, characterized by their enhanced performance and minimal adverse effects on marine ecosystems.

Submission number: 132

RANDOM NUMBER GENERATION DRIVEN BY VOLTAGE-CONTROLLED MAGNETIC ANISOTROPY AND THEIR USE IN PROBABILISTIC COMPUTING

Raimondo, Eleonora; Grimaldi, Andrea; Giordano, Anna; Chiappini, Massimo;

Carpentieri, Mario; Finocchio, Giovanni*

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Spintronics

Ising machines are becoming increasingly popular as efficient and hardware-friendly solvers for combinatorial optimization problems. One promising approach for solving Ising models is through probabilistic Ising machines (PIMs), wherein conventional bits are replaced by bistable tunable stochastic bits (p-bits). The generation of random numbers is a crucial component of PIMs. Stochastic magnetic tunnel junctions (MTJs) have been proposed to physically implement p-bits; however, their scalability faces challenges due to the required fine tuning of a small energy barrier. Alternatively, the voltage-controlled magnetic anisotropy (VCMA) effect in deterministic perpendicular MTJs can be used to generate random binary states. Here, we present a comprehensive phase diagram to delineate the characteristics of VCMA pulses for the generation of true random numbers. We introduce the design of an MTJ-based p-bit, where the precision of the stochastic component is linked to the number of MTJs employed. We explore the impact of adaptive p-bit precision in solving an instance of a maximum satisfiability problem. The results show that a limited number of VCMA-based MTJs (less than 20) are sufficient to ensure performance comparable to the software solutions.

Submission number: 133

ORGANIC FIELD EFFECT TRANSISTOR MODELING WITH PMMA INSULATING LAYER

Ternisien, Marc*; Kahri, Rahma; Khalfaoui, Mohamed; Buso, David

Keywords: Modeling and Simulation; Nanoelectronics

Organic field-effect transistors (OFETs) have emerged as a crucial area of research due to their low manufacturing costs and flexibility. Recent studies [1-2] have shown that it is possible for transistors, to exceed the performance of an OLED adapting their design technology. Research in this field focuses on the development of more durable materials and a deeper understanding of the characteristics and internal mechanism of these devices. In this context, our work focuses on the study of the electrical characteristics of OFETs composed of a PMMA insulating layer. This work is part of a collaboration between ISIMM in Tunisia and the LAPLACE laboratory in Toulouse. In order to understand and further investigate these experimentally realized devices, we undertook a numerical simulation to predict the I-V characteristics. As a first step, we performed DFT (Density Functional Theory) quantum modeling. This approach enabled us to determine the structural properties of our PMMA polymer for use in the simulation. We then used ATLAS SILVACO TCAD software to perform the numerical modeling. This simulator enabled us to predict I-V electrical characteristics and compare them with experimental data, thus facilitating understanding of certain internal physical phenomena. Finally, we tried to study the impact of channel length and dielectric layer thickness on the operation of our OFET.

Submission number: 134

LEAKY-INTEGRATE-FIRE NEURON BASED ON ANTIFERROMAGNETIC SKYRMION UNDER STRAIN GRADIENT

Raj, Ravish Kumar*; Verma, Ravi Shankar; Saini, Shipra; Kumar, Mohit; Shukla, Alok Kumar; Kaushik, Brajesh

Keywords: Spintronics; Quantum, Neuromorphic, and Unconventional Computing; Nanomagnetics

Antiferromagnetic (AFM) skyrmion-based spintronic devices are favored over their ferromagnetic (FM) counterparts due to compelling characteristics including robust exchange interaction, interfacial Dzyaloshinskii-Moriya interaction (DMI), minimal stray fields, low susceptibility to external fields, and inherent non-volatility. The straight trajectories followed by AFM skyrmions prevent their annihilation at the edges of nanoscale racetracks, making them a more promising candidate than FM skyrmions for future spintronic applications. In this work, AFM skyrmion dynamics under strain gradient is studied. It is observed that creating the strain gradient is an efficient way to drive AFM skyrmions with a high longitudinal speed in the order 800 m/s. Furthermore, a leaky integrate-and-fire (LIF) neuron is proposed based on strain gradient for enhancing energy efficiency in neuromorphic computing systems. This opens a new alternative way to manipulate AFM skyrmions for the development of energy-efficient AFM skyrmion based devices in neuromorphic computing.

Submission number: 135

HYDROPHOBIC HYBRID SOL-GEL BASED COATINGS WITH ICE-PHOBIC BEHAVIOUR

Brusciotti, Fabiola*; Suarez-Vega, Ana; Agustin, Cecilia

Keywords: Hydrophobic, Oleophobic and/or Icephobic nanostructured surfaces

Hydrophobic, oleophobic, and icephobic surfaces represent materials designed to repel water, oil, and ice, respectively, offering various applications across industries. The development of materials with these properties is being thoroughly investigated, leading to innovative solutions for diverse challenges in engineering, manufacturing, and everyday life.- Sol-gel is a promising approach, offering a vast range of possibilities for coating design. Its ability to synergistically combine inorganic and organic moieties leads to the formation of hybrid materials with covalently bonded parts. In this work, researchers have accomplished the development of ice-phobic solutions by functionalizing an anticorrosion hybrid sol-gel formulation with alkyl and polyfluoroalkyl moieties. The quantity and chain length of these moieties has been optimized to achieve hydrophobicity. The morphology of the surface has also been taken into account, as the wetting of a surface by a liquid is affected by its topography. Therefore, the combination of topographical morphology and surface chemistry has been tailored to achieve super-hydrophobicity, leading to improved ice-phobic performance.- The best results have been obtained with a thin, hybrid organic-inorganic coating with low surface free energy. It provides high mechanical properties needed to resist erosion in specific conditions, while maintaining and protecting the topographical character and chemical composition required for super-hydrophobicity. The resulting coating is also very flexible, and it presents very good adhesion to metal, plastic and glass substrates.- The researchers evaluated the anti-icing properties of the treated surfaces in a classical ice tunnel and a dedicated test set-up to reproduce specific conditions of ice formation, accretion, and erosion phenomena.- Moreover, as perfluorinated polymers, while effective for achieving super-hydrophobic surfaces, have been rising toxicological concerns, alternative compounds are being investigated to replace fluorinated molecules in the coating matrix. Promising results were obtained, without losing the surface free energy properties of the original coatings.

Submission number: 136

TOWARDS MXENE BIOCOMPATIBILITY WITH FOCUS ON THEIR STRUCTURAL AND CHEMICAL PROPERTIES

Pogorielov, Maksym*; Kyrylenko, Sergiy; Inna, Chorna; Aguilar-Ferrer, Daniel; Lyndin, Mykola; Wennemuth, Gunther; Baginskiy, Ivan; Korniienko, Viktoriia; Deineka, Volodymyr; Diedkova, Kateryna; Kube-Golovin, Irina; Iatsunskyi, Igor

Keywords: Nanobiomedicine; Nanomaterials

The discovery of graphene in 2004 catalyzed an intensive exploration for new two-dimensional (2D) materials. Amongst other, MXenes stand out as exceptionally promising, identified by Yury Gogotsi and Michel Barsoum at Drexel University in 2011. Presently, there are over fifty synthesized variants of MXenes, with numerous others theoretically predicted. Over the decade following their discovery, MXenes have showcased significant versatility, finding potential applications across a spectrum of industries—ranging from lithium and sodium-ion batteries to electrocatalysis, optoelectronic devices, flexible electronics, and a myriad of biomedical uses such as in cancer therapy, bacteriology, immunology, precision drug delivery, and tissue engineering. Given the intense application of MXenes in biomedical fields, thorough examination of their biocompatibility is imperative for their successful integration. Moreover, assessing the biosafety of MXenes is critical, considering the environmental impact associated with their extensive deployment. Upon a detailed review of the current literature, it is evident that defining precise toxicity profiles for MXenes remains challenging due to inconsistent results, even when the same MXene chemical compositions are investigated. Such results may be attributed to the differences in chemical purity, oxidation levels, and terminal groups of the MXenes used in these studies. Regrettably, a significant portion of biomedical research does not sufficiently address the control over the chemical structure, which includes managing oxidation states and the configuration of T_x terminations. Our study has established a link between the size of Ti_3C_2, V_2C, Nb_3C_2 and Nb_2C MXene flakes, their surface terminations (T_x), and the resulting cellular responses. These responses encompass the cellular uptake of MXenes, as well as the processes of apoptosis/necrosis and genotoxicity. The findings underscore the critical role that precise control over the size and surface chemistry of MXenes plays in tailoring their properties for biomedical applications. Acknowledgement: This project was supported by MSCA-2021-SE-01 projects MX-MAP (101086184) and by LRC Project (#lzp2023/1- 0243).

Submission number: 138

SKYRMION-BASED TRANSISTOR UTILIZING DZYALOSHINSKII–MORIYA INTERACTION BARRIER

Kumar, Mohit*; Raj, Ravish Kumar; Verma, Ravi Shankar; Kaushik, Brajesh

Keywords: Spintronics; Nanomagnetics; Nanoelectronics

Magnetic skyrmions represent localized and topologically protected spin configurations, which hold significant interest for both fundamental research and practical applications in future microelectronics. Skyrmion-based electronic devices, such as transistors and logic gates, are regarded as the next generation of electronic technology. In this work, skyrmion-based transistor is proposed that utilizes Dzyaloshinskii–Moriya Interaction (DMI) barrier control via an electric field applied to the middle of the nanotrack. The DMI barrier can be controlled over the gate region by manipulating a voltage, enabling ON and OFF functionality. The proposed transistor has an optimized area of 3000 nm^2 and requires an SOT current of only 0.2 GA/m^2 to drive the skyrmion, making it energy-efficient and suitable for low-power applications. This functionality replicates a conventional transistor for magnetic devices and can be applied to logic families and memory devices.

Submission number: 139

EXPLORING SEX/GENDER PERSPECTIVES IN NANOTECHNOLOGY AND NANOMATERIALS RESEARCH

Bencivenga, Rita; Leone, Cinzia; Peddis, Davide; Laureti, Sara*

Keywords: Nanomaterials; Nanobiomedicine

This article aims to draw attention to the integration of sex/gender dimensions within the scientific community investigating nanomaterials and nanotechnology. Despite the significant impact of these fields on society, there remains a gap in understanding how the gender dimension can intersect with research practices and outcomes. The presence of gender-specific terminology, involving references to gender, sex, masculinity, femininity, and other related concepts can allow us to shed light on the current state of a sex/gender dimension integration in nanotechnology research. By analyzing the presence of gender-related terms in the proceedings of the IEEE Nano-Community, this paper contributes to the ongoing discussions on the importance of integrating a sex/ gender dimension in research and education in the field and highlights the need to make the nanotechnology and nanomaterials research landscape more inclusive and insightful in the future.

Submission number: 140

INVESTIGATION OF TEMPERATURE IMPACTS ON TRANSFER CHARACTERISTICS TO ANALOG/RF OF DRAIN UNDERLAP BASED L-SHAPED TFET

Singh, Prabhat; Raman, Ashish; Kumar, Naveen*; Dixit, Ankit; Kumar, Prateek; Yadav, Dharmendra Singh

Keywords: Modeling and Simulation; Nanoelectronics

In this work, an L-shaped Tunnel FET is demonstrated for the impact of the simulation models and temperature variations. When temperature increases above the room temperature (250K to 450K), it significantly affects the carrier mobility and carrier injection process. The SRH and TAT show their significance in increasing the OFF-state current (ambipolar behavior) for the lower and negative values of gate voltage. When gate voltage rises, the BTBT model starts to show its presence, and the impact of SRH and TAT models starts decreasing. Because of this, the OFF-state current starts diminishing as gate voltage increases. According to the applied electric field, the BTBT, SRH, and TAT current functionalities have particular confining regions. TAT and SRH aspects predominate drain current at weak electric fields, as they are very susceptible to temperature variations. Hence, the change in models and temperature affects the device efficacy, such as analog and high-frequency functionality, and it necessitates a detailed investigation.

Submission number: 141

TWIST-ANGLE TUNABLE SPIN TEXTURE IN PROXIMITIZED GRAPHENE VAN DER WAALS HETEROSTRUCTURES

Yang, Haozhe*

Keywords: Spintronics; Nanoelectronics

Angle-twisting engineering has emerged as a powerful tool for modulating electronic properties in van der Waals heterostructures. Recent theoretical works1,2 have predicted the modulation of spin texture in graphene-based heterostructures by twist angle, although an experimental verification is missing. Here, we fabricate WSe2/graphene vdW heterostructures with controllable twist angles, which are accurately measured using optical second harmonic generation and Raman spectroscopy. Spin and charge interconversion (SCI) was measured with non-local spin precession experiments. Both the Rashba-Edelstein effect (REE) and the unconventional REE (UREE) effects are detected in our heterostructures, with an opposite sign when the carriers in graphene transit from electrons to holes and with a maximum near the charge neutrality point of proximitized graphene. Importantly, the UREE shows a sign reversal when twisting the angle, due to the modulation of the in-plane spin texture. This twist-angle-induced UREE is detected up to room temperature. Our findings3 provide the first experimental demonstration of spin texture modulation by the twist angle, which turns the radial spin component on and off and even changes its sign, leading to a full control of the spin texture helicity. Harnessing this phenomenon, that merges the fields of spintronics and twistronics, unlocks new opportunities for both fundamental research in moire heterostructures and practical applications in spin-based devices.-

References: 1.--Lee, S. et al. Charge-to-spin conversion in twisted graphene/WSe2 heterostructures. Phys. Rev. B 106, 165420 (2022). 2.--Naimer, T., Zollner, K., Gmitra, M. & Fabian, J. Twist-angle dependent proximity induced spin-orbit coupling in graphene/transition metal dichalcogenide heterostructures. Phys. Rev. B 104, 195156 (2021). 3.--Yang, H. et al. Twist-angle tunable spin texture in WSe 2 /graphene van der Waals heterostructures. arXiv:2312.10227.

Submission number: 142

SENSITIVITY INVESTIGATION OF UNDERLAP GATE CAVITY-BASED RECONFIGURABLE SILICON NANOWIRE SCHOTTKY BARRIER TRANSISTOR FOR BIOSENSOR APPLICATION

Kumar, Suraj; Kale, Sumit*; Singh, Kaustubh Ranjan; Kumar, Anil

Keywords: Nanosensors and Nanoactuators; Modeling and Simulation; Nanofabrication

This study investigates the sensitivity of Underlap Gate Cavity-based Reconfigurable Silicon Nanowire Schottky Barrier Transistor (UGC-RSiNW SBT) for Biosensor Application. The featured unique reconfigurable capability enables the device to operate as either p-type or n-type, dependent on the applied bias polarity. The proposed biosensor incorporates a cavity beneath the control gate on the source side, facilitating the placement of both neutral and charged biomolecules with varying dielectric constant (K) values. Upon injection of biomolecules into the cavity, the device changes electrostatic characteristics, including modulation in threshold voltage, potential, electric field, and sub-threshold swing, ION , ION /IOF F ratio. The threshold voltage (VTH) Sensitivity of n-mode is enhanced by 97.91%, while that of p-mode is raised by 16% compared to conventional RFET biosensors. The findings from this study provide valuable insights into the development of highly sensitive biosensors for applications in diverse fields, including healthcare and biotechnol

Submission number: 143

INTEGRATION OF POSIT ARITHMETIC IN RISC-V TARGETING LOW-POWER COMPUTATIONS

Mallasen, David; Murillo, Raul; del Barrio, Alberto Antonio*; Botella, Guillermo;

Prieto-Matias, Manuel

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Modeling and Simulation

In this talk, we will describe how to leverage the promising posit number format introduced by John Gustafson in 2017 to reduce the energy consumption of the whole system. Posits were released as a direct drop-in replacement for the standard IEEE 754 and they are particularly accurate in the surroundings of 1. Furthermore, they do not suffer the IEEE 754 drawbacks when it comes to reproducing calculations across different machines. Our discussions will be centered around the promising posit properties as well as how to perform real deployments thanks to the RISC-V ISA.

Submission number: 144

AB-INITIO STUDY OF VALLEY-ORBIT STATES IN SI/SIGE AND SI/SIO2

Cvitkovich, Lukas*; Stano, Peter; Niquet, Yann-Michel; Grasser, Tibor

Keywords: Nanomaterials; Modeling and Simulation; Quantum, Neuromorphic, and Unconventional Computing

We present an ab-initio study of electronic states at the conduction band minimum of commonly used Si/SiGe and Si/oxide (Si-MOS) heterostructures. While previous theoretical investigations have relied on tight-binding and/or effective mass approaches - both of which require the extensive use of empirically fitted parameters - our density functional theory (DFT) modeling technique seamlessly integrates the complex interplay between interface quality, well design, atomistic disorder, strain and electric fields from first principles. The confining interfaces between the Si layer and the barrier play a crucial role in the context of spin devices because they induce couplings to the spin carrier's valley and spin degree of freedom. This talk will cover two of these interactions. First, we show DFT results on valley splitting, the splitting of nearly degenerate states at the conduction band minimum of Si. Here, we consider various well designs (e.g. oscillating Ge profiles) that were proposed to enhance the detrimentally low valley splitting in Si/SiGe systems. Our results confirm certain trends and predictions of earlier studies while also revealing shortcomings and significant impacts, such as the formation of mixed valley-orbit states, which are typically neglected within effective mass techniques. Both qualitative and quantitative differences between the modeling techniques are systematically analyzed by comparison with a sp3d5s* tight-binding model which is capable of treating strain and alloy disorder. The second part of the talk will be devoted to hyperfine interactions with nuclei in the barrier layer of the heterostructures. Here, we utilize DFT to determine the hyperfine tensors of all atoms in the system. Based on these results, we estimate the dephasing time T2* due to magnetic noise from the spin bath and show that the coherence is limited by interactions with non-Si barrier atoms to 10 μs in Si/SiGe (for non-purified Ge) and about 200 μs in Si-MOS.

Submission number: 145

A NOVEL DRAIN ENGINEERED TFET WITH SUPPRESSED AMBIPOLAR CURRENT

Nimje, Saloni; Garg, Rupak; Rohtagi, Sachit; Kale, Sumit*; Uddin Shaikh, Mohd Rizwan; Kumar, Prashanth

Keywords: Modeling and Simulation; Nanofabrication; Nanoelectronics

This manuscript reports a novel drain-engineered Tunnel FET (TFET) with a suppressed ambipolar current. The proposed device used an L-shaped Si channel with an upright drain on the top and a lateral source. In addition, pocket doping was introduced at the interface of the source and channel with dual gate oxide. The proposed device uses dual gate oxides such as Hafnium Oxide (HfO_2) and Silicon Oxide (SiO_2). The employment of pocket doping and dual gate oxide enhances the performance of TFET remarkably. This work aims to fully suppress ambipolar current and improve ON-current (I_{ON}). A 2D calibrated simulation study shows a four times increase in I_{ON} and considerably suppressed ambipolar current compared to conventional TFET. Also, ten times increase in the magnitude of I_{ON} /I_{OFF} ratio, 3.15 times increase in transconductance (gm), 13.2 times increase in cut-off frequency (f_T) and 203 times increase in GBW (Gain Bandwidth) are obtained by the proposed device. The possible fabrication flow is also presented for the proposed device.

Submission number: 146

HIGH ENDURANCE BACK-END-OF-LINE PECVD AMORPHOUS SIC SINGLE AND BI-LAYER MEMRISTORS FOR NEUROMORPHIC COMPUTING

Kapur, Omesh; Guo, Dongkai; Huang, Ruomeng; de Groot, Kees*

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Nanofabrication; Nanoelectronics

Memristors have emerged as one of the most promising neuromorphic artificial electronic devices for their structural resemblance to biological synapses and ability to emulate many synaptic functions. We present here a memristor system based on amorphous SiC deposited by plasma-enhanced chemical vapour deposition (PECVD). Both elemental composition and deposition method make this system intrinsically back-end-of-line native allowing them to be stacked directly above the logic [1]. The conductance of our Cu/SiC/W based memristor can be modulated gradually through the application of both DC and AC signals. It allows emulation of several vital synaptic functions including paired-pulse facilitation (PPF), post-tetanic potentiation (PTP), short-term potentiation (STP), and spike-timing-dependent plasticity (STDP) [2]. The synaptic function of learning-forgetting-relearning processes was successfully demonstrated using a 3×3 artificial synapse array. The unique short-term plasticity is capable of encoding temporal signals, as demonstrated by implementation of a physical reservoir computing system [3]. Here we further report the fabrication and measurement of a memristor bilayer of PECVD amorphous Si/SiC to stabilise the Cu conductive filament formation in the dielectric and converting the memory from interfacial switching to filamentary switching. This results in stable switching between high resistance and low resistance memory state with an endurance of over 109 cycles, all the while maintaining an on/off ratio of nearly two orders of magnitude. We show that the switching voltage is much smaller than the electroforming voltage, due to the filament residuals in the Si grain boundaries which serve as the reduction sites for the re-growth of Cu filaments. The SET pulse voltage allows the ability to generate multi-level states. The combined advantage of using the PECVD deposition method and extremely high endurance performance of the amorphous SiC bilayer promises this to be a new class of resistive memory devices with great potential for implementation.

Submission number: 147

LEVERAGING THE TUNABILITY OF HOLE SPIN QUBITS

Bosco, Stefano*

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Modeling and Simulation; Spintronics

Hole nanostructures are leading candidates for large-scale quantum computers due to their pronounced spin-orbit interactions (SOIs) and remarkable tunability. In this presentation, I will discuss various strategies for harnessing this tunability to enhance the performance of current hole spin qubits, with a focus on both silicon and germanium qubits.-One avenue of exploration involves exploiting the tunable nature of hole spin qubits to mitigate the impact of charge and hyperfine noise, which directly influences the qubit decoherence time. By identifying optimal operating conditions, referred to as sweet spots, where such noise is effectively eliminated, the performance of the qubits can be significantly improved.- Moreover, charge noise presents a significant obstacle for shuttling spins, a critical requirement to establish long-range connectivity between distant qubits. Here, I will explore how SOIs can induce intricate spin dynamics that effectively filter out low-frequency noise, thereby improving the efficiency of spin shuttling processes.-Furthermore, the influence of SOIs extends to two-qubit gates, where exchange anisotropies, induced by these interactions, offer avenues for accelerating the execution of two-qubit gates without compromising fidelity. This implies that by leveraging the unique properties of SOIs, novel methods can be devised to expedite gate operations, paving the way towards large-scale spin based quantum information processing.

Submission number: 148

SINGLE-MOLECULE ELECTRONIC DEVICES FOR BIOSENSING

Liu, Bo; Aminiranjbar, Zahra; Hihath, Josh*

Keywords: Nanoelectronics; Nanofabrication; Nanosensors and Nanoactuators

Single-molecule electronic devices have long been envisioned as the ultimate miniaturization of electronic devices, and a potential end-point for Moore's law. However, despite impressive demonstrations of molecularly enabled devices including transistors, diodes, switches, memristors, wires, and more, these devices have not been translated into viable technologies due in large part to the difficulty of integrating single-molecule devices into electronic systems at scale. Sensing systems provide an opportunity to bypass this issue, because systems can be created where limited device lifetimes can still be used to extract biologically or chemically relevant information, and statistical measurements provide an advantage to sensitivity and selectivity. Here we explore the possibility of using single-molecule electronic devices as active components for biosensing applications. Specifically, we explore the whether the electrical conductance of individual DNA or DNA:RNA duplexes can be used to identify specific strains of pathogenic species. In particular, we demonstrate that RNA-based, single-molecule conductance experiments can be used to identify specific variants of Escherichia coli and SARS-CoV-2. To this end, we describe how to i) select target sequences of interest for specific variants, ii) utilize single-molecule conductance measurements to obtain conductance histograms for each sequence and its potential mutations, and iii) analyze the results to quickly identify the presence of target molecules in solution with a limited number of conductance traces. In addition, we will explore the fundamental underpinnings of the charge transport properties that allow single-molecule conductance measurements to be sensitive to single base mismatches within the DNA stacks, and how this methodology can be expanded to recognize the emergence of new variants as they arise. Finally, we expand these systems into platforms that are sufficiently stable and reliable to perform sensing functions on chip-based platforms. In particular, we will utilize a combination of bottom-up and top-down approaches to create stable and reliable single-molecule electronic biosensors and demonstrate their utility for detecting specific sequences.

Submission number: 149

ENGINEERING THE ELECTRONIC PROPERTIES OF DNA

Liu, Bo; Aminiranjbar, Zahra; Hihath, Josh*

Keywords: Nanoelectronics; Nanofabrication; Nanotechnology in Soft Electronics

DNA has recently emerged as an important nanomaterial. Its ability to be programmed into well controlled shapes, mechanical devices, and chemical and biological machines has led to an explosion of interest in this system as a functional material. However, in addition to these structural properties, DNA is also an intriguing material for molecular electronics applications. Recently, single molecule conductance measurements have demonstrated that reproducible conductance values can be obtained for short double-stranded (ds) DNA sequences. Through these experiments it has been demonstrated that the conductance DNA in solution is sensitive to both length and sequence, single-base mismatches, and that the coherence length of transporting electrons spans several base pairs. These observations imply that DNA does not behave as a semiclassical electronic structure, and instead operates in the quantum transport regime. In this work, we will explore how length, sequence, nearest neighbour interactions, the presence of non-canonical bases, and different metal ions affect the electronic structure and overall transport properties of DNA-based systems. Here we test whether it is possible to control the transport behavior of DNA by modifying its sequence without modifying the overall composition. Our analysis centers on understanding the influence neighboring bases have on the density of electronic states in both the spatial and energy domains, providing insights into how the delocalization of states and the implied coherence length affect charge transport in DNA. We initially employ a series of 16 base sequences with identical composition and focus on controlling energy state distribution and nearest neighbor interactions by modifying the four central bases. By examining the energy level density and distribution in conjunction with the conductance measurements, we establish a series of design guidelines for engineering longer DNA sequences, resulting in high conductance values even in sequences as long as 20 bp (~7nm). Finally, we build on this capability by exploring the role of non-canonical bases, and the presence of metal ions as a means for directly modifying the electronic structure and transport properties.

Submission number: 150

HARDWARE IMPLEMENTATION OF A SIGNAL RECONSTRUCTION SYSTEM FOR AN INTEGRATE AND FIRE NEURON

RAVIPATI, SASI PUJITHA; SRIKANTHAM, SRIKARI; KAILATH, BINSU*

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Modeling and Simulation

Spiking Neuronal Networks are gaining attention for their efficiency in area and power compared to traditional circuits such as Analog to Digital Converters. Spiking neurons such as Simple Integrate and Fire, Leaky Integrate and Fire Neurons can be used as encoders, effectively converting analog signals into digital spikes. This paper is dedicated to the development of a reconstruction system to rigorously validate the encoding process. The mathematical blocks such as computation of sinc function, integration of time shifted sinc function and pseudo inverse of a matrix are implemented in MATLAB and Xilinx Vivado using Verilog HDL. The system is tested on composite sinusoidal signal resulting in a Signal-to-Error Ratio of 88 dB. Additionally, the system is deployed on a Zynq ZCU104 FPGA Evaluation Board. Further, the system is tested on different arrhythmia cases and an SER of 82.52 dB is obtained for the record no. 105 of MIT BIH Arrhythmia database.

Submission number: 151

UNIVERSAL FILTER ARRAY WITH MEMRISTIVE CROSSBAR

Akhila, Remanan; Anitha, Gopi; A.R., Aswani; James, Alex*

Keywords: Quantum, Neuromorphic, and Unconventional Computing

This study explores the integration of memristor crossbar as filter arrays for image processing applications exploit the various filtering tech- niques. Memristor crossbar arrays offer a promising platform for parallel processing and efficient imple- mentation of filtering operations due to their dense and scalable architecture. Configuring each column in the crossbar array to act as a filter, it becomes possible to perform multiple filtering operations simul- taneously on input images. This research investigates the feasibility and performance of utilizing memristor crossbar arrays as filter arrays with different filter structures and random dropouts in image processing. This analysis focusing on the potential of memristor based reconfigurable filter arrays in advancing the field of image processing.

Submission number: 153

ENERGY-EFFICIENT VERTICALLY STACKED NSFET-BASED CTM FOR LOGIC IN-MEMORY COMPUTING

Ansari, Md Hasan Raza; Kumar, Naveen; Georgiev, Vihar; El Atab, Nazek*

Keywords: Modeling and Simulation; Quantum, Neuromorphic, and Unconventional Computing; Nanoelectronics

This work highlights the implementation of Boolean logic functions (AND, OR, NOR, XOR, and XNOR) in two steps for logic in-memory computing applications through a double gate vertically stacked nanosheet-based charge-trapping memory (DG-NSFET-CTM). The charge-trapping memory operation with high--954; blocking oxide material is based on the Fowler-Nordhiem (FN) tunneling mechanism at a lower voltage (± 6V), which makes the device energy efficient. The device achieves a memory window of ~1.77 V and consumes less energy (~45.5 fJ) during inference. The work also shows the effect of vertically stacking nanosheets on the implementation of logic gates and energy consumption. The obtained results confirm the proposed dual gate NSFET-based CTM could be a promising candidate for next-generation in-memory computing.

Submission number: 154

QUANTUM-INSPIRED EVOLUTIONARY PROGRAMMING FOR ECONOMIC FACTS ALLOCATION IN POWER SYSTEMS: ADVANCING QUANTUM COMPUTING APPLICATIONS

Ochi, Arman Riaz*; Mahmud, Syed Golam; Ghosh, Bashudeb Chandra; Margala, Martin

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Modeling and Simulation

Quantum Mechanics and Quantum Computing stand at the forefront of a computational revolution, promising the ability to solve problems previously deemed unsolvable. This has sparked interest in leveraging these disciplines to address complex computational challenges across various fields. Among the innovative approaches emerging from this intersection is Quantum Inspired Evolutionary Programming (QIEP), a technique that skillfully combines the principles of quantum mechanics and quantum computing with the robustness of evolutionary algorithms. By incorporating core concepts of quantum mechanics, such as qubit representation, superposition, and entanglement, QIEP significantly enhances the efficacy of evolutionary programming, offering more efficient solutions for complex tasks. Despite the promising capabilities of quantum computing and its algorithms, their practical application, particularly in areas such as power system optimization, has remained limited. Our research explores the application of the QIEP methodology, with a specific focus on optimizing the allocation of Flexible AC Transmission System (FACTS) devices while considering economic criteria. Although these FACTS devices play a crucial role in improving controllability, increasing power transfer capacity, enhancing stability, and maintaining voltage levels within desired thresholds in power systems, their installation is limited to a few locations from a vast pool of potential sites due to economic consideration. Consequently, the allocation process presents a complex optimization problem, which can be effectively addressed through algorithms like QIEP. Through a comparative study with traditional genetic algorithms (GAs), our analysis showcases the superior efficiency and accuracy of QIEP, even on classical computing platforms. Notably, QIEP achieves a 35% reduction in FACTS allocation costs while maintaining the total system cost at its minimum level. Moreover, despite operating in a similar computing environment, QIEP completes the optimization process 10% faster than its GA counterparts.

Submission number: 155

NANODIAMOND-METFORMIN COMPLEX CYTOTOXICITY IN MCF-7 BREAST CANCER CELLS

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Keywords: Nanobiomedicine; Nanomaterials

Breast cancer represents a significant burden of mortality worldwide. Conventional treatments, such as surgery, chemotherapy, and radiotherapy, cause serious side effects due to toxicity to healthy tissues. Nanotherapy, such as nanodiamond (ND) functionalized with different drugs, emerges as an innovative approach that offers greater precision in targeting cancer cells. Studies revealed that the ND-metformin (ND-Met) complex showed cytotoxicity in triple-negative breast cancer cells (MDA-MB-231 and HS578T) and SOKV3 ovarian cancer cells. This project aimed to evaluate the cytotoxic effect of the ND-Met on the MCF-7 breast cancer cell line. MCF-7 cells were exposed to the ND-Met complex and incubated to determine cell viability using the resazurin assay. Non-functionalized ND, Met, and DMSO at the same concentrations were used as controls.--The results showed that the ND-Met complex significantly decreased MCF-7 cell viability dose-dependently at 24 h. However, the ND-Met complex's effect could not inhibit cell proliferation at 48 and 72 h. In the analysis of morphological alterations, the cells showed signs of cell death induced by apoptosis, such as cell shrinkage, condensation, and nuclear fragmentation. These results suggest that the cytotoxic effect of the ND-Met complex could be related to the induction of apoptosis. In conclusion, the results demonstrate that the ND-Met complex has therapeutic potential in luminal A breast cancer, providing the first innovative and promising approach to developing new effective therapies against this type of breast cancer.

Submission number: 156

RESPONSE STABILITY ANALYSIS OF PRINTED NANOSTRUCTURED TIO2-BASED DISPOSABLE AMMONIA SENSOR LABEL

Tripathy, Kamalesh*; Bhattacharjee, Mitradip

Keywords: Nanomaterials; Nanotechnology in Soft Electronics

Aqueous solution of ammonia (NH3) is utilized in a variety of applications such as cleaning reagents, medication manufacture, fertilizer, farming, refrigeration, etc. To prevent unintentional health risks, it is crucial to have cost-effective deployable sensors to monitor the concentration. In this regard, a printed washable TiO2 nanoparticle (NP) layer-based sensing solution for ammonia detection can be a good choice. The sensor's response over a period of time was monitored to evaluate its performance, so that the concentration can be detected reliably. The sensor shows a sensitivity of 0.47/% for a range of 5% to 17% (aq. NH3 solution). Although the sensor shows current response till 1 day, but its magnitude decreases drastically due to crack formation. The sensor can be used reliably for up to 4 hr. and can be used to detect the presence of ammonia qualitatively for up to 1 day. Due to its simple fabrication, reusability, and easy set-up, the sensor is a viable option for detecting NH3 solution leaks in both homes and commercial buildings.

Submission number: 157

A COMPARISON OF OSCILLATORY ISING MACHINES AND SIMULATED BIFURCATION MACHINES FOR SOLVING MAXIMUM CUT PROBLEMS

Ansari, Md Shabaz*; Nehete, Hemkant; Grimaldi, Andrea; Mazza, Luciano; Raimondo, Eleonora; Puliafito, Vito; Finocchio, Giovanni; Kaushik, Brajesh

Keywords: Quantum, Neuromorphic, and Unconventional Computing

Unconventional computing approaches have gained significant attention in the search for hardware-friendly solvers capable of finding the solution of combinatorial optimization problems COPs. Among others, oscillator-based, or oscillatory, Ising machines (OIMs), and simulated bifurcation-based Ising machines (SBMs) are two promising paradigms that are based on dynamical equations. This work presents a preliminary direct software comparison between an OIM and an SBM on instances from the G-set, a well-known benchmark library of maximum cut problems. The performance of the two paradigms is compared in terms of their average optimal approximation within a given number of timesteps using the same integration scheme. Our findings show that OIM performs better when optimizing its parameter for a specific problem or topology, while SBM has better performance in scenarios in which preprocessing is not possible, i.e., when considering large batches of instances with varied topologies and scales.

Submission number: 158

A PARTIALLY GATED REGENERATIVE FEEDBACK DEVICE FOR ULTRA-HIGH SENSITIVITY BIOSENSING APPLICATIONS

Kalra, Sumeet*; Kannan, N.; Kumar, Mamidala Jagadesh

Keywords: Nanosensors and Nanoactuators; Nanoelectronics; Modeling and Simulation

This work proposes and investigates the performance of a feedback field effect device for biosensing applications. The device features a partially gated structure, enabling its function as a high-sensitivity, charge-modulated biosensor. The sensing principle relies on the regenerative feedback effect, giving rise to ultra-steep slope characteristics. 2D TCAD device simulations show a sharp turn-on profile in response to the conjugation of charged biomolecules on the ungated sensing surface. Consequently, a large shift in turn-ON voltage (-916;VT) exceeding 50% and a very high current sensitivity (~1e11) are observed, which are both considerably higher than the conventional FET-based biosensors. By simultaneously achieving a high ON-state current, low leakage, and ultra-steep subthreshold slope at low voltages, the device overcomes limitations of the existing steep slope FET biosensors. Given these attributes and compatibility with the standard semiconductor process technology, the proposed device is a promising candidate for future ultra-high sensitivity integrated biosensors.

Submission number: 159

ON PECULIAR SENSITIVITY TRENDS OF N-CHANNEL DIELECTRIC MODULATED FET BIOSENSORS

Kalra, Sumeet*

Keywords: Nanosensors and Nanoactuators; Nanoelectronics; Modeling and Simulation

The orientation of biomolecules is known to affect the sensing performance of Dielectric Modulated Field Effect Transistor (DMFET) biosensors. However, the existing research lacks a comprehensive explanation and gives only limited insight into the sensitivity trends of such devices. This study elucidates how orientation changes the dominant sensing mechanisms for low and high dielectric constant biomolecules immobilized in the nanogaps. The results provide the first explanation for observed sensitivity trends and reason out the appearance of two different regimes in the sensitivity characteristics of an n-channel DMFET for DNA detection. Consequently, the findings, validated by TCAD simulations, offer new insights into the sensor's operation and contribute to advancing the understanding of these devices.

Submission number: 160

APPLYING THE TIME-DOMAIN PARADIGM TO INTERFACE MULTILEVEL PHASE CHANGE MEMORY

de Gracia Herranz, Amadeo*; Lopez-Vallejo, Marisa

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Modeling and Simulation; Nanoelectronics

Phase Change Memory (PCM) is a prominent non-volatile memory technology that offers high-density, multilevel solutions. However, the circuitry required to read and write such devices has not been fully solved due to the highly non-linear behaviour of these devices and the complex voltage and current ranges required for reliable operation. Most of the proposed interfaces require very large area and power consumption and are accompanied by an odd form factor. This study explores time-domain interfaces as a potential solution for driving PCM cells by linking the physical attributes of the devices to a time variable. Here, we present a proof of concept for the implementation of time-domain interface architectures adapted to this type of memory.

Submission number: 161

EXPLORING THE USE OF ANTIAROMATIC COMPOUNDS IN SINGLE MOLECULE CIRCUITS

Zotti, Linda Angela*

Keywords: Nanoelectronics; Modeling and Simulation

Antiaromatic compounds have generated a lot of interest in the field of molecular electronics over recent years. They typically display low HOMO-LUMO gaps, which has been envisaged to yield high electrical conductance. However, incorporating these kinds of compounds in molecular wires requires extra care regarding the connectivities within the molecule as well as with the electrodes. In this talk, I will present our recent efforts towards addressing this issue, ranging from molecular junctions based on dithienopentalenes to dibenzopentalenes. I will show that the final result is ruled by a delicate interplay between the expected reduction of the HOMO-LUMO gap, the energetic level alignment of the frontier orbitals and the appearance of destructive quantum interference [1,2,3].-[1] Antiaromatic Non-Alternant Heterocyclic Compounds as Molecular Wires, E Leary, C Roldan-Pinero, R Rico-Sanchez-Mateos, LA Zotti, Journal of Materials Chemistry C, DOI: 10.1039/D3TC04266A (2024) [2] Single-molecule conductance of dibenzopentalenes: antiaromaticity and quantum interference, M. Schmidt, D. Wassy, M. Hermann, M. T. Gonzalez, N. Agräit, L. A Zotti, Birgit Esser, E. Leary, Chem. Commun., 57, 745-748 (2021) [3] Taming quantum interference in single molecule junctions: induction and resonance are key, L.A. Zotti and E. Leary, Phys. Chem. Chem. Phys. 22 (10), 5638-5646 (2020)

Submission number: 162

ELECTRON TRANSPORT THROUGH METAL-PROTEIN-METAL JUNCTIONS

Zotti, Linda Angela*

Keywords: Nanoelectronics; Modeling and Simulation

Proteins have proven to be promising candidates for molecular electronics, showing in some cases much higher conductance than one would naively expect from their size. In particular, the blue-copper azurin extracted from Pseudomonas aeruginosa has been the subject of many experimental studies. The exact nature of the transport mechanism, however, is still under debate [1-7]. Here I will present our efforts towards gaining an insight into this issue from a theoretical perspective, analyzing both coherent-tunneling and hopping transport.- [1] M. P. Ruiz et al. , J. Am. Chem. Soc. 139, 43, 15337 (2017). [2] C. Romero Muniz, M. Ortega, J.G Vilhena, I. Diez Perez, R. Perez, J. C. Cuevas, L. A. Zotti, Phys. Chem. Chem. Phys., 20, 30392 (2018). [3] C. Romero Muniz, M. Ortega, J.G Vilhena, I. Diez Perez, R. Perez, J. C. Cuevas, L. A. Zotti, Biomolecules, 9(9), 506 (2019). [4] C. Romero Muniz, M. Ortega, J.G Vilhena, I. Diez Perez, R. Perez, J. C. Cuevas, L. A. Zotti, J.Phys.Chem.C 125 (3), 1693 (2021). [5] C. Romero Muniz, M. Ortega, J.G Vilhena, R. Perez, J. C. Cuevas, L. A. Zotti, Appl. Sci. 11 (9), 3732 (2021). [6]C. Romero Muniz, J.G Vilhena, R. Perez, J. C. Cuevas, L. A. Zotti, Front. Phys. 10:950929. doi: 10.3389/fphy.2022.950929 (2022). [7] C. Roldan-Pinero, C. Romero Muniz,--I.Diez-Perez, J.G Vilhena, R. Perez, J. C. Cuevas, L. A. Zotti, J. Phys. Chem. Lett. , 14, 49, 11242 (2023)

Submission number: 163

MANIPULATION OF HOLE SPINS UNDER REALISTIC ELECTRIC AND STRAIN FIELDS IN QUANTUM DOTS

Abadillo-Uriel, Jose Carlos*

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Modeling and Simulation; Nanoelectronics

In recent years, there has been a growing interest in utilizing hole spins in silicon and germanium for quantum information processing. One reason for this is the strong spin-orbit interaction present in the valence band of these materials, which allows for versatile interactions with electric fields. As a result, there have been demonstrations of fast electrical manipulation of hole spin qubits [1] and strong spin-photon interactions [2], which are useful for generating long-range entanglement. Interestingly, recent experiments in Ge hole qubits have shown efficient manipulation with in-plane magnetic fields [3], which cannot be easily explained by the usual spin-orbit mechanisms, expected for circular quantum dots, such as cubic Rashba spin-orbit coupling or g-tensor modulation resonance.- In our work, we go beyond the usual models for electrical spin manipulation in semiconductor quantum dots. We perform simulations of realistic Ge devices and find that both the electrostatics [4] and the strain [5] display inhomogeneities that dominates the performance of hole spin qubits. In particular, we identify overlooked spin-orbit mechanisms mediated by strains and the interfaces [6] that enable manipulation under in-plane magnetic fields and enhance the expected Rabi frequencies. Our simulations show that these mechanisms are dominating the physics of isotropic hole spin qubits. [1] G. Scappucci et al., Nat. Rev. Mater 6, 926-943 (2021) [2] C. Yu et al., Nat. Nano. 18, 741–746 (2023) [3] N. Hendrickx et al., Nature 591, 580–585 (2021) [4] B. Martinez et al., Phys. Rev. B 106, 235426 (2022) [5] J. C. Abadillo-Uriel et al., Physical Review Letters 131, 097002 (2023). [6] E. Rodriguez-Mena et al., Phys. Rev. B 108, 205416 (2023).

Submission number: 164

MACHINE LEARNING METHODS FOR SINGLE MOLECULE IDENTIFICATION USING CONDUCTANCE DATA

Das, Arindam*

Keywords: AI for Nanotechnology; Modeling and Simulation; Nanoelectronics

Genetic sequence identification from electrical characterizations (conductance probability distributions) of single molecules has emerged as a promising alternative to traditional approaches. Since conductance data on single molecules is extremely noisy due to limitations of even state-of-the-art approaches, achieving high detection rates is challenging, particularly when distinguishing a sequence from its single base-pair mismatches. One approach to address the noise issue is to employ an ensemble learning method, such as Extreme Gradient Boosting (XGBoost). An alternate approach is to fit a piecewise linear approximation to the current (alternately, conductance) traces and retain a few segments from the traces which correspond to linear approximations whose slopes do not exceed a predefined threshold. The underlying hypothesis behind this approach, which can be viewed as local low pass filtering of the experimental traces, is that the characteristic information of a molecule is embedded in the “plateau-like” regions of the current/conductance traces. We have conducted extensive experiments with both approaches, in conjunction with four different input feature representations: 1D and 2D conductance probability distributions, with and without averaging over the experimental parameters such as the applied bias. We employed the XGBoost classifier for 1D feature representations and a convolutional neural network paired to an XGBoost classifier for 2D feature representations. While adoption of a 2D probability distribution is helpful with respect to classifier accuracy, we find that averaged conductance probability distributions are much more impactful and significantly improve the prediction accuracy. Furthermore, pre-filtering the data through a piecewise linear approximation scheme enhances the classifier accuracy by an additional 3-4%. Although the basis of our analysis in this paper is time series conductance data of DNA strands for COVID-19 Alpha, Beta, and Delta variants and their single base-pair mismatches, our method is generally applicable to other single-molecule electrical data. This work was performed in conjunction with students Yiren Wang and Hongning Wang.

Submission number: 165

NOVEL TARGETED MXENE-AB COMPLEXES FOR MELANOMA PHOTO-THERMAL TREATMENT

Konieva, Anastasia*; Deineka, Volodymyr; Aguilar-Ferrer, Daniel; Zahorodna, Veronika; Gogotsi, Oleksiy; Kube-Golovin, Irina; Iatsunskyi, Igor; Wennemuth, Gunther; Pogorielov, Maksym

Keywords: Nanobiomedicine; Nanomaterials

In our study, we consider MXenes as optical absorbing agents for photothermal therapy (PTT). To ensure the target delivery of nanoparticles only to tumor cells, we developed an MXene-anti-CEACAM1 complex. Anti-CEACAM1 monoclonal antibody (mAb) exhibits specificity for CEACAM1 that is expressed on the surface of melanoma cells and is absent in normal melanocytes. The combination of MXenes and the anti-CEACAM1 mAb emerges as a promising platform for developing an innovative model of targeted photothermal ablation of melanoma. Our study aims to elaborate the MXene-anti-CEACAM1 antibody complex and to provide its biological characterisation with the evaluation of the targeted photothermal effect in vitro using an NIR-I laser. Delaminated $Ti_3C_2T_x$ MXenes were modified with polydopamine (PDA) containing different thicknesses followed by human anti-CEACAM1 mAb immobilization. The biocompatibility of the complex, its specificity, affinity, and selective photothermal ablation were studied. Our results demonstrate that MXene-anti-CEACAM1 complex, as well as its individual components (MXenes, MXene-PDA, anti-CEACAM1 mAb), have no cytotoxicity after 4 and 24 hours of incubation with different types of melanoma cells, human dermal fibroblasts and keratinocytes. Our data demonstrates that increasing the thickness of the PDA layer does not affect the biocompatibility, specificity and affinity, but reduces the photothermal conversion. Laser exposure modes were experimentally selected to effectively influence the complex and ensure the safety of non-targeted cells. Highly selective tumor cell ablation using near-infrared irradiation (NIR) is observed in target cells loaded with MXene-PDA-anti-CEACAM mAb complexes. Conclusion. Selective PTT of tumor cells using MXene-anti-CEACAM mAb complex shows great promise for the development of a new model of targeted melanoma treatment. Improvements to this approach, such as surface modification of MXene with PDA and conjugation with specific antibodies, could expand its applicability to different types of cancer. Acknowledgements. This research is supported from the HORIZON Call: HORIZON-MSCA-2021-SE-01 (Project #101086184) and MSCA4Ukraine project (Project #1232462).

Submission number: 166

MICRO-NANOTECHNOLOGY PLATFORMS FOR IN VITRO STUDIES OF NEURAL CELLS AND BRAIN MODELS

Que, Long*

Keywords: Nanobiomedicine; Nanosensors and Nanoactuators; Nanofabrication

The progress of micro-nanotechnology enabled platforms for studying neural cells and brain models are reported, mainly focusing on the work in our lab for the past several years. (1) Glial cell-derived neurotrophic factor (GDNF) is a small protein potently promoting the survival of dopaminergic and motor neurons and can be secreted from dopaminergic neural cell line, N27, an in vitro model for Parkinson's disease (PD). For PD treatment, transcranial magnetic stimulation (TMS) showed beneficial clinical effects, but the mechanism for its benefit is not understood. It is of great value to evaluate if GDNF secretion from N27 cells can be affected by TMS. We detected GDNF using nanopore sensors and showed that TMS can promote GDNF secretion from N27 cells. (2) The formation of adult hippocampal neural stem/progenitor cells (AHPCs) neutrospheres (AHPC-NSs) provides a potential in vitro brain model. A microchip to culture AHPC-NSs was developed. It was found that the AHPC-NSs remained highly viable. Cell proliferation and neuronal differentiation have been observed, indicating the feasibility of AHPC-NSs as the in vitro brain model on chip. (3) To improve our understanding of how the central nervous system functions, a microchip was developed for studying the effects of the neurotransmitters on AHPC-NSs. Experiments showed that the AHPC-NSs remain highly viable and cell proliferation and neuronal differentiation were observed following neurotransmitters' treatment, suggesting the feasibility of using the chip to better understand the interactions between microbiota and brain via the gut–brain axis. (4) The effects of shockwave (SW) impacts on AHPC-NSs were assessed for enhancing our understanding of the mechanisms of traumatic brain injury (TBI) using a microchip. Experiments showed the negative SW impact on the viability, proliferation, and differentiation of the cells within the AHPC-NSs. The microchip was used to monitor lactate dehydrogenase released from the NSs subjected to SW impacts, verifying this chip can be used for assessing the degrees of injuries of NSs and indicating the possibility of establishing in vitro TBI models on a chip.

Submission number: 167

MERGING REACTOR AND FEATURE SCALES FOR PLASMA ETCH MODELING

Filipovic, Lado*

Keywords: Modeling and Simulation; Nanofabrication; Nanoelectronics

When modeling plasma etching, our approach can come from three distinct length scales: atomistic simulations using ab-initio DFT, nano- or micrometer scale simulations of the features being etched, and reactor-level simulations of the condition inside the plasma chamber. Each of these scales has its own modeling approach and inherent complexity. When discussing plasma etching in the context of semiconductor device fabrication and process TCAD, the most common scale we apply is the feature scale, meaning we try to describe the fabrication of a particular device or geometric feature. At this scale, the surfaces and interfaces are often described using a signed distance function, the etch rates are calculated with the help of stochastic ray tracing Monte Carlo methods, and the topography is advanced by solving the level set equation. These simulations are thought to be physical – or at least semi-empirical – in approach since they can qualitatively reproduce the geometric features quite well. However, the link to true physics of surface interactions comes from atomistic simulations, while the link to the chamber settings comes from reactor simulations or from experiments. This talk will describe how the feature-scale model can be efficiently merged with chamber-level simulations or experiments to provide a more meaningful connection between process TCAD model inputs and the equipment settings. From reactor-scale simulations, we extract the fluxes of relevant particles – radicals and ions – immediately above the wafer of interest, which serve as inputs to our feature-scale models. However, to avoid repeated use of computationally expensive and complex multi-scale simulations, we perform reactor simulations on a typical plasma recipe for a wide range of input settings. The results are used to devise an interpolative spline model which allows us to devise a feature-scale model whose inputs are equipment settings in lieu of the fluxes at the top of the wafer.

Submission number: 168

HETEROGENOUS INTEGRATION; AN ENABLER FOR CHIPLETS

Mukherjee-Roy, Moitreyee*; Tessier, Theodore (Ted) Gerard

Keywords: Nanofabrication

Industry trends today show an increasing need for Heterogenous Integration (HI) driven by a need to add diverse functionality that can be realized with different IP on silicon technology nodes from multiple different suppliers. This provides opportunity for improved yields, IP reuse, and rapid time to market giving a distinct cost advantage. Recognizing the importance of HI, the IEEE Electronics Packaging Society (EPS) has come up with a roadmap to provide guidance to the industry [1].- 2D, 2.X D and 3D package architectures are ideal heterogeneous integration platforms because they provide short, power-efficient, high-bandwidth connections between components in compact form factors. HI is an enabler for chiplet technology which in turn enables artificial intelligence (AI) systems. AI is driving the need for memory intensive computing workloads which require new energy efficient architectures, and this is well-aligned with the industry movement to chiplets. Assembling chiplets require innovative packaging which drives need for new materials, new higher precision process equipment, advanced substrates that allow for high density packaging, specific interface standards to ensure interoperability, and seamless integration into the larger systems.- A path to accelerated progress, in this new paradigm, is an ecosystem where expertise from materials, EDA, circuit design, as well as equipment and process technology converge. At IBM we work with an ecosystem of such partners and have built expertise in advanced packaging design, process development and prototyping within IBM research with volume production capabilities in place at IBM Bromont, CA. We have made great progress in key areas such as Chiplet architecture and design, 2.5D and 3D integration, Characterization & test and more.[2]- As angstrom-sized transistors intersect with multi-die Si-substrates, we see transition from a system on Chip to a system of chips and this opens up opportunities for us to fulfill the ever-increasing hunger in the industry for more powerful systems.-

References

[1] IEEE EPS Heterogeneous Integration Roadmap. http://eps.ieee.org/hir
[2] https://research.ibm.com/blog/what-are-computer-chiplets

Submission number: 169

NETWORKED NANOPARTICLE ARRAYS FOR AUTONOMOUS COMPUTING

Wei, Xingfei; Harazinska, Ewa; Zhao, Yinong; Hernandez, Rigberto*

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Nanomaterials;

Modeling and Simulation

We have pursued the use of polymer-networked engineered nanoparticles as a candidate material capable of retaining information or perhaps even processing information in some prescribed way. Such operations would be of usage for the neuromorphic engineering of materials that can compute intrinsically—that is, that they are in no way subject to a von Neumann architecture—and they have been identified as autonomous computing materials. Using trajectories integrated to much longer time steps than previously observed, we can now confirm that the response of the polymer-networked engineered nanoparticle arrays are highly sensitive to external perturbations. That is, the specific internal connections around given nanoparticles can be assigned to states useful for information processing, and the variations in their physical properties can result in specific responses allowing the state to be read. Moreover, their resulting equilibrium properties also depend on such external driving, and hence are subject to control which is a minimal requirement for these materials to be candidates for autonomous computing. We also demonstrate that using long polymer chains can help regulate the networks structures by increasing the 1st nearest links and reducing other links.

Submission number: 170

BREAKING SENSITIVITY BARRIERS: SOFT OECTS IN BIOELECTROCHEMISTRY

Zhang, Shiming*

Keywords: Nanotechnology in Soft Electronics

Bioelectronics research has reached a new level. The emergence of soft bioelectrochemical technologies has further enabled a seamless interface between research tools and biological tissues, allowing for the collection of high-quality and more informative biochemical signals at their origin, even under prolonged use and arbitrary motions. However, the sensitivity of conventional soft bioelectrochemical sensors shows incapability when used in complicated and noisy wearable scenarios. In this talk, I will introduce materials, devices, and manufacturing of emerging soft organic electrochemical transistors (OECTs) technologies. I will discuss how soft OECTs can enrich the toolbox of current bioelectrochemical sensors to promote translational biomedical innovations, spanning from smart wearables, medical imaging, brain-inspired computing, to human-machine interfaces.

Submission number: 171

ENHANCING PERFORMANCE OF GANAS NANOWIRE LASERS BY GROWTH OPTIMIZATION AND NONLINEAR OPTICAL EFFECTS

Jansson, Mattias; Nosenko, V; Torigoe, Y; Nakama, K; Yukimune, M; Higo, A.; Ishikawa, Fumitaro; Chen, Weimin; Buyanova, Irina*

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanomaterials

Nanowire (NW) lasers made of semiconductor materials are currently attracting significant research efforts for future integrated photonic devices. Utilizing dilute nitride III-N-V alloys in NW lasers provides additional advantages for such applications. In this work [1], we demonstrate that significant improvements in the performance of GaNAs-based NW lasers can be achieved by employing selective area growth (SAG) during molecular beam epitaxy (MBE). We show that such growth conditions lead to a higher yield of lasing NWs, an increased operational temperature, and reduced average lasing threshold in the NWs as compared with the reference structures grown by conventional MBE. Based on the comprehensive analysis of carrier localization in these NWs combined with rate equation modeling, we attribute these improvements to a reduced density of localized states in the GaNAs alloy achieved under the SAG conditions. This could be partly related to a lower density of structural defects, such as twinning planes and wurtzite inclusions, revealed by transmission electron microscopy. We also explore nonlinear optical phenomena in the NWs under lasing conditions. It is found that the fundamental laser light experiences self-frequency conversion through second harmonic generation and sum-frequency generation leading to coherent light emission within the technologically challenging cyan-green spectral range. The self-conversion efficiency varies between different fundamental lasing modes. Specifically, the measured upconversion efficiency is the lowest for the HE11b mode but is enhanced by more than two orders of magnitude for the HE21b mode. According to the performed finite-difference time-domain simulations, these differences in the upconversion efficiency could be related to different electric field distributions of the fundamental lasing modes inside the NWs. Our work, therefore, significantly advances the performance of GaNAs-based NW lasers paving the way for the development of multi-wavelength coherent light generation and room temperature applications of GaNAs-based NW lasers. [1] M. Jansson et al. ACS Nano 18 (2024) 1477.

Submission number: 172

HIGH-FIDELITY SINGLE-SPIN SHUTTLING IN SILICON

Matsumoto, Yuta*; De Smet, Maxim; Zwerver, Anne-Marije; Tryputen, Larysa; Snoo, Sander; Amitonov, Sergey; Sammak, Amir; Samkharadze, Nodar; G -776;ul, Onder; Wasserman, Rick; Rimbach-Russ, Maximilian Florian; Scappucci, Giordano; Vandersypen, Lieven

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Nanoelectronics; Nanofabrication

The future of quantum computing promises unprecedented power and resilience, largely dependent on the way individual qubits link up with each other. A promising strategy to enhance this connectivity involves managing interactions between distant qubits. Another effective method to boost connectivity is by physically displacing qubits such that a pair of qubits comes close together whenever we want them to interact. Such techniques have been explored using ions or atoms as qubits, held in place in a vacuum environment[1,2], offering insights into how we might improve qubit interactions.-For semiconductor spin qubits, several studies have investigated spin coherent shuttling of individual electrons[3,4,5], but fidelities were far below what is required. Here, we report the coherent shuttling of electrons through an electrostatically-defined channel in a Si/SiGe heterostructure covered with a set of gate electrodes. Initially, we configure these gates to capture electrons in electrostatic potential known as quantum dots, which serve as our qubits. By manipulating these gates, we can make electrons hop between quantum dots, observing how spin coherence are affected by these movements.-Taking this a step further, we then utilize the gates to generate a moving electric potential, effectively carrying an electron along a set path within the semiconductor, akin to a moving quantum dot[6]. This technique substantially improves spin coherence. We are able to displace an electron back and forth over an effective distance of 10 -956;m in under 200 ns with a fidelity of 99%. These achievements mark a significant milestone towards building scalable semiconductor-based quantum computers, highlighting the role of electron shuttling in enhancing qubit connectivity within and across quantum processor arrays[7].
[1] Pino, J. M. et al. Nature 592, 209–213 (2021) [2]Bluvstein, D. et al.. Nature 1–3 (2023) [3] T. Fujita et al., npj Quantum Information 3, 22 (2017) [4] J. Yoneda et al., Nature Communications 12, 4114 (2021)-[5] A. Noiri et al., Nature Communications 13, 5740 (2022) [6] T. Struck et al., Nature Communications 15 1325 (2024) [7] L.M.K. Vandersypen et al., npj Quantum Information 3, 34 (2017)

Submission number: 173

FILAMENTARY OXIDE-BASED MEMRISTORS: A JOURNEY THROUGH CHARACTERIZATION, RELIABILITY, AND APPLICATIONS

BargallO Gonzalez, Mireia*; Saludes Tapia, Mercedes; Poblador, Samuel; Maestro Izquierdo, Marcos; Campabadal, Francesca

Keywords: Nanoelectronics; Nanofabrication

In this paper, a comprehensive analysis of filamentary oxide-based memristors is presented. The study includes the operational mechanisms of these devices, focusing on the complexities of filamentary resistive switching. Central to the discussion are issues associated with cycle-to-cycle variability and overall device reliability, which are crucial for the advancement of the memristive technology in practical applications. Moreover, the paper analyzes the use of memristors in real-world scenarios, particularly their role as electronic synapses. Their ability to emulate synaptic functions is demonstrated by features such as plasticity and multi-level conductance states, highlighting their potential for brain-inspired computational systems.

Submission number: 174

OPTOELECTRONIC INTEGRATED NEUROMORPHIC COMPUTING

Ma, Xinyu; Pernice, Wolfram*; Dijkstra, Jelle; BRÜCKERHOFF-PLÜCKELMANN, FRANK

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Quantum, Neuromorphic, and Unconventional Computing; Nanofabrication

Artificial intelligence (AI) based on neural network has made great influence in various fields, including healthcare, autonomous vehicles and security. It leads to an explosive demand for high-efficiency data computation and parallel information processing, while approaching human-level accuracy. Conventional electronic computer has von Neumann architecture with separated memory and processor, as well as electronic circuits with inherent delays and power consumption limitations, making it not the optimal choice for AI-required hardware. Photonic neuromorphic computing is a hardware-level architecture based on optical circuits and in-memory computing to mimic neural network. Optical circuits have the advantages of high parallelism, low latency, and power efficiency, while electrical circuits at present are more foundry-friendly and controllable. Optoelectronic integration turns out to be a potential pathway to combine the advantages of both optical and electrical worlds, which is highly promising for data-heavy applications. This presentation will first give an introduction of photonic neuromorphic computing, and then focus on our group’s solution and progress on optoelectronic integrated computing circuits using electro-absorption modulators and photonic crossbar array. In addition, our group’s recent work on high-speed probabilistic computation and uncertainty quantification with chaotic light source will be discussed.

Submission number: 176

FROM EARTH TO THE COSMOS - REVIEWING ADVANCED NANOSTRUCTURES FOR SPACE SOLAR POWERING

Santos, Ivan*; Alexandre, Miguel; Teixeira, Cristina; Vicente, AntOnio T.; Almeida, Eva; Martins, Rodrigo; aguas, Hugo; Mendes, Manuel J.

Keywords: Nanostructures for extreme environments; Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanomaterials

Amidst the rising demands of space exploration, the pursuit of optimal energy capture drives the exploration of advanced photovoltaic (PV) technologies. Photonics emerges as a crucial approach, enabling precise light manipulation to address challenges in space, prioritizing stability and efficiency. Despite limited space testing, insights from terrestrial experiments and simulations are pivotal. This work distills recent terrestrial findings to inform the development of photonics-driven PV solutions tailored for space applications. It contrasts the performance of thick- and thin-film PV devices with traditional absorption models and delves into the potential of photonic coolers for effective thermal management. Additionally, it examines spectrum modification techniques and their importance in space.

Submission number: 177

ADVANCES IN NONWETTABLE NANOSTRUCTURED COATINGS: HARNESSING GAS-AGGREGATED NANOPARTICLES FOR ENHANCED SURFACE FUNCTIONALITY

Hanuš, Jan*

Keywords: Nanomaterials; Hydrophobic, Oleophobic and/or Icephobic nanostructured surfaces

It is widely known that on a smooth surface, the highest achievable water contact angle (WCA) reaches around 120°, typically attained through fluorocarbon surface chemistry. Achieving a greater WCA necessitates surface roughening. Proper surface morphology, combined with appropriate surface chemistry, can result in super-nonwettable surfaces, characterized by static contact angles exceeding 150°. One promising method for structuring surfaces involves inducing nanoroughness using nanoparticles (NPs). NPs are commonly produced in powder form through milling or grinding, or as a suspension via wet chemistry methods. However, both approaches pose challenges for coating surfaces. An entirely different approach to NP synthesis relies on low-pressure, low-temperature plasma synthesis. NPs are produced by the aggregation of supersaturated metal vapors on the working gas in Gas Aggregation Source (GAS) of NPs. This method enables the vacuum deposition of thin NP coatings on any type of substrate. NP production is not restricted to metals; oxides and nitrides can also be synthesized. Furthermore, plasma polymerization (PECVD) can occur within the GAS, allowing the production of plasma polymer NPs. The typical size of metal-based NPs is a few tens of nanometers, while polymeric NPs can reach diameters of up to a few hundred nanometers. The morphology of the surface is influenced by the type and quantity of deposited NPs, while the surface chemistry is adjusted through the deposition of the appropriate overlayer. The impact of different morphologies of NP coatings, as well as the thickness and chemistry of the overlayer, will be discussed. Examples of semitransparent and transparent superhydrophobic coatings utilizing transparent metal oxide NPs will be presented. Acknowledgement: This work was supported by grant 22-16667S from the Czech Science Foundation.

Submission number: 178

SMALL-ANGLE NEUTRON SCATTERING, FROM ANGSTROMS TO ALMOST MICRONS AND BACK AGAIN

DeBeer-Schmitt, Lisa*

Keywords: Spintronics; Nanomaterials; Nanomagnetics

Neutron scattering is a powerful technique for investigating material characteristics. By using the properties of a neutron such as the isotopic differences in scattering length among elements and the fact that the neutron has spin-- making it sensitive to changes in magnetic states and structures-- one can probe structural and magnetic properties of a whole host of materials. Small-angle Neutron Scattering (SANS) is a technique used to study large-scale structures varying from 1 to 500 nanometers. I will present a few different ways SANS can be used to investigate different materials ranging from manipulating spin waves in skyrmions using ferromagnetic resonance to very long range magnetic structures in single crystal neodymium and everything in between.- Funding Acknowledgments-This research used resources at the High Flux Isotope Reactor and Spallation Neutron Source, DOE Office of Science User Facilities operated by the Oak Ridge National Laboratory. This manuscript has been authored by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725 with the U.S. Department of Energy. The United States Government retains and the publisher, by accepting the article for publication, acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this manuscript, or allow others to do so, for United States Government purposes. The Department of Energy will provide public access to these results of federally sponsored research in accordance with the DOE Public Access Plan (<http://energy.gov/downloads/doe-public-access-plan>).

Submission number: 179

QUANTUM NEUTRON SCATTERING ADVANCEMENTS TOWARDS THREE-DIMENSIONAL SKYRMION SPINTRONIC DEVICES

Henderson, Melissa*

Keywords: Nanomaterials; Nanomagnetics; Spintronics

Topological magnets represent an unprecedented era in quantum technologies, exploiting new correlations and degrees of freedom to realize the next generation of spintronic devices. Marked by non-trivial Berry curvatures in energy and spin, topological magnets manifest exotic phases and emergent dynamics which inspire novel bit states and control pathways that transcend the limits of conventional semiconductor-based electronics. While existing material probes are primarily restricted to thin and confined systems, biasing device conceptualizations to two dimensions, advancements in three-dimensional probing techniques are transforming our understanding of topological and emergent physics to reimagine spintronic devices. Here, we review recent small angle neutron scattering (SANS) breakthroughs which harness structured wavefronts and tomographic methods to enable three-dimensional topological investigations of quantum materials. We examine applications of these techniques to magnetic skyrmion systems, motivating three-dimensional logic infrastructures through composite topological objects and multi-bit encoding schemes. SANS-based dynamic visualizations and coherent manipulations of three-dimensional topological bits are proposed using spin-orbit scattering modes and depth-mediated electric field controls. Together, these investigations uncover a new world of three-dimensional topological physics which overturns previous frameworks of skyrmion nucleation and manipulation, reshaping future quantum devices through a novel set of structures, dynamics, and controls.- This research used resources at the High Flux Isotope Reactor and Spallation Neutron Source, DOE Office of Science User Facilities operated by the Oak Ridge National Laboratory. This manuscript has been authored by UT-Battelle, LLC under Contract No. DE-AC05-00OR22725 with the U.S. Department of Energy.

Submission number: 180

CATALYTIC HIGH-ENTROPY AND MULTIELEMENTAL LIQUID METAL NANODROPLETS

Allioux, Francois-Marie*; Kalantar-Zadeh, Kourosh

Keywords: Nanomaterials; Nano-Energy, Environment, and Safety; Nanotechnology in Soft Electronics

This work explores the versatile nature of liquid metals as catalytic nanomaterials, focusing on post-transition metals and alloys such as gallium, tin, indium, and bismuth, and their transformation into nanoscale liquid metal droplets. Using gallium-based alloys as a platform, this study introduces high-entropy liquid metal alloys, and the nanoscale homogenization of multielemental post-transition metals through mechanical agitation with the addition of catalytic species. It showcases their potential in nanotechnology and environmental catalysis, including applications in hydrogen evolution reaction and carbon dioxide electro-reduction.

Submission number: 183

CHEMICAL CONTROL OF SINGLE-MOLECULE FUNCTIONAL DEVICES: FROM RHEOSTATS TO TRANSISTORS AND BEYOND

Vezzoli, Andrea*

Keywords: Nanoelectronics; Nanosensors and Nanoactuators

Wiring single molecules into electrical circuits developed from a scientific curiosity into a vibrant research field. The bottom-up fabrication approach and the ability to tailor the final junction properties by chemical design have been hailed as the main advantages of molecular electronics, and single-entity electrical junctions that behave, as resistors, transistors, diodes, and nanoelectromechanical systems have been demonstrated.-In this talk, I will present our recent efforts in understanding and controlling charge transport and functionality in single-molecule devices, presenting our past work and our most recent efforts focussed on three distinct applications: mechanically controlled conductance switches that can act as very efficient single-molecule rheostats by exploiting quantum interference phenomena,[1], [2], [3], [4] redox-controlled molecular wires showing clear and significant charge transport modulation as a function of the applied electrochemical potential,[5], [6] and our recent results on molecular wires showing anti-ohmic behaviour, with conductance greatly increasing with length. The focus of this talk will be on the chemistry of molecular wires and on the fine degree of control of the final properties of the junction that can be imparted by exploiting the vast chemical space available through substitution chemistry, exploitation of unique chemical interactions and resonance structures, and supramolecular effects that include complexation and solvation of molecular wires in electrolytic media.-While the dream of extremely small circuits made entirely by molecules – the “molecular computer” – is still far from realisation, the exploration of the quantum mechanical phenomena operating in these devices makes the field exciting and adventurous, and each measurement we perform presents us new challenges and new opportunities.-[1] Angewandte Chemie 2017, doi: 10.1002/anie.201709419 [2] Nano Letters 2020, doi: 10.1021/acs.nanolett.0c02815 [3] Small 2024, doi: 10.1002/smll.202308865 [4] Angewandte Chemie 2019, doi: 10.1002/anie.201906400 [5] Angewandte Chemie 2020, doi: 10.1002/anie.202002174 [6] Angewandte Chemie 2022, doi: 10.1002/anie.202116985

Submission number: 184

SINGLE-MOLECULE GRAPHENE JUNCTION AFLATOXIN SENSORS: CHEMO-PHYSICAL INSIGHTS FROM AB INITIO SIMULATIONS

Mo, Fabrizio; Ala, Walter; Spano, Chiara Elfi; Piccinini, Gianluca; Graziano, Mariagrazia; Ardesi, Yuri*

Keywords: Nanosensors and Nanoactuators; Nanoelectronics; Modeling and Simulation

The aflatoxin B1 (AFB1) is a cancerogenic compound affecting the agri-food chain, endangering food safety and public health. Worldwide regulatory agencies establish strict limitations for the presence of AFB1 in crops. Current detection methods require bulky equipment, long measurement time, and skilled laboratory researchers, which make it challenging to measure the AFB1 in the whole food chain pervasively. In this field, molecular junctions represent an exciting alternative in the sensing application, providing a highly integrable device for the fast measurement of chemical compounds. Through ab initio simulation, this work investigates graphene junctions for detecting AFB1. The results show that applying a bias voltage of 1.2 V to a graphene layer permits varying the electrical current of the junction by more than 3 µA when the AFB1 is present. The obtained results motivate research on the integrability of the device in more complex sensing systems such as intelligent sensors and electronic noses.

Submission number: 185

IMPLEMENTATION OF LAYERED SEMICONDUCTORS IN INTEGRATIVE BIOSENSING DEVICES

Liang, Xiaogan*

Keywords: Nanobiomedicine; Nanoelectronics; Nanofabrication

Layered semiconducting transition metal dichalcogenides (TMDCs) keep attracting attention-from both academia and industry because of their superior electronic, optoelectronic, chemical,-mechanical properties as well as their 2D structure that is compatible to state-of-the-art planar-micro/nanofabrication techniques. Some specific physical and chemical properties of these layered materials could be further exploited for making high-performance biosensing devices. First, because of their atomically thin structures, the transport properties (e.g., conductivity, carrier-mobility, and photoconductivity) of the sensing channels made from 2D layers are extremely-sensitive to the external stimulations, which could result in unprecedented sensitivity for-biodetection applications. Furthermore, layered semiconductors, when serving as sensing channel-or electrode materials, exhibit an extremely low level of internal electronic noise. This is attributed-to the fact that the surfaces of layered materials have an extremely low density of dangling bonds.-Such a unique 2D surface property is expected to result in the active sensing channels with low-densities of scattering centers (and hence low Flicker noise level), and enables highly-sensitive,-low-noise-level detecting of biomolecules (i.e., a high signal to-noise ratio).

This presentation will review our recent works associated with nanofabrication and-characterization of biosensing devices based on layered semiconductors (e.g., transistor, resistor,-photo-FET and memristor based sensors) These biosensors exhibit superior sensing-performance as compared to other nanoelectronic biosensors, in terms of fM-level (or single_x0002_molecue-level) limit-of-detection (LOD), short response time (seconds for pM level, <20 min for-fM level quantification), and good scalability enabling construction of large arrays of 2D-semiconductor sensors.

Submission number: 186

FUNDAMENTALS OF LOW-DIMENSIONAL-MATERIAL TRANSISTORS AT THE NANOSCALE: A DFT-NEGF MODELLING PERSPECTIVE

AFZALIAN, ARYAN*

Keywords: Modeling and Simulation; Nanoelectronics; Nanomaterials

In this talk, we will discuss advanced DFT-NEGF techniques – that we have implemented in our ATOmistic MOdelling Solver, ATOMOS [1,2] – towards the exploration of innovative 2D and other low-dimensional material devices. A particular emphasis will be set to the modeling of large DFT supercells, required to encompass both the semiconducting material and its surrounding oxide or metal interfaces in the atomistic simulation domain, as well as their impact on nanoscale device physics and performance [3-6]. We will discuss our methodologies based either on plane-wave or linear-combination-of-atomic-orbital DFT models [2]. We will present our methods to include the electron-phonon coupling from first principle into our transport simulations, as well as our atomistic mode-space acceleration-technique implementation [2,3,4]. We will apply our methods towards the exploration of novel low-dimensional materials and devices. This includes 2D material transistors and Dynamically-Doped FETs for ultimately scaled MOSFETS [1,4,5,6,7], the exploration of 2D material steep slope transistors [2], or more exotic topologically protected 2D nanoribbons [8].-[1]--Afzalian, A. npj 2D Mater Appl 5, 5 (2021). https://doi.org/10.1038/s41699-020-00181-1. [2]--A. Afzalian, E. Akhoundi G. Gaddemane, R. Duflou and M. Houssa, IEEE Transactions on Electron Devices, vol. 68, no. 11, pp. 5372-5379, Nov. 2021. https://doi.org/10.1109/TED.2021.3078412. [3]--A. Afzalian, et al., J. Phys.: Condens. Matter, vol. 30, no. 25, p 254002, May 2018. https://doi.org/10.1088/1361-648X/aac156. [4]--A. Afzalian, F. Ducry, 2023 SISPAD 2023, September 27 – 29, 2023, Kobe, Japan, pp. 305-308. [5]--F. Ducry, B. Van Troeye, C. J. L. de la Rosa, G. S. Kar, G. Pourtois, and A. Afzalian, IEEE EDTM 2024, 2024. [6]--Duflou, R., Pourtois, G., Houssa, M., Afzalian A. npj 2D Mater Appl 7, 38 (2023). https://doi.org/10.1038/s41699-023-00402-3. [7]--Afzalian A., Zubair A. and Julien R., Solid-State Electronics, 199, 108524 (2023).https://doi.org/10.1016/j.sse.2022.108524. [8]--E. Akhoundi, M. Houssa, A. Afzalian, Solid-State Electronics, 201, 108587 (2023). https://doi.org/10.1016/j.sse.2022.108587.

Submission number: 187

UNVEILING CHARGE DYNAMICS IN MOLECULAR FIELD-COUPLED NANOCOMPUTING

Listo, Roberto; Ravera, Federico; Beretta, Giuliana; Ardesi, Yuri; Piccinini, Gianluca;

Graziano, Mariagrazia*

Keywords: Nanoelectronics; Modeling and Simulation; Nanomaterials

Molecular Field-Coupled Nanocomputing (molFCN) emerges as a promising technology for addressing the challenges posed by CMOS scaling. In molFCN, the charge distribution of molecules encodes binary information. Properly arranging molecules in specific layouts produces wires and logic gates in which the information propagates by electrostatic intermolecular interaction with nearby molecules. Prior research offered promising insights into the static properties of information propagation within molFCN circuits, providing a theoretical description of the mechanism. However, the promising frequency-switching capabilities of molFCN still need to be validated. The frequency study of molecules is essential for ensuring the overall reliability of future molFCN devices. Consequently, this paper introduces a new methodology combining Density Functional Theory (DFT) and Real-Time Time-Dependent Density Functional Theory (RT-TDDFT) simulations for determining the maximum switching frequency of molFCN candidate molecules. We validate the methodology using the oxidized 1,4-diallyl butane molecule. Our findings demonstrate the possibility of achieving hundreds of gigahertz-level switching frequencies for the 1,4-diallyl butane. Moreover, the results report the nonlinear molecule behavior when subjected to electric field excitations above its charge-switching frequency limits. Overall, this work presents advances in addressing the time-domain modeling of molFCN candidate molecules, opening pathways for improving existing models for molFCN circuits.

Submission number: 188

MODELING MOLECULES FOR FIELD-COUPLED NANOCOMPUTING CIRCUIT DESIGN

Ardesi, Yuri; Ravera, Federico; Piccinini, Gianluca; Graziano, Mariagrazia*

Keywords: Nanoelectronics; Modeling and Simulation; Nanomaterials

Molecular Field-Coupled Nanocomputing (molFCN) is a highly low-power technology promising for digital electronics. It encodes information in the charge distribution of molecules and propagates it through electrostatic intermolecular interaction. Despite its potential, the molFCN technology suffers the absence of a functional design and simulation methodology. This paper provides a complete explanation of the characterization and modeling of molecules, from the molecular ab initio analysis to the design of molecular circuits and systems. Considering the diallyl-butane, we show how to use the ORCA package to derive, with DFT, the molecule geometry and charge distribution by correctly setting DFT functionals and basis sets. We study the molecule polarization when subjected to electric fields and enable the investigation of the interaction by exploiting the SCERPA tool. We set up the SCERPA simulation engine to simulate molecular circuits such as diallyl-butane wires. Finally, we show how to use literature results to model more complex molecules. We implement the bis-ferrocene cation in SCERPA and use it to create complex clocked logical devices. We simulate, as a means of explanation, a 0.0004µm2 NAND gate.

Submission number: 189

ELECTROTHERMAL ACTUATION FOR SOFT ROBOTICS

Zhu, Yong*

Keywords: Nanotechnology in Soft Electronics; Nanosensors and Nanoactuators;

Nanomaterials

Soft robots have received extensive interests recently. In this talk, I will present our efforts in exploring thermal actuation for novel capabilities while overcoming its limitation towards soft robotics applications. First, I will talk about a caterpillar-inspired, energy-efficient crawling robot with multiple crawling modes, enabled by joule heating of a patterned soft heater consisting of silver nanowire (AgNW) networks in a liquid crystal elastomer (LCE)–based thermal bimorph actuator [1]. With patterned and distributed heaters and programmable heating, different temperature and hence curvature distribution along the body of the robot are achieved, enabling bidirectional locomotion as a result of the friction competition between the front and rear end with the ground.-Second, I will discuss snap-through instability that can lead to significant increase in the actuation speed of a bimorph thermal actuator [2]. The snap-through instability is enabled by simply applying an offset displacement to part of the actuator structure. The actuator yields a bending speed as high as 28.7-8201;cm-8722;1/s, 10 times that without the snap-through instability. A fast crawling robot with locomotion speed of 1.04 body length per second and a biomimetic Venus flytrap were demonstrated. Finally, I will discuss the steering motion of soft robots. The modular origami unit offers an excellent building block for mimicking the segmented caterpillar body. Here, we report a modular soft Kresling origami crawling robot enabled by electrothermal actuation. A compact and lightweight Kresling structure is designed, fabricated, and characterized with integrated thermal bimorph actuators consisting of LCE and polyimide layers.

References:

[1] S. Wu, Y. Hong, Y. Zhao, J. Yin, Y. Zhu, Caterpillar-inspired soft crawling robot with distributed programmable thermal actuation. Sci. Adv. 9, adf8014 (2023).
[2] S. Wu, G. L. Baker, J. Yin, Y. Zhu, Fast thermal actuators for soft robotics. Soft Robot. 9, 1031–1039 (2022).
[3] S. Wu, Z. Tuo, Y. Zhu, G.H. Paulino, Modular multi-degree-of-freedom soft origami robots with reprogrammable electrothermal actuation. PNAS 121 (20), e2322625121 (2024).

Submission number: 190

TKWANT: A SOFTWARE PACKAGE FOR TIME-DEPENDENT QUANTUM TRANSPORT

Kloss, Thomas*

Keywords: Nanoelectronics; Modeling and Simulation

Tkwant is a Python package for the simulation of quantum nanoelectronic devices to which external time-dependent perturbations are applied. Tkwant is an extension of the Kwant package (https://kwant-project.org/) and can handle the same types of systems: discrete tight-binding-like models that consist of an arbitrary central region connected to semi-infinite electrodes. For such systems, Tkwant provides algorithms to simulate time-dependent manybody expectation values, such as densities and currents. In this talk I will present the theoretical framework behind Tkwant, which is based on a wave-function approach. For non-interacting systems, the wave-function approach is mathematically fully equivalent to the nonequilibrium Green's function formalism, but it is much better suited for numerical simulations in terms of scaling. With the latest version of Tkwant, two new features have been added that allow the computation of nonequilibrium Green functions and the numerical solution of generic time-dependent mean-field equations. This second functionality enables the solution of self-consistency equations describing, for instance, plasmonic excitations in Luttinger liquids or anyons in the franctional quantum Hall effect.- Tkwant is free software distributed under a BSD license and can be found at https://tkwant.kwant-project.org/.

Submission number: 191

STOCHASTIC NEURAL NETWORKS WITH LAYER-WISE ADJUSTABLE SEQUENCE LENGTH

Wang, Ziheng; Reviriego, Pedro; Niknia, Farzad; Liu, Shanshan*; Gao, Zhen; Lombardi, Fabrizio

Keywords: Quantum, Neuromorphic, and Unconventional Computing; AI for Nanotechnology; Modeling and Simulation

The implementation of Neural Networks (NNs) on resource-limited devices poses significant challenges, with Stochastic Computing (SC) emerging as a solution for efficient execution. By representing values as sequences of bits that are processed serially, SC implementations significantly reduce the energy dissipation of NNs. However, with NNs growing in size, SC can also become energy-intensive, prompting a need for enhanced efficiency. This paper introduces Adjustable Sequence Length (ASL), a method employing varied sequence lengths across different NN layers to reduce overheads on energy/latency at the cost of negligible impact on performance. The feasibility of sequence truncation across layers is assessed with proposed implementations. As per the simulation results, the ASL method demonstrates significant savings in energy and latency of up to 54.75% when compared with conventional SC implementations.

Submission number: 194

MULTI-SCALE QUANTUM SIMULATIONS AND NOVEL TRANSPORT MECHANISMS IN 2D MATERIAL-BASED DEVICES AND CIRCUITS

Fiori, Gianluca*

Keywords: Modeling and Simulation; Nanoelectronics; Spintronics

Abstract Advances in semiconductor technologies have been fundamental to keeping pace with Moore's Law. As the industry approaches the physical limits of traditional materials, two-dimensional materials (2DMs) have emerged as promising candidates to further advance the development of advanced devices and transistors for the next technology nodes. In this work, we present a detailed analysis of device performance through multi-scale quantum simulations, while investigating their performance against industry requirements.-The developed approach also offers us the opportunity to provide physical insights into the mechanisms at play in novel and advanced materials, which can be exploited for the realisation of novel device concepts beyond the thermionic transport mechanism. To this end, we will also focus on 2D nanomagnets, which offer new paradigms for device operation. Devices using these materials take advantage of novel carrier transport mechanisms such as valleytronics, which exploits the valley degree of freedom in electronic systems for information processing.- In the talk, I will also present results on a novel Verilog-A model tailored for 2D material-based circuit simulation. This model has been rigorously validated against experimental data, demonstrating its effectiveness in predicting the behaviour of circuits incorporating 2D materials. It represents a significant step towards the practical realisation of circuit-level applications and provides insights into the integration of 2D materials into existing semiconductor technologies.

Submission number: 195

CHARGE TRANSPORT IN THE D2 BRANCH OF PHOTOSYSTEM II AND ELECTRICAL CONDUCTANCE OF DNA AND RNA

Maiti, Prabal*

Keywords: Nanoelectronics; Modeling and Simulation

Photosynthesis, the fundamental process sustaining life on Earth, depends on the-Photosystem II (PSII) reaction center's ability to initiate the charge transport process. Using multi-scale simulation methodologies, we have investigated this charge transport process-with a focus on the dissimilarity between the two branches of the PSII reaction center, D1-and D2. Utilizing Marcus theory, we have calculated the reorganization energies and-activation barriers for all the key steps involved in the charge transport process. Our analysis-reveals that while both D1 and D2 branches exhibit similarities in the initial stages, the rate_x0002_determining step in the D2 branch has a significantly higher activation barrier (0.2 eV) than-D1 branch (0.1 eV), suggesting a much less favorable energetic landscape. Further, the-calculation of current-voltage (I-V) characteristics confirms the higher resistance in the D2-branch compared to the D1 branch, emphasizing its non-conductive nature. If time permits,-we will also report the electrical conductance of native DNA and RNA and in the presence-of oxidatively damaged basses. Oxidatively damaged DNA can act as molecular diodes with-a record tunable rectification ratio of as high as 106

Submission number: 196

COMPUTER SIMULATIONS OF A NANOPARTICLE TRANSLOCATING THROUGH A NANOPORE

Gracheva, Maria*

Keywords: Modeling and Simulation; Nanoelectronics; Nanosensors and Nanoactuators

This is for an invited talk in the Session organized by M. P. Anantram and Jean-Pierre Leburton titled "Ion and Electron Transport in Bio-nanostructures"- Abstract-In recent years, various solid state membranes equipped with a single nanopore have been used as biomolecular detectors and filters. This nanometer-size aperture that can be used to selectively permeate nanosize objects such as ions, nanoparticles and biomolecules (proteins and DNA in particular) for biomolecular detection, separation of species, and even sequencing. Frequently, the ionic current blockades recorded as an object translocates through the pore are used to identify, for example, protein and RNA molecules, nanoparticles and perform DNA sequencing We use a Brownian Dynamics approach, in conjunction with a full three-dimensional self-consistent solution of the Poisson–Nernst–Planck and Navier–Stokes system of equations to describe realistic ionic current response arising due to the random motion of a nanoparticle through a nanopore. By performing statistical analysis of the current traces, we observe that, in general, smaller current blockade values correspond to faster translocation times, while increased dwell times result in a larger current decrease. Other recent projects involving a translocating protein, DNA, spherical or ellipsoidal particle will be discussed as well.-Short Bio-Professor Maria Gracheva is a solid state engineer-physicist by training, she obtained both of her equivalent MS ('95) and PhD ('98) degrees from Moscow State Engineering Institute (MEPhI), Russia. She held several post-doctoral research positions at the US Universities, including Lehigh University, University of Minnesota (Minneapolis) and University of Illinois at Urbana-Champaign. Currently, she holds a professor position at Clarkson University. She is the author of over 50 research papers published in refereed journals, multiple book chapters including works on solid-state nanopores, and a patent in the area of nanopores. She is the editor of a book entitled “Nanopore-based Technology”. Her current research interests are in computer modeling of physical processes at the nanoscale, involving nanopores and nanoparticles, for bio-sensing applications.

Submission number: 197

QUANTUM CONFINEMENT EFFECT ON THERMAL PROPERTIES AND DIFFUSION OF LITHIUM IN GE NANOSTRUCTURES

Barranco Rivera, Dafne Dayan*; Salazar, Fernando; Cruz-Irisson, Miguel

Keywords: Nanomaterials; Nanoelectronics; Modeling and Simulation

Germanium (Ge) is a semiconductor of great importance in the semiconductor industry. Ge-based nanostructures allow good control of its electronic and vibrational properties due to surface effects and quantum confinement. The Ge nanowires have a high charge rate, Coulombic efficiency near at 100 %, and better electrical conductivity in comparison with graphite anode. In this study, we investigate the effect of dimensionality on the phonon bands spectrum and specific heat curve of one Ge monolayer and an hydrogen passivated nanowire [1], considering one surface lithium (Li) atom. Likewise, we investigate the diffusion path of one Li atom in both nanostructures. The study is performed using the density functional theory in the local density approximation incorporate at the SIESTA and phonopy codes [2]. The results indicate that the frequencies of the Ge monolayer are lower in comparison with the nanowire as shown Figure 1 due to surface hydrogen atoms. The specific heat for the monolayer reproduces the classical limit in the high temperature region. Likewise, for low temperatures the specific heat follows a T^2 trend for the monolayer and aT+-12310;bT-12311;^2 for the nanowire. On the other hand, the potential barrier between two hexagonal places of one Li atom placed at 1.47 -8491; from the surface of the monolayer is symmetric with a value of 0.027 Ha. In contrast, Td is the more favourable position of one Li atom in the nanowire structure, the values obtained for the potential barrier of the Li atoms is 0.019 Ha from the surface to the nearest interstitial Td place, and 0.016 Ha between two Td places. These results indicate that the dimensionality restriction in the Ge nanostructures have an important effect on thermal properties and diffusion of Li atoms.

Submission number: 198

CONTROL OF SUB-MONOLAYER METALLO-PHTHALOCYANINES ADSORPTION MECHANISM AS A TOOL FOR TAILORING LOW-DIMENSIONAL ORGANIC-BASED TRANSISTORS' PROPERTIES

Powroznik, Paulina*; Przybyla, Aleksandra; Agnesod, Giacomo; Mo, Fabrizio;

Trefon-Radziejewska, Dominika; Juszczyk, Justyna; Krzywiecki, Maciej

Keywords: Nanomaterials; Modeling and Simulation; Nanoelectronics

The increasing progress in material science opened many possibilities for exploring new designs for low-dimensional electronic devices. One of the trends is the application of semiconducting organic molecules, due to their great versatility. In the practical application, organic molecules are usually a part of a hybrid junction with inorganic material serving as a component of the device or a substrate for the molecules' deposition. From this point of view, an in-depth understanding of the properties of the interface is extremely important for the conscious design of devices. These properties, in the case of sub-monolayer films of organic molecules, are mostly governed by the adsorption mechanism. Thus, the investigation of adsorption is the main means of gaining knowledge about the interface. Therefore, we present a complex approach to the adsorption process influence on the interface properties in metallo-phthalocyanines-aluminum oxide junction that can be applied in low-dimensional organic-based transistors. As phthalocyanines are one of the most popular organic semiconductors, there are many studies regarding their adsorption on metallic substrates. Yet, for the application in transistors, the interface of high interest is organic molecules / wide band-gap oxides. Additionally, there are no comprehensive studies of the influence of central metal in metallo-phthalocyanine on interface formation. For these reasons, our approach is focused on the study of different phthalocyanines adsorption on aluminum oxide surface. Specifically, we choose phtalocyanines with central metals of different electronegativities. The methodology is based on the theoretical modeling of adsorption by density functionals method (DFT) and experimental studies using spectroscopic methods (photoemission, thermal desorption and scanning tunelling spectroscopies). The combination of theoretical and experimental approaches gives us a comprehensive image of the interface formation mechanism and following properties of a potential electronic device.

Submission number: 199

CARBON NANOTUBE-BASED HIGH-PERFORMANCE BIOELECTRONICS

Hu, Youfan*

Keywords: Nanoelectronics; Nanotechnology in Soft Electronics

The continuous advancements in wearable and flexible electronics are expected to enable advanced bioelectronics with the capability of health assessment, physical activity tracking, and even personalized therapy. An intimate interface between the electronics and organisms for high fidelity information capture and high-performance electronics to support advanced functions are the key enablers of these applications. Here, we show several examples of our recent progress to construct such bioelectronic systems for physiological information monitoring from human body surface, which integrate flexible sensors, carbon nanotube based interface circuits and memory. The carbon nanotube-based electronics demonstrate great performance to enable advanced functions, such as in-situ signal processing and information storage, revealing a great possibility in advanced health monitoring, medical diagnostics, etc.

Submission number: 200

SPATIAL TRANSCRIPTOMIC EVALUATION OF THE EFFECT OF MXENE QUANTUM DOTS ON TUMOR MICROENVIRONMENT

recep, uyar*; celik, Dogantan; ahmet, ceylan; sanjiv, dhingra; Acelya, Yilmazer

Keywords: Nanobiomedicine; Nanomaterials

Nanomedicine holds promise in revolutionizing tumor treatment strategies. However, the intricate tumor microenvironment (TME) poses challenges, housing diverse immune cell populations alongside tumor cells [1,2]. Despite advancements in nanoparticle-based therapies, understanding the nuanced interactions within the TME remains elusive. In this study, we employed spatial transcriptomics to unravel the gene expression landscape and discern the impact of nanoparticle exposure on immune cell dynamics within the TME. Utilizing Ti3C2Tx MXene quantum dots (MQDs), we tracked their distribution in orthotopic breast cancer models. Our findings revealed distinct responses in tumor and immune cells contingent upon MQD accumulation, unveiling a tumor-suppressive phenotype in regions with variable MQD accumulation. Furthermore, pathway analysis and cell deconvolution unveiled alterations in B cells and neutrophils induced by MQDs, including recruitment, activation, and neutrophil degranulation. Through spatial transcriptomics, we delineated the molecular and cellular changes instigated by MQDs within the TME. Future studies leveraging spatial omics approaches with diverse nanoparticles hold promise in refining nanotherapeutic design for enhanced efficacy.

Submission number: 201

DEPENDABILITY EVALUATION OF STABLE DIFFUSION WITH SOFT ERRORS ON THE MODEL PARAMETERS

Gao, Zhen*; Yuan, Lini; Reviriego, Pedro; Liu, Shanshan; Lombardi, Fabrizio

Keywords: AI for Nanotechnology; Modeling and Simulation

Stable Diffusion is a popular Transformer-based model for image generation from text; it applies an image information creator to the input text and the visual knowledge is added in a step-by-step fashion to create an image that corresponds to the input text. However, this diffusion process can be corrupted by errors from the underlying hardware, which are especially relevant for implementations at the nanoscales. In this paper, the dependability of Stable Diffusion is studied focusing on soft errors in the memory that stores the model parameters; specifically, errors are injected into some critical layers of the Transformer in different blocks of the image information creator, to evaluate their impact on model performance. The simulations results reveal several conclusions: 1) errors on the down blocks of the creator have a larger impact on the quality of the generated images than those on the up blocks, while the errors on middle block have negligible effect; 2) errors on the self-attention (SA) layers have larger impact on the results than those on the cross-attention (CA) layers; 3) for CA layers, errors on deeper levels result in a larger impact; 4) errors on blocks at the first levels tend to introduce noise in the image, and those on deep layers tend to introduce large colored blocks. These results provide an initial understanding of the impact of errors on Stable Diffusion.

Submission number: 202

EXPLOITING OMIC BIOLOGY TO BETTER UNDERSTAND AND IMPROVE CANCER NANOTHERAPEUTICS

yilmazer, acelya*

Keywords: Nanobiomedicine

In the realm of cancer nanotherapeutics, nanomaterials have emerged as promising platforms for drug delivery due to their unique properties such as targeted delivery, prolonged circulation, and stimuli-responsive drug release. These nanotherapeutic agents have showed their potential in cancer treatment by enhancing drug efficacy, minimizing side effects, and improving patient outcomes [1]. However, cancer arises from a complex interplay of genomic aberrations, including mutations, copy number alterations, expression changes, and epigenetic modifications across multiple omic layers [2]. Therefore, in order to design much effective treatment modalities for the clinic, we need to consider the biology behind these nanosystems. This talk delves into the integration of omics data in the nanomedicine field to enhance the understanding and efficacy of cancer nanotherapeutics. The utilization of 'omics' technologies, including metabolomics, genetics, metagenomics, transcriptomics, and proteomics, offers a comprehensive approach to unravel the intricate relationships between tumor cells, tumor microenvironment and nanomaterials. Our group has used various omic approaches to reveal the mechanisms behind various cancer nanotherapeutics including carbon dots, quantum dots and 2D materials including MXenes [3-6]. The talk will underscore the importance of harnessing omic biology to propel cancer nanotherapeutics forward, ultimately improving patient outcomes and revolutionizing cancer care.

Submission number: 203

NONLINEAR MULTIPLEXED SUPER-RESOLUTION IMAGING WITH UPCONVERSION NANOPARTICLES

Chen, Chaohao*; Fu, Lan

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanomaterials

Optical multiplexing for nanoscale object recognition is of great significance within the intricate domains of biology, medicine, and microscopic imaging. Traditionally, the multiplexing dimensions of nanoscopy are limited to emission intensity, colour, lifetime, and polarizability. Here, we propose a novel optical nonlinearity dimension for super-resolved multiplexing microscopy. This optical nonlinearity is caused by the doped lanthanide ions in upconversion nanoparticles (UCNPs) switching between different energy levels. This makes UCNPs with different compositions have their own unique optical fingerprints. We apply a vortex beam to transport the optical nonlinearity onto the imaging point spread function (PSF). This creates a robust, super-resolved multiplexing imaging strategy for differentiating UCNPs with distinctive optical nonlinearities. The composition information of the nanoparticles can be retrieved with variations of the corresponding PSF in the obtained image. We demonstrate two orthogonal colour dimensions and 4 channels of nonlinearity-multiplexed super-resolved imaging of UCNPs with a spatial resolution of 150 nm. Our work provides one powerful dimension for multiplexed imaging nanoparticles and shows great potential in bioimaging, anti-counterfeiting, deep tissue multiplexing detection, and high-density data storage.

Submission number: 204

TACKLING LEAKAGE, DRIFT, AND VARIATION IN PRINTED CARBON NANOTUBE-BASED ELECTRONIC BIOSENSORS

Franklin, Aaron*

Keywords: Nanoelectronics; Nanofabrication; Nanomaterials

Semiconducting carbon nanotubes (CNTs) have been pursued for use in electronic biosensors for decades. Their all-surface molecular structure, sizeable semiconducting bandgap, and solution-phase compatibility make them highly sensitive and versatile options for transducing biomarker-related electrical signals. However, amid the thousands of reports on CNT-based electronic biosensors, very little attention has been given to identifying (let alone addressing) the impact of leakage current, signal drift, and device-to-device variation, particularly under operation in biologically relevant ionic media. This talk will present recent results focused on tackling these issues in a CNT transistor-based biosensor platform (i.e., bioFETs or ion-sensitive FETs). For instance, a variety of passivation strategies were studied to determine the role of leakage current compared to the detection signal, revealing that a bilayer epoxy/high-k dielectric stack was most effective at minimizing deleterious leakage. The influence of signal drift, particularly in strong ionic solutions (e.g., 1X PBS), was also found to play a significant role in many previous reports of CNT-based biosensors that were characterized by sequential biomarker concentration spikes. Finally, strategies for addressing device-to-device variation in these biosensors will be discussed, including the motivation for a printed thin-film device rather than a single-CNT configuration. Two things seem certain about this field: 1) the promise of CNT-based biosensors continues to suggest they are worth ongoing pursuit, and 2) there is much work remaining towards achieving a reproducible, reliable electronic biosensing technology from CNTs.

Submission number: 205

THE IMPACT OF INFORMATION FLOW CONTROL ON FCN CIRCUIT DESIGN

Vilela Neto, Omar Paranaiba*; Luz, Laysson; Silva, Pedro Arthur; de Oliveira Bicalho, João Gabriel; Ruella, Emanuel; Nacif, Jose Augusto; Ferreira, Ricardo

Keywords: Nanoelectronics

Following the continuous advancement of CMOS technology, propelled by transistor miniaturization and Moore's Law, the scientific community is currently exploring emerging paradigms to discover novel approaches for developing computational systems. One of the emerging alternatives is Field-Coupled Nanocomputing FCN, which, unlike conventional CMOS, doesn't rely on electric current as the state variable for encoding information. Instead, logic is dictated by the coupling of near fields. This paper presents critical concepts for understanding how information flow control is a crucial aspect in the design of Field-Coupled Nanocomputing circuits. We have reviewed the leading alternatives for FCN implementation, examining how each executes information control and how this ultimately impacts EDA tools.

Submission number: 206

THE MUNICH NANOTECH TOOLKIT (MNT)

Walter, Marcel; Drewniok, Jan; Hofmann, Simon; Hien, Benjamin; Wille, Robert*

Keywords: Modeling and Simulation; Nanoelectronics; Nanofabrication

As traditional computing technologies near their physical limits, the demand for beyond-CMOS alternatives intensifies. Among these, Field-coupled Nanocomputing (FCN) emerges as a class of multiple promising candidates, offering computational capabilities at a sub-nanometer scale. Breakthroughs in the fabrication of Silicon Dangling Bonds (SiDBs) exemplified by sub-30nm2 OR gates and wire segments underscore FCN's potential to revolutionize computing paradigms. However, existing software tools for FCN circuit design lack functionality and suffer from maintenance issues. Addressing this gap, in this work, we introduce the open-source Munich Nanotech Toolkit (MNT), providing accessible interfaces including a Command-Line Interface, a C++ header-only library, and Python bindings. Our toolkit adheres to modern software standards, ensuring continuous integration and testing across diverse platforms with substantial code coverage. This toolkit aids in advancing FCN design automation, and serves as a sandbox for designers and researchers in the domain, paving the way towards the beyond-CMOS era.

Submission number: 207

INSIGHTS INTO THE OXIDATION OF SIC FROM A DEEP POTENTIAL MODEL

Kälin, Colin*; Etzelmüller Bathen, Marianne; Grossner, Ulrike; Luisier, Mathieu

Keywords: Modeling and Simulation; Emerging Plasma Nanotechnologies;

Nanofabrication

The 4H polytype of silicon carbide (4H-SiC) is a wide-bandgap semiconductor that features many favorable properties for power semiconductor applications. However, in transistor configurations, it suffers from reduced channel mobility compared to bulk and from high specific ON-state resistances due to the high density of electrically active defects at the silicon-carbide/silicon-oxide (SiC/SiO2) interface. Previous work has been done with reactive force fields (ReaxFF) and at the ab initio level with density functional theory (DFT) to study the nature of these defects. Because of their computational cost, the DFT results are usually limited to very short timescale molecular dynamics simulations or to the calculation of the energy levels of the relevant defect structures. On the other hand, ReaxFF analyses have been conducted using models parameterized either for oxidation under very high-pressure conditions or for chemical vapor deposition, neglecting the examination of the types of defects generated. Thermal oxidation has not yet been investigated fully, especially not with a focus on the types and frequency of defects that are formed. In this presentation, we will show a newly trained deep potential model to investigate the formation of defects during thermal oxidation of 4H-SiC at different temperatures and pressures, focusing on the [0001] face. The DeePMD-kit tool was used as it is theoretically able to train force fields with DFT-level accuracy at a cost that is orders of magnitude lower. This computational efficiency allows for the simulation of oxidation processes involving thousands of atoms over nanosecond timescales, which is key to study the formation of the oxide on top of the SiC as well as defects in the interface region. Shedding light on defect formation will enable further research into the impact of these defects on the transport properties of SiC/SiO2 transistors and on the origin of their reduced carrier mobility.

Submission number: 208

OVERVIEW OF THE HARC ETCHING PROCESS, ITS CHALLENGES, ITS CHEMICAL REACTION MODELING AND FUTURE PROSPECTS

Kang, Song-Yun*

Keywords: Modeling and Simulation; Emerging Plasma Nanotechnologies;

Nanofabrication

The High Aspect Ratio Contact (HARC) etch process is key to successfully forming the capacitors and cells that determine the performance of DRAM and 3D NAND devices. With each successive generation, the HARC etch difficulty increases exponentially as the aspect ratio increases due to shrinking DRAM and increasing 3D NAND stacks. This paper reviews multiple methods for improving HARC etch performance, including chemical reaction modeling, and introduces new approaches for etching future devices. Channel hole etching of the ON stack layer of 3D NAND requires the addition of CHxFy gas in addition to CxFy/O gas. This causes profile distortion and the aspect ratio dependent etching (ARDE) phenomenon, which results in either a reduced etch rate and no hole opening or a smaller critical dimension (CD) at the bottom of the hole. To overcome these problems, bias voltage was used as the main solution in the early generations and has continued to increase since then. In recent years, however, aspect ratios have further increased and voltage alone can no longer overcome the limitations. A second method that has emerged to overcome the limitations of high-voltage processes is the low_x0002_temperature etch process. The low-temperature etch process suppresses sidewall reactions, resulting in a higher concentration of etchant at the bottom of the hole, avoiding ARDE and increasing the etch rate. Low-temperature processes are an innovative way to etch high mold stacks, but innovative technology development is needed for next-generation devices with even higher mold stacks According to papers presented at VLSI2023 [1] and DPS2023 [2], the combination of low-temperature processes and A new gas combination has been successfully used to induce a pseudo-wet reaction that significantly improves etching rates. Such an approach could extend the height limit of 3D NAND and lead to breakthroughs in next-generation HARC etch processes.

References

[1] Y. Kihara, et al., Proceeding of VLSI2023, T3-2 (2023).
[2] R. Suda, et al., Proceeding of DPS2023, A-3 (2023).

Submission number: 209

REWORKABLE AND REHEALABLE ELECTRONIC MATERIALS: EXPLOITING DYNAMIC COVALENT CHEMISTRY

Singh, Ishwar*; Wojtecki, Rudy; Magbitang, Teddie

Keywords: Nanomaterials; Nanopackaging; Nanotechnology in Soft Electronics

Packaging has become a key part of the design process across all major semiconductor manufacturers, and a critical factor in extension of Moore’s law.A consequence of this is the rise in physical complexity of multi-chip modules and their incorporation in mainstream applications. This presents as a challenge to traditional electronic packaging material, as they may reach fundamental limitations. For eg. capillary underfill(CUF)when subjected to thermal or mechanical stress from regular operation are susceptible to fatigue, crack formation,adhesion loss and related failure mechanisms–all of which have significant consequences to package lifetime, performance, and device fidelity.Generally, packaging materials are complex formulations that include fillers, matrix polymers, catalysts, and adhesion promoters–but the curing chemistry is reliant on irreversible bond formation where significant focus is directed to minimize rupture of these bonds.With careful incorporation of chemical components capable of bond formation under an equilibrium could provide access to a dynamic system with multiple products in equilibrium.This behaviour could be modulated to introduce properties such as shape-memory behaviour,self-healing,and mechanosensitivity,to name a few.We describe a design of a multi-responsive CUF that can be reworked,to ensure extensibility of advanced package yield and component recovery at end of life, rehealed to extend package lifetime through damage repair, while also meeting the critical requirements of an electronic package–low coefficient of thermal expansion, high modulus, low viscosity when dispensed and mild curing temperatures.Utilizing the principles of green chemistry in the design,a series of materials were synthesized and demonstrate,through orthogonal dynamic covalent chemistries, rehealing in a thermally driven process and chemoresponsive solution rework process.Deployment of this material present several attractive attributes(i)reworkability can be used to recover packages with faulty chiplets during assembly or in the recovery of the material and electronic components at the end of life and(ii)rehealability to repair materials damage and extend package lifetime.

Submission number: 210

ATOMISTIC SIMULATIONS OF EMERGING QUANTUM ELECTRONICS: DFT-NEGF TOOLS AND CHALLENGES

Brandbyge, Mads*

Keywords: Nanoelectronics; Modeling and Simulation; Spintronics

The down-scaling of basic electronic building blocks has accentuated the need for predictive, atomistic approaches to theory and modelling. This is especially the case for the emerging quantum devices based on low-dimensional molecular or two-dimensional structures harnessing coherent quantum properties, for example involving wave interference or spintronic applications.- For nano-meter scale electronic devices the non-equilibrium working conditions controlled by bias, currents, and electrostatic gating are crucial. To this end, the combination of Density Functional Theory and non-equilibrium Greens functions (DFT-NEGF) is popular [1].-In this presentation, I will discuss challenges and progress in the use of DFT-NEGF high-lighted by selected problems including: (i) Device boundary conditions beyond the standard periodic setup to treat f.ex. point contacts geometries [2], and (ii) a simple approach to nonequilibrium effects using periodic boundary conditions in all directions [3]. (iii) Gating control of localized spins [4], and (vi) time-dependence due to applied strong THz electro-magnetic fields [5], and finally (v) the bridging of length scales in device modelling from the few to hundreds of nanometer range [6].-

References:

[1] M. Brandbyge, et al., Phys. Rev. B 65, 165401 (2002); N. Papior, et al., Comp. Phys. Comm., 212, 8, (2017); S. Smidstrup et al, J. Phys. Cond. Mat. 32, 015901 (2020).
[2] D. Li,, et al., Phys. Rev. Res. 3, 033017 (2021).
[3] N. Papior, S. Leitherer, M. Brandbyge, Phys. Rev. B 106, 155401 (2022).
[4] F. Gao, et al., Phys. Rev. B Lett. 103, L241402 (2021); F. Gao, D. Li, C. Barreteau, M. Brandbyge, Phys. Rev. Lett. 129, 027201 (2022).
[4] J. K. Svaneborg, et al., Frontiers in Phys. 11:1237383, doi: 10.3389/fphy.2023.1237383 (2023)
[6] G. Calogero, et al., Nanoscale 11, 6153 (2019); I. Alcon, et al., Adv. Funct. Mater. 2104031 (2021).

Submission number: 211

ADVANCING SILICON PHOTONICS THROUGH MACHINE LEARNING: FROM DEVICE DESIGN TO FABRICATION

Xu, Danxia*

Keywords: AI for Nanotechnology; Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanofabrication

The advances in fabrication technologies have enabled the development of new nanophotonic devices, utilizing improved structural resolution for greater integration density and functionality. The complexity of these devices necessitates the adoption of algorithm-assisted design methods to navigate the vast design space. This evolution presents a push-pull dynamic: while striving for advanced device functionalities, the limits of fabrication technology are tested, potentially affecting device robustness. Our research leverages machine learning to address this challenge, balancing the drive for innovation with the practicalities of manufacturing. This paper outlines our strategies to optimize device design and predict fabrication outcomes, improving both the performance and robustness of next-generation silicon photonic devices.

Submission number: 212

PRINCIPLES AND MODELING OF CHIRALITY INDUCED SPIN SELECTIVITY

Palacios, Juan*

Keywords: Nanoelectronics; Spintronics; Modeling and Simulation

Spin–orbit coupling gives rise to a range of spin-charge interconversion phenomena in nonmagnetic systems where certain spatial symmetries are reduced or absent. Chirality-induced spin-selectivity (CISS), a term that generically refers to a spin-dependent electron transmission in nonmagnetic chiral systems, is one such case, appearing in a variety of seemingly unrelated situations ranging from inorganic materials to molecular devices. In particular, the origin of CISS in molecular junctions is a matter of an intense current debate. I will present a set of geometrical conditions for this effect to appear, hinting at the fundamental role of symmetries beyond otherwise relevant quantitative issues. This approach, which draws on the use of point-group symmetries within the scattering formalism for transport, is complemented with DFT quantum transport calculations carried out with our code ANT [1]. Furthermore, how this chirality-induced spin selectivity (CISS) manifests in experiments, where the system is taken out of equilibrium, is also still debated. Aided again by group theoretical considerations and nonequilibrium DFT-based quantum transport calculations, I will show the conditions required for a net spin accumulation to appear at finite bias in an arbitrary two-terminal nanojunction. When a suitably magnetized detector is introduced into the system, the net spin accumulation, in turn, translates into a finite magneto-conductance. Finally, a quantitative measure of chirality will be presented. This measure aims at relating geometry and the strength of CISS, going beyond the yes/no predictions of group theory.- [1] https://github.com/juanjosepalacios/ANT.Gaussian

Submission number: 213

ADVANCES IN LOW-LOSS FIBER-CHIP COUPLERS FOR SILICON NITRIDE PHOTONIC INTEGRATED CIRCUITS

Benedikovic, Daniel*

Keywords: Nanomaterials; Nanoscale Communications; Modeling and Simulation

We present our recent progress in the development of low-loss fiber-chip surface grating couplers realized on silicon nitride photonic platform for applications in optical interconnects and quantum integrated circuits.

Submission number: 214

AN EFFICIENT SIMULATED OSCILLATOR-BASED ISING MACHINE ON FPGAS

Liu, Bailiang; Zhang, Tingting; Gao, Xingjian; Han, Jie*

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Modeling and Simulation

Ising model-based computing has emerged as an efficient approach for solving combinatorial optimization problems. In particular, oscillator-based Ising machines (OIMs) have shown promising performance in such metrics as solution quality, time-to-solution, and energy-to-solution. Existing designs, however, require customized chips and use sparsely connected topologies with limited precision for the spin coupling coefficients. In this paper, a simulated oscillator-based Ising machine (SOIM) is designed with a fully connected topology and high coefficient precision for an efficient implementation on field-programmable gate arrays (FPGAs). To this end, an FPGA-oriented model is first developed to describe the underlying mechanism of an oscillator-based Ising machine based on revised differential equations. To save hardware, periodic functions that are expensive to implement are replaced by piecewise linear functions. Moreover, Gaussian noise is omitted in the system to further save hardware. An OIM simulation algorithm is then proposed to solve the new differential equations using the Euler integration method. From experiments on solving 800-node max-cut problems, the results reach a level of 99% of the best-known values. SOIMs of different sizes are then developed and synthesized on a Zynq UltraScale+ board. Compared with state-of-the-art FPGA-based Ising machines, the SOIM is expected to utilize fewer hardware resources to efficiently solve complex combinatorial optimization problems by leveraging a high coefficient precision and a fully connected topology.

Submission number: 215

HEXAFERRITE NANOCERAMICS FROM NANOPARTICLES SYNTHESIS TO ELECTRIC MACHINE INTEGRATION

Gaudisson, Thomas; Vazquez-Victorio, Gabriela; Valenzuela, Raul; Sehab, Rabia;

Ammar, Souad*

Keywords: Nanomaterials; Nanomagnetics; Nanofabrication

Nowadays, the most used materials for magnetically driven electrical machines are rare earth (RE) based alloys like Nd2Fe14B. They exhibit the maximum magnetic energy product (BH)max around room temperature. Unfortunately, the economic situation of RE under the monopoly of China, their strong environmental impact during their extraction, their low resistivity against corrosion [1-3] and their low Curie temperature encourage motor constructors to look for alternative materials [4]. In this context, two improvement lines have been proposed: (i) improving the intrinsic anisotropy of already known RE-free ferromagnetic compounds by including other anisotropy sources (domain wall motion prevention, shape anisotropy…) or (ii) producing new ferromagnetic materials with a high magnetocrystalline anisotropy. Focusing on the former strategy, encouraging results have been reported on nanostructured granular ferromagnets. In this context, we succeeded to produce BaFe12O19 hexaferrite nanoceramics. BaFe12O19 is a well-known hard ferrimagnet, used for a while as a permanent magnet for certain technological uses, even if its (BH)max ~ 8 kJ/m3 remains two orders lower compared to the standard Nd2Fe14B magnets, for which (BH)max ~ 400 J/m3 [5]. We successfully used a soft chemistry route, namely forced hydrolysis in polyol [6], to produce nanoparticles and we consolidate them as granular solid magnets without losing their inner nanostructuration, using Spark Plasma Sintering (SPS) [7]. We started investigating their integration into a lab-scaled electric machine, namely a three phases permanent magnet synchronous machine (PMSM) operating as a compressor for air conditioning in electric vehicles. Based on finite element modeling (FEM), we evaluated the performances of the designed BaFe12O19 nanoceramics as the active components of the designed PMSM's rotor within two different geometries (surface and interior) and we compared them to those of Nd2Fe14B magnets in a similarly sized rotor.

Submission number: 216

MECHANICAL-TO-ELECTRIC POWER CONVERSION IN DYNAMIC SEMICONDUCTOR JUNCTIONS

Zhang, Qing*

Keywords: Nano-Energy, Environment, and Safety; Nanosensors and Nanoactuators; Nanobiomedicine

Electric current can be generated when a doped semiconductor electrode is intermittently contacted or slid against another doped semiconductor electrode or metal electrode as long as the two electrodes are of distinct work functions. The electric power is converted from the mechanical power which activates the intermittent contacts or frictional motions between these electrodes. Since the experimental observations were reported several years ago, the relevant research has attracted a great deal of attention. Till today, a large number of papers on a wide range of experimental findings have been published. However, understanding of the mechanical to electric power conversion mechanisms seems still remaining at the superficial stage. In this presentation, I shall review several mechanisms proposed by different groups. The impacts of surface states, interlayers and unevenness on the interactions at the contacted surfaces are discussed.-Acknowledgements: This project is financially supported by MOE AcRF Tier1 (RG131/22), Singapore.

Submission number: 217

THE NEW ROLES OF SUBSTRATES IN THE PACKAGING TECHNOLOGIES FOR SYSTEMS

Oggioni, Stefano Sergio*

Keywords: Modeling and Simulation

There are plenty of new challenges facing the whole Microelectronic Industry in the coming years, and the great majority of those challenges will implicate the roles of packaging and substrates in the overall System's performance. While is it difficult to see the future without the use of substrates, it is acknowledged the fact that organic substrates have to transform their role, and their contribution in serving the over growing complexity of interactions between computational units, data storage, and communication. It is important to understand what kind of substrate will have the capabilities to do that. This paper highlights some of the key areas undergoing development. The R&D goal is to identify new approaches capable of expanding the desired level of contributions in the Systems' performance, with the construction of improved substrates. With that, there is a clear understanding that in the coming years for the organic substrates, the challenge has just started.

Submission number: 218

2D SEMICONDUCTORS FOR FUTURE COMPUTING

Wang, Xinran*

Keywords: Nanoelectronics; Nano-Optics, Nanophotonics, and Nano-Optoelectronics;

Nanomaterials

2D transition-metal dichalcogenide semiconductors are promising candidates in future electronics due to unmatched device performance at atomic limit and low-temperature heterogeneous integration. In this talk, I will present our recent advances in this area. The main topics include wafer-scale single-crystal materials growth, high-performance FETs scaled to a 40 nm footprint, ring oscillator circuits operating at gigahertz frequency, monolithically integrated micro-LED displays, and architecture-level innovations toward neuromorphic computing. These advances demonstrate the potential of 2D semiconductors in future computing beyond silicon.

Submission number: 219

SILICON NITRIDE FOR ENHANCED INTEGRATED PHOTONICS

gardes, frederic*

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics

We present recent progress in the development of silicon nitride integration schemes for high-speed modulation, broadband non-linear photonics, device trimming and photonic memories.

Submission number: 221

MAGNETO-IONIC CONTROL OF HYSTERESIS, DOMAINS AND MAGNETORESISTANCE FOR ENERGY-EFFICIENT MAGNETOELECTRIC NANODEVICES

Leistner, Karin*

Keywords: Nanomagnetics; Nanomaterials; Spintronics

Magneto-ionic materials are an emerging class of materials which may enable magnetoelectric nanodevices with exceptional energy efficiency for information storage, spintronics, neuromorphic computing, sensing, and actuation [1]. A magneto-ionic material consists of a magnetic film or nanostructure adjacent to a solid or liquid electrolyte. A gating voltage induces reversible ion migration and electrochemical reactions at the nanomagnet/electrolyte interface, which affect the magnetic properties at room temperature. In my talk I will focus on our work on magneto-ionic Fe- and Co-based nanomaterials. In these materials, voltage-tunable magnetization, coercivity, magnetic domains and magnetoresistance have been demonstrated by inducing electrochemical reactions [2-6]. We reveal the interaction of oxygen and hydrogen with the magnetic structures as the underlying mechanism by electrochemical and surface analytical techniques, combined with in situ magnetotransport measurements and in situ MOKE magnetometry and microscopy. For example, Neel wall interactions and pinning sites in FeOx/Fe thin films are affected by oxidation/reduction reactions, enabling an ON-OFF-switching of hysteresis [3]. The combination of ferromagnetic films with magneto-ionic functionality with antiferromagnetic layers leads to nonvolatile control of exchange bias by voltage [4]. Furthermore, we show that magneto-ionic effects can be achieved in electrodeposited 3D geometries such as nanoislands and aerogel composites [5,6].

References

[1] M. Nichterwitz et al., APL Mater. 9, (2021) 030903.
[2] M. Huang et al., Nat. Nanotechnol. 16 (2021) 981.
[3] J. Zehner et al, Adv. Electron. Mater. 6 (2020) 2000406.
[4] J. Zehner et al., Adv. Electron. Mater. 5 (2019) 1900296.
[5] S. Guo et al. Nano Lett. 22 (2022) 4006.
[6] M. Nichterwitz et al., ACS Mater. Au 4 (2024) 55.

Submission number: 222

SENSITIVE AND LOW-COST NANO AND MICRO-DEVICES FOR POINT-OF-CARE TESTING OF INFECTIOUS DISEASE

Tan, Huiling; Bai, Hao; Hu, James; Xie, Harris; Wu, Ian; Zhuang, Weihua; Hu, Jie; Hu, Walter*

Keywords: Nanosensors and Nanoactuators; Nanomaterials; Nanobiomedicine

Global public health is greatly threaten by emerging infectious diseases. Since the 21st century, public health emergencies caused by major viral infectious diseases such as SARS (2003), avian influenza (2006), influenza A (2009), Ebola (2014), Zika (2015), and SARS-COV-2 (2019) have occurred more frequently. Infectious disease outbreaks pose a major threat to the health of people and worldwide economic development. Rapid and sensitive viral infection testing is essential for the early diagnosis and early treatment of infectious diseases, especially in life-threatening circumstances where smart clinical decisions are urgently needed. In this talk, we present our recent work of sensitive antigen test of respiratory syncytial virus (RSV) and protein biomarkers of heart failure using various nanoparticles by naked eyes, and also microfluidic device to test DNA and RNA for Covid and HPV, etc. For the antigen and protein biomarker test, we developed nanozymes including bimetallic Au-core/Ag-shell nanoparticles as well as novel V2(SnPt)C MAX material to greatly enhance detection sensitivity and enable colorimetric reading with naked eyes. The limit of detection (LOD) of the devices reaches as low as 6 pg/mL. For the DNA/RNA test, we developed a self-driven microfluidic device of 10 tiny reaction chambers of 12 microliters. Combined with a single-step sample lysis and loop-mediated isothermal amplification with lyophilized reagent beads, LOD as low as a couple of copies per reaction has been achieved. To validate these devices, we then tested various viruses using over 500 clinical samples. Across these tests, sensitivity over 92% and specificity over 97% have been achieved. In summary, these nanoscale and micro-devices utilize colorimetric signals to realize sensitive but low cost "sample-in and result-out" tests that can be used by anyone in anywhere, providing a quick and accurate result for point-of-care testing and self-testing of infectious disease.

Submission number: 223

OPERANDO IMAGING OF STRAIN AND DEFECTS AT THE NANOSCALE

Julie, Barringer; N'gom, Moussa; Fohtung, Edwin*

Keywords: Nano-Metrology and Characterization; Nanoscale Communications;

Nanoelectronics

Nanomaterials are profoundly influenced by defects, which can either enhance or impede their properties, contingent on the intended application. In semiconducting nanomaterials, defects can alter conductivity and optical properties by introducing states within the band gap. Similarly, in catalyst nanoparticles, defects can augment chemical reactivity and selectivity through active sites. The mechanical properties of metals can be either strengthened or weakened depending on the controlled introduction of defects. In magnetic nanomaterials, defects are pivotal in determining coercivity, magnetic susceptibility, and saturation magnetization, while in optical materials, they can significantly affect luminescence and absorption properties. In the context of battery cathode nanomaterials, defects can either facilitate or obstruct ion movement, thus impacting performance. Given this complexity, the identification and spatial resolution of defects and structural dynamics in nanomaterials are crucial for both fundamental understanding and practical applications. This presentation will delve into our group's pioneering work in employing X-ray Bragg Coherent Diffractive Imaging (BCDI). BCDI is a cutting-edge technique that enables imaging of 3D strain and defects with atomic scale volumetric resolution. We have applied BCDI to investigate semiconductor, magnetic, metallic, and battery nanostructures, offering unprecedented insights into their structural dynamics in-operando.

Submission number: 224

FINE PITCH FLIP CHIP BONDING FOR HETEROGENEOUS CHIPLET INTEGRATION

Oppermann, Hermann*; Manier, Charles-Alix; Fröhlich, Juliane; Schneider-Ramelow, Martin

Keywords: Nanopackaging; Nanomaterials; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

Silicon is the main working horse, but many chiplets are based on alternative semiconductors. For heterogeneous integration flip chip is a key technology, but due to CTE mismatch and material compatibility specific bump interconnects should be considered, which must also address challenges in fine pitch and precision bonding.

Submission number: 225

ENHANCEMENTS IN FLEXIBLE PRINTED BATTERIES THROUGH ADVANCED MATERIALS AND CARBON DOPANTS

Sliz, Rafal*

Keywords: Nanotechnology in Soft Electronics

The rapid evolution of wearable technology and soft electronics has sparked an urgent need for energy storage solutions that are not only lightweight and efficient but also flexible. Flexible printed batteries, notable for their ability to bend, twist, and even stretch while powering devices, are at the forefront of this energy revolution. However, the development of these batteries faces significant challenges, particularly in achieving the desired mechanical flexibility without compromising electrical performance. This research presents recent advancements aimed at overcoming these obstacles through the innovative use of plasticizers, polymers, and carbon dopants, highlighting progress and future directions in flexible battery technology. The emergence of flexible and wearable devices, from medical monitors to smart textiles, has generated a compelling demand for power sources that can adapt to various shapes and withstand mechanical deformation. Traditional rigid batteries fall short of these requirements, underscoring the importance of developing flexible batteries for the progression of these technologies. Key challenges in developing flexible batteries include maintaining conductivity and battery integrity under deformation, ensuring safety, and securing long-term stability. Additionally, conventional battery materials often lack the needed flexibility, resulting in reduced performance and durability under stress. This research addresses these challenges by investigating various materials that can improve flexibility while preserving or even enhancing battery performance. Notably, plasticizers such as homo- and co-polymers, including HSV1810 and VT475, have shown significant promise.[1] These materials increase the flexibility of the battery's electrodes and solid electrolyte matrix, allowing for greater mechanical deformation without substantial loss of functionality. Moreover, the incorporation of carbon dopants, particularly carbon nanotubes (CNTs), into the cathode structure has proven to be a crucial strategy. CNTs not only boost electrical conductivity across the cathode, facilitating more efficient electron transport but also enhance the mechanical strength of the battery.

Submission number: 226

IN-MEMORY COMPUTING: GLOBAL ENERGY CONSUMPTION, CARBON FOOTPRINT, TECHNOLOGY, AND PRODUCTS STATUS QUO

TaheriNejad, Nima*

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Nanoelectronics

In this paper, we highlight and quantify the importance and potential role of In-Memory Computation (IMC) and memory technologies in the future of humans' global footprint. To this end, we calculate the estimated energy consumption and carbon emission associated with the data movement inside computing systems and put them in perspective using tangible examples. Next, we review various memory technologies as well as their advantages and disadvantages (especially regarding their energy consumption), for usage in computing systems as memory and computing elements. We calculate what their impact is and what would be the potential savings of migrating towards emerging memory technologies. We discuss some of the challenges these emerging memory technologies face, before presenting the highlights of the IMC products on or near the market. This paper aims at providing an insight on the impact of IMC and memory technology on the society at large and clarify the importance of working on IMC and emerging memory technologies to lower the power consumption and overall footprint of computing systems. The status of IMC products show that while moving in the right direction, there is a substantial body of work to be done. We hope this will help engineers to better grasp the extent of the impact they can produce and motivate them further in the pursuit of better computing systems.

Submission number: 227

MODELING ELECTRON-ION INTERACTION IN 2D SEMICONDUCTOR NANO-FLUIDICS

Jean-Pierre Leburton, Jean-Pierre*

Keywords: Modeling and Simulation; Nanotechnology in Soft Electronics;

Nanobiomedicine

During the last two decades, solid-state nanochannels have gained significant attention due to their-unique properties in ionic transport and their broad range of applications in biosensing, drug delivery, water-filtration, lab-on-a-chip devices and energy harvesting. Among them, semiconductors nanopores offer-advantages of their electronic response and modulation of ion flows. In this talk we discuss fundamental issues related to the interaction between ions flowing through-sub-nanometer pores in 2D semiconductor materials such as graphene and transition metal dichalcogenides-(TMD), and the electronic environment. In this context, we pay special attention to so-called 2D "Janus"-layers such as MoSSe, where the charge imbalance between sulfur and selenium atoms on each side of the-atomic molybdenum layer creates an asymmetry in the ionic current. Our methodology integrates-molecular dynamics simulations with semiclassical Boltzmann transport formalism to investigate the-dynamics of ions and electrons influenced by electrical and steric interactions in solid-state membranes. These fundamental issues lead us to propose nanometer scale ion channels made of semiconductor-structures to evidence electronic Coulomb drag by flowing ions as a versatile process for blue energy-harvest, for which we predict current amplification as a consequence of interaction between heavy ions and-light electronic particles. Design optimization of the 2D channels for Coulomb drag enhancement are-discussed.

Submission number: 228

HARNESSING NONLINEAR AND OPTOMECHANICAL INTERACTIONS IN SILICON NANOSTRUCTURES

Alonso ramos, Carlos*

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Modeling and Simulation; Nanofabrication

We present our recent progress in the use of periodic nanostructures to harness nonlinear and optomechanical interactions in silicon photonics for applications in sensing, quantum and microwave photonics

Submission number: 229

SPACE-TIME ANALOGY IN NONLINEAR DELAY DYNAMICS AND APPLICATION TO RESERVOIR COMPUTING IN OPTOELECTRONICS

Larger, Laurent*

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Modeling and Simulation; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

Delay dynamical systems are known for an intrinsic complexity related to their infinite dimensional phase space. They also became popular in optoelectronics for their highly robust and relatively simple experimental implementations [1]. In applications-dedicated research, they have first served as high spectral purity microwave source for Radar application [2]. The diversity of their dynamical features also led to the use of chaotic waveforms serving as optical carrier in secure chaos communications for fibre optics links [3]. During the past decade, delay dynamics have been intensively studied for a novel and particularly challenging application targeted toward physical hardware dedicated to artificial intelligence processing, according to recurrent neural network concepts known as Reservoir Computing [4]. In this talk we will present on how physical properties of nonlinear delay dynamics can be used to emulate a virtual neural network, and how signal processing theory applied to delay dynamics can be used in a relatively simple way to the transpose into the time domain the actual spatial arrangement of neural network. A particular experimental realization of optoelectronic delay dynamics, the electro-optic differential phase chaos generator, will illustrate how one can design experimentally processing systems implementing Reservoir Computing concepts that have been tested on ultra-fast speech recognition. Recent results and future challenges will be presented in the framework of photonic integration of Reservoir Computing processors [5].

References

[1] Y.K. Chembo, D. Brunner, M. Jacquot, and L. Larger, Review of Modern Physics 91 (2019) 035006.
[2] S. Yao, L. Maleki, Electronics Letters 30 (1994) 1525.
[3] A. Argyris et al., Nature 437 (2005) 343.
[4] L. Larger et al., Phys. Rev. X 7 (2017) 011015.
[5] I.K. Boikov, D. Brunner, A. De Rossi, New Journal of Physics 25 (2023) 093056.

Submission number: 230

FLEXIBLE TRIBOVOLTAIC DC GENERATOR FOR SELF-POWERED ROBOTICS MANIPULATION

Liu, Jun*

Keywords: Nano-Energy, Environment, and Safety; Nanotechnology in Soft Electronics;

Nanosensors and Nanoactuators

The integration of self-powered mechanisms within robotics holds immense potential for enhancing autonomy and operational efficiency. This presentation introduces a novel approach to address this paradigm through the development of a self-powered tactile sensing system with flexible tribovoltaic DC generator based on dynamic Schottky junctions, which is tailored explicitly for robotic hand manipulation. Such integration represents a pioneering advancement in self-powered multimodal and multidirectional sensing. The new technology incorporates flexible Schottky junctions optimized for dynamic energy conversion, enabling seamless integration into robotic hand systems. Through detailed analyses and experimental validation, we demonstrate the adaptability, efficiency, and reliability of using dynamic DC generator for bio-inspired static and dynamic friction sensing, and the optimization of feedback loop control.

Submission number: 231

SMTJ-BASED DROPOUT MODULE FOR IN-MEMORY COMPUTING BAYESIAN NEURAL NETWORKS

Danouchi, Kamal*; Prenat, Guillaume; Anghel, Lorena

Keywords: Spintronics; Quantum, Neuromorphic, and Unconventional Computing; AI for Nanotechnology

Bayesian Neural Networks (BayNNs) are powerful tools for making predictions while also providing uncertainty estimates, a crucial aspect in safety-critical systems. However, implementing BayNNs in edge applications poses challenges, often necessitating transformations such as quantification or approximation, especially for Gaussian processes, commonly achieved through Dropout methods. This paper explores a new implementation of the Dropout module by using Superparam- agnetic Tunnel Junction (SMTJ). The stochastic circuit enables fine-tuning of the generated stochastic bitstreams used to drop different parameters in the BayNN. The proposed module implementation leads to better power efficiency and robustness against variability. The results demonstrate an improvement in the energy efficiency of up to 34.8× when compared to the related works.

Submission number: 232

INTEGRATING ULTRASOUND-COMPATIBLE SILVER NANOWIRES BASED FLEXIBLE SURFACE ELECTROMYOGRAPHY SENSORS FOR ENHANCED REHABILITATION MONITORING

Moon, Sunho*; Xue, Xiangming; Shukla, Darpan; Ganesh, Vidisha; Zhu, Yong; Sharma, Nitin; Jiang, Xiaoning

Keywords: Nano-Acoustic Devices, Processes, and Materials; Nanosensors and Nanoactuators; Nanoelectronics

Surface electromyography (sEMG) is a non-invasive diagnostic method in rehabilitation used to measure muscle activity by sensing electrical signals at the skin's surface. Despite its widespread use, EMG alone faces challenges such as limited detection depth, crosstalk from adjacent muscles, and interference from electrical stimulation. B-mode Ultrasound (US) imaging offers an alternative non-invasive approach to monitor targeted muscle activity, particularly deep muscles, without interference from adjacent muscle activity. However, using US imaging alone is challenging in interpreting intention or accurately detecting fatigue. Studies have shown that combining US imaging with sEMG enhances motion prediction accuracy compared to using either modality alone. While sEMG provides electrical muscle activity information, US imaging offers insight into muscle elasticity. Integrating these modalities requires an acoustically matched EMG sensor compatible with a US probe, enabling simultaneous assessment of muscle activity. In this abstract, we present the development of US compatible surface EMG (US-EMG) sensors, evaluated against a commercial EMG sensor during wrist contraction, and validate US compatibility by collecting B-mode US imaging with a commercial US probe placed vertically on the US-EMG sensor.

Submission number: 233

QUALITATIVE RAMAN SPECTRAL CHANGES OF MOS2 MODIFIED WITH FUNCTIONALIZED AU-LOCKED NUCLEIC ACID OLIGOS TO DETECT MIRNAS

Zablon, Faith; Khan, Md Arifur Rahman; Ignatova, Tetyana; Dellinger, Kristen; Aravamudhan, Shyam*

Keywords: Nanomaterials; Nanosensors and Nanoactuators; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

2D molybdenum disulfide (MoS2) as a biosensor platform have gained wide attention due to their tunable bandgap, along with controllable optical properties [1]. However, MoS2 alone is limited by low sensitivity and poor Raman signal for practical applications [2]. Also limited studies have exploited the MoS2 as a platform for surface-enhanced Raman (optical) biosensing, especially for disease markers, such as microRNAs (miRNAs). In this study, we investigate the spectral effects of multilayer MoS2 nanosheets when modified with gold nanoparticles (AuNPs) for detecting miRNAs. We design a target nanohybrid structure of AuNPs functionalized with modified locked nucleic acid (LNA) oligos hybridized to extracellular vesicle (EV)-derived miRNA. By integrating AuNPs/ MoS2 as a substrate with the plasmonic resonance effect and the Raman probed determinant LNAs with Cy3, we evaluate the functional Raman spectral changes on the vibration modes of the MoS2 and the changes in the Raman intensity during Au-LNA nanohybrid growth. We observed detectable shifts in the optical properties of MoS2, and corresponding Raman intensities were enhanced upon integration with AuNPs, which are attributed to the aggregation of AuNPs on MoS2 active sites. We calculated the Raman enhancement factors (EF) of the Raman substrate (20 nm AuNPs), compared to that of the Raman reporter, Cy3 without the AuNPs, and matched to the fully functionalized MoS2@Au-nanohybrid structure based on the signal intensities to detect miRNAs. The findings show that magnification in EF contributes to the optimization of MoS2 biosensors for detecting and quantifying diagnostic miRNAs, which are crucial biomarkers in the fight against cancer. Furthermore, SEM images confirm the self-assembly of Au and Au-bioconjugates on the MoS2, creating hot spots and significantly increasing the Raman intensity (1e4 – 1e6 orders of magnitude), compared to MoS2 alone. This work is fundamental for designing a MoS2-based SERS sensing platform with oligonucleotide technology. It also offers qualitative and quantitative insights into the design, characterization, and functionalization of MoS2 nanosheets for biomarker detection for complex diseases like cancer.

Submission number: 234

ENABLING COMPUTER AIDED DESIGN OF ATOMIC SILICON QUANTUM DOT CIRCUITS AND SYSTEMS

Walus, Konrad*

Keywords: Nanoelectronics; Modeling and Simulation; Quantum, Neuromorphic, and Unconventional Computing

Field-coupled nanocomputing (FCN) using silicon dangling bonds (SiDBs) has emerged as a promising avenue, offering unprecedented scalability, energy efficiency, and integration density and the potential for a practical path to computing at the limits of scaling. Experimental efforts have validated an SiDB logic OR gate at the scale of 5×6 nm2, pushing the boundaries of logic miniaturization. To enable research into this emerging platform, we have led the development of SiQAD (Silicon Quantum Atomic Design), a CAD tool suite tailored for SiDB circuits. SiQAD facilitates intricate design explorations by offering multiple calibrated physical models, including a ground state charge configuration model which allows users to simulate logic gate behavior, a dynamic charge hopping model which models the temporal behavior of these charge systems, and an electrostatic landscape solver for the exploration of clocked systems. Using these tools, researchers have been able to design and simulate a wide range of SiDB logic gates and circuits. To scale design efforts beyond hand-designed components, we have also developed an automated design tool employing deep reinforcement learning, which has significantly expedited the design process for SiDB-based logic gates and circuits, as evidenced by the construction of the Bestagon gate library – the first standard tile library available to the SiDB logic design automation community. Our research not only unveils the fundamental principles governing SiDB-based FCN but also charts a path forward for the realization of ultra-compact, energy-efficient computing devices. We have designed architectures for SiDB machine learning accelerators and analog-to-digital converters, in each case finding orders of magnitude improvement in power efficiency compared to CMOS counterparts.

Submission number: 235

CONVERGENCE AND MACHINE LEARNING ACCELERATION OF NANOCARBON ELECTRODE-BASED DNA SEQUENCING SIMULATIONS

Kim, Yong-Hoon*

Keywords: Modeling and Simulation; Nanoelectronics; AI for Nanotechnology

First-principles electronic structure and quantum transport calculations are playing an increasingly important role in modern atomistic device simulations, but there remain many areas where the methods need to be further improved and developed. In this presentation, using the example of electrical and spin current DNA sequencing based on a nanogap formed between nanocarbon electrodes [1], I will discuss several methodological developments recently made in our group. Zigzag graphene edges (ZGEs) can ideally host spin-polarized edge states, providing significant potential for spintronics applications. As the introduction, I will first show that the silicon edge passivation is a reliable method to preserve the spin-polarized ZGE states and also an effective scheme to realize spin sensors with the sensing capacity much improved compared with the hydrogenated ZGE counterparts. The possibility to distinguish 8-oxoGuanine and Guanine based on Si-passivated ZGEs will be discussed [2]. Next, using the graphene-DNA-graphene junction model, I will consider the convergence of quantum transport calculations with respect to localized basis sets. Systematically testing the number and extension of atomic basis sets, it will be shown that unconverged or overcomplete atomic basis sets can produce ghost transmissions and spurious quantum interference patterns. As the practical rules assuring the numerical convergence, we establish that diffuse basis sets should be avoided, and the smallest radii of basis orbitals of the outermost graphene and DNA atoms should be larger than the minimum graphene-DNA distances [3]. Finally, I will present a machine learning strategy DeepSCF in which the map between the self-consistent field (SCF) electron density and the initial guess density using 3D convolutional neural networks. After describing several strategies that ensure the high accuracy and transferability of DeepSCF, the effectiveness of DeepSCF is demonstrated using a large carbon nanotube-based DNA sequencer model [4].

Submission number: 236

NEXT-GENERATION POLYIMIDE-BASED HIGH-TEMPERATURE LASER ULTRASOUND TRANSDUCER DEVELOPMENT

Liu, Sipan*; Wu, Huaiyu; Garcia, Nicholas; Tang, Yuqi; Chen, Mengyue; Pirzada, Tahira; Khan, Saad; Yao, Junjie; Jiang, Xiaoning; ryu, jong eun

Keywords: Nano-Acoustic Devices, Processes, and Materials; Nanofabrication; Nanomaterials

In this study, a high-temperature polyimide-based LUT was developed. The statistical analysis (design of experiment, DoE) was conducted based on the multiphysics LUT FEA model (COMSOL) with high prediction accuracy [5]. The statistical analysis showed that Young's modulus, absorption layer thickness, and absorption coefficient of the laser absorption layer correlated most significantly with the peak negative pressure, center frequency and -6dB bandwidth. Based on these results and the high-temperature demand, a kind of polyimide (Pyromellitic dianhydride and 2,2'-Dimethyl-4,4'-diaminobenzene (PMDA-DMDB)) was chosen to fabricate LUT with high performance and thermal stability (>450 oC). The PMDA-DMDB possesses a relatively high thermal expansion coefficient of 200×10-6 and a Young's Modulus of 3 GPa which is much higher than PDMS's (0.8-10 MPa). The experiments revealed that the polyimide-based LUT on glass substrate could achieve a peak-to-peak pressure of 3.4 MPa, a center frequency of 6.7 MHz and a – 6dB bandwidth of 19.9 MHz excited by 50 ns laser pulse with 5 mJ/cm2, whereas the PDMS-based LUT could achieve a peak-to-peak pressure of 4.7 MPa, a center frequency of 3.4 MHz with a – 6dB bandwidth of 14.2 MHz. Moreover, these LUTs displayed exceptional flexibility and negative pressure performance when transferred on a Kapton tape substrate. When the Kapton tapes substrate thickness were around 50 – 70 µm, the backward acoustic waveform was reflected from the substrate-air interface with a phase change to negative, and integrated with forward waveform to obtained an enhanced peak-to-peak pressure of 3.7 MPa under 50 ns laser pulse with 5 mJ/cm2.

Submission number: 237

SUPERCONDUCTING SPIN QUBITS IN HOLE QUANTUM DOTS

Loss, Daniel*

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Spintronics;

Nanoelectronics

Hybrid systems comprising superconducting and semiconducting materials are promising architectures for quantum computing. Superconductors induce long-range interactions between the spin degrees of freedom of semiconducting quantum dots. These interactions are widely anisotropic when the semiconductor material has strong spin-orbit interactions such as for holes in Ge or Si [1]. We show that this anisotropy is tunable and enables fast and high-fidelity two-qubit gates between singlet-triplet (ST) spin qubits [2]. Our design is immune to leakage of the quantum information into non-computational states and removes always-on interactions between the qubits, thus resolving key open challenges for these architectures. Our spin qubits do not require additional technologically-demanding components nor fine-tuning of parameters. They operate at low magnetic fields of a few milli Tesla and are fully compatible with superconductors. In realistic devices, we estimate infidelities below 10-3.-

References-

[1] The germanium quantum information route. G. Scappucci, C. Kloeffel, F. A. Zwanenburg, D. Loss, M. Myronov, J.-J. Zhang, S. De Franceschi, G. Katsaros, and M. Veldhorst; Nat Rev Mater (2020).
[2] M. Spethmann, S. Bosco, A. Hofmann, J. Klinovaja, and D. Loss, Phys. Rev. B 109, 085303 (2024).

Submission number: 238

FLEXIBLE HIGH-PERFORMANCE TRANSISTORS BASED ON ALIGNED CARBON NANOTUBES

Xia, Fan*; Hu, Youfan

Keywords: Nanotechnology in Soft Electronics; Nanoelectronics; Nanomaterials

High performance flexible transistors have long been desired for real-time data processing and wireless communication in emerging applications of flexible systems. Carbon nanotubes (CNTs) have excellent electrical properties and ultrathin mechanical structures, which are ideal materials for high performance flexible electronics. However, the difficulties of scaling down flexible transistors and the poor heat dissipation efficiency on polymer-based flexible substrates set upper limits for the on-state currents and the power, which greatly hinders the performance improvement and further applications of flexible transistors. Herein, we report the fabrication of high-performance flexible transistors based on aligned single-walled CNTs on ultrathin substrates with a thickness of 2 -956;m. Thermal issues in high-performance flexible CNT-based transistors were observed and modified with heat management technologies. A designed bottom-gated structure is used to obtain good heat dissipation efficiency, by which the thermal issues are alleviated and no longer limit the performance of flexible CNT-based transistors. A record high on-state current of 1.1 mA/-956;m and a transconductance of 0.5 mS/-956;m are achieved with good uniformity.

Submission number: 239

UNDERLYING MIRNA PROFILE OF CARBON DOT LOADED EXOSOME-INDUCED PDT

besbinar, omur*; kirbas cilingir, emel; recep, uyar; Acelya, Yilmazer

Keywords: Nanomaterials; Nanobiomedicine

Chlorophyll-derived carbon dots (CDs) exhibit promising characteristics due to their size (2-3 nm), functional groups, and red emission optical properties, making them ideal candidates for both drug delivery and imaging applications. Furthermore, CDs demonstrate a robust Photodynamic Therapy (PDT) response, highlighting their potential in nanomedicine research [1]. This study demonstrated that CDs can be successfully loaded into MSC-derived exosomes (Figure 1), and CDs preserve their optical and therapeutic properties [2]. In addition, it was observed that when CDs were delivered via exosomes, they exhibited a cytotoxic effect in U87 with markedly reduced doses of CDs compared to their free administration. Finally, the underlying mechanisms of the response of U87 cells to free CDs-mediated and CD-loaded exosome-mediated PDT have been evaluated through miRNA profiling of the cancer cells and the exosomes.

Submission number: 240

ENHANCEMENT OF METAL-ORGANIC FRAMEWORKS FOR CARBON DIOXIDE CAPTURE USING IONIC LIQUIDS

Kim, Duckjong*

Keywords: Nano-Energy, Environment, and Safety; Nanomaterials

The rising global threat posed by CO2 emissions has prompted the creation of innovative materials designed to effectively capture CO2, aiming to reduce its atmospheric levels [1]. This research presents the synthesis and study of ionic liquid (IL)-enhanced Metal-Organic Frameworks (MOFs) for CO2 capture. Usually, most of the literature describes two-step methods for IL functionalization on MOFs, where prepared MOFs are post-processed with IL-containing solvents. We employed a novel one-pot, in-situ microwave-irradiation method for incorporation of ionic liquid [BMIM][BF4] into the MOF UTSA-16 (Co). Our findings reveal that the composite material shows significantly improved CO2 adsorption capacity (5.35 mmol/g), and an enhanced CO2/N2 selectivity (127). The synergy between the high surface area of UTSA-16 (Co) and the CO2 susceptibility of the IL plays a pivotal role in augmenting the overall CO2 capture performance. Notably, the introduced ionic liquid serves as a favorable adsorption site for CO2, thereby contributing to the improved selectivity. While previous reports have explored the incorporation of ILs in MOFs to enhance selectivity, our work distinguishes itself by successfully mitigating the reduction in the adsorption capacity while functionalizing MOF with IL molecules. Further assessments of material stability and recyclability indicated suitability for practical, repetitive use. The findings contribute to the field of CO2 capture by offering insights into the potential of IL-modified MOFs in CCUS applications, presenting a material class that may yield operational and environmental benefits in industrial carbon management strategies.-Acknowledgements This work was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government (MOTIE) (20212050100010, Chemisorption heat pump system using electrochemical compressor).-

References

[1]--J.-R. Li, R.J. Kuppler, H.-C. Zhou, Chemical Society Reviews 38(5) (2009) 1477-1504.

Submission number: 241

FUNCTIONAL NANOSTRUCTURES OF ZINC OXIDE FOR AGROCHEMICAL APPLICATIONS

DENDRINOU-SAMARA, CATHERINE*; Giannousi, Kleoniki; Moustaka, Julietta; Tryfon, Panagiota; Andreadis, Stefanos; Sperdouli, Ilektra; Moustakas, Michael

Keywords: Nanomaterials; Nano-Energy, Environment, and Safety

The use of conventional agrochemical products is a major global issue, as it has consequences for the food security of the population and for the balance and quality of the natural environment. Advances in nanomaterials provide prospects for their development in the agricultural sector in order to overcome the problems. Herein, we have undertaken a study[e.g.1-5] on the synthesis and characterization of coated primary nanoparticles of ZnO nanopartictles and their development into secondary nanostructures, as well as their evaluation as nanoagrochemicals. Specifically, seven primary and differently coated ZnO NPs were prepared and physicochemically characterized in terms of sizes (15 -822; 27 nm), organic coating (oleylamine (OAm), octadecylamine (ODA), polyethylene glycol 8000 (PEG)) and shape (irregular, rods, flowers) as a result of different synthetic approaches and nanoparticle growth mode. The syntheses were carried out by solvothermal and microwave-assisted method. Based on the primary nanoparticles, secondary nanostructures such as nanocapsules of ZnO with geraniol(Ge), a natural active ingredient with fungicidal activity were prepared. The characterization of the primary nanoparticles and nanocapsules in terms of their composition, structure, morphology and surface properties was carried out by X-ray diffraction, TEM and SEM/SEM electron microscopy, FT-IR, UV-Vis spectroscopy, thermogravimetric analysis, and dynamic light scattering. The release study of the geraniol was determined using zero-order, first-order, Higuchi and Korsmeyer-Peppas models. In vitro and in planta bioassays were performed; evaluation in lettuce of primary nanoparticles ZnO NPs to control the growth of the plant pathogenic fungi B. cinerea and S. sclerotiorum and the nematode M. javanica. The nanocapsules of ZnO NPs with geraniol (ZnO@-927;-913;m@Ger NCaps) were evaluated for their antifungal activity against B. cinerea both in vitro and in planta, cucumbers. Moreover, coated ZnO NPs of different shapes (irregular and rod-shaped) and of different percentage of oleylamine coating(ZnO@OAm NPs) were studied for their effect on photosystem II photochemistry of tomatoes. Additionally, the prepared nanosystems ZnO@OAm NPs, ZnO@-927;

Submission number: 242

IMAGE PROCESSING AND PHASE CONTRAST IMAGING WITH NONLOCAL METAOPTICS

Wesemann, Lukas*

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

While optical systems have been utilized for image processing in the Fourier plane since the 1940s, commonly implemented operations such as edge enhancement are now predominantly carried out digitally. This comes at the cost of processing time and energy requirements, particularly when the rapid increase in spatial information being collected is considered. Additionally, capturing phase information in an optical wavefield introduced by phenomena such as propagation through transparent objects or turbulence results in information loss upon acquisition with a camera. Recent research has shown that all-optical image processing using meta-optical devices, including phase visualization, could overcome these challenges. Meta-optical approaches enable ultra-compact, real-time sensing of phase gradients by converting them into easily measurable intensity distributions. Initial experiments have demonstrated the effectiveness of these approaches in phase imaging of human cancer cells and wavefront sensing. Here we will present the concepts behind image processing with metasurfaces with a specific focus on applications in phase contrast imaging. Furthermore, we will present progress in using tuning strategies such as the inclusion of phase change materials, to modify the modality of the obtained image.

Submission number: 243

ACCELERATING BAYESIAN NEURAL NETWORKS ON LOW-POWER EDGE RISC-V PROCESSORS

Perez, Samuel*; Resano, Javier; Suarez Gracia, Dario

Keywords: Quantum, Neuromorphic, and Unconventional Computing

Neural Networks (NNs) are a very popular solution for classification tasks. As the combination of Internet of Things (IoT) with Machine Learning (ML), also known as TinyML, grows in popularity, more NN are being executed on low-end edge systems. The reliability of the predictions is crucial for safety-critical applications. Bayesian Neural Networks (BNNs) address this issue by calculating uncertainty metrics with their predictions at the cost of increasing computing requirements. This work addresses the challenges of executing BNNs inference on low-end systems. BNNs require multiple forward passes in which the weights are sampled from distributions. This sampling process can take up to 85,13% of execution time. This work optimizes the weight sampling and integrates it within a low cost custom extension for a RISC-V CPU, improving speedup up to ×8,10 and similar energy savings.

Submission number: 244

SYSTEMATIC HIGH-FIDELITY OPERATION AND TRANSFER IN SEMICONDUCTOR SPIN-QUBITS

Rimbach-Russ, Maximilian Florian*

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Nanoelectronics;

Modeling and Simulation

Spin-based semiconductor quantum dots qubits are a promising candidate for long-term applications in quantum information processing [1]. Their similarity to classical transistor allows for lithographic fabrication techniques [2], relevant for scaling to fault-tolerant device sizes. Additionally, using silicon electrons or germanium holes as the host material for the QDs allows for significant longer decoherence times due to the low abundance of nuclear spins. One common feature of such spin qubits, however, is the need for electric control on the nanoscale for operation, which also couples the qubits to electrical noise sources.-Recent developments have shown that high-fidelity shuttling, movement of the charge carrier while preserving spin-coherence, can be experimentally realized [3,4]. Such charge carrier shuttling can be used to enable intermediate-distance connections. At the same time, a spin-non-adiabatic implementation can be used to enable power efficient and high-fidelity quantum control [5]. Such spin-non-adiabatic dynamics can be realized through intrinsic and/or artificial spin-orbit interaction.-Systematic high-fidelity operations can be achieved by static protected against decoherence through operating in regimes that provide high protection against noise electric noise sources, so-called sweet spots [6]. Furthermore, optimized pulse control allows for an additional dynamic protection against error sources, e.g. electric noise and non-adiabatic errors [7].- [1] G. Burkard, T.D. Ladd, A. Pan, J.M. Nichol, and J.R. Petta, Rev. Mod. Phys. 95, 025003, 2023 [2] A.M.J. Zwerver et al., Nat Electron 5, 3,. 3, 2022 [3] F. van Riggelen-Doelman et al., arXiv:2308.02406. [4] C.-A. Wang et al., arXiv:2402.18382. [5] Matsumoto, Y., et al. Bucket brigade and conveyor-mode coherent electron spin shuttling in Si/SiGe quantum dots, Bulletin of the American Physical Society 2024. [6] C.-A. Wang, G. Scappucci, M. Veldhorst, and M. Russ, arXiv:2208.04795. [7] M. Rimbach-Russ, S.G.J. Philips, X. Xue, and L.M.K. Vandersypen, Quantum Sci. Technol. 8, 045025, 2023.

Submission number: 245

OPTOELECTRONIC CHARACTERIZATION OF CRYSTALLINE INTERFACES

Paracana, Ana*; AvO, João; Alves, Helena

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanofabrication

Organic semiconductors have unique optical, mechanical, and electronic properties and in the crystalline form they provide an ideal platform for the studies of its intrinsic properties and of the important factors for high performance devices, as they present high periodic order and superior features for optoelectronic devices [1-4]. To understand the operation of the excitonic devices, and to allow an improved control of its intrinsic properties, we conducted a study on the influence of crystalline organic interfaces in such devices. Therefore, we have fabricated rubrene-based crystalline samples and photonic devices composed of single crystals and crystalline interfaces. Different samples were submitted to photoluminescence and ultrafast transient absorp-tion spectroscopy (Figure 1, bottom) and its corresponding devices (Figure 1, top) subjected to optoelectronic characterization. During this study we witnessed an increase of the organic semiconducting single crystal pho-todetector's responsivity (photoresponse) of ~ 103 %, and an increase of 200% in organic field-effect transis-tors (OFETs) mobility when added another semiconducting crystalline layer to the active layer, meaning the use of the appropriate organic interfaces could enhance the photoelectric conversion process efficiency of the excitonic devices.

Submission number: 246

PROGRESS ON MAGNETIC 3D NANOWIRE NETWORKS FOR SPACE TECHNOLOGY

G. Vivas, Laura*; Ruiz-Clavijo, Alejandra; Caballero-Calero, Olga; Navas, David; Sanz, Ruy; Martin-Gonzalez, Marisol

Keywords: Nanostructures for extreme environments; Nanomagnetics; Modeling and Simulation

Space environment is harsh and pushes devices to the limits of radiation tolerance, temperature swiftness and mechanical loads. Moreover, electronic devices in payloads and platforms must be lightweight and low-volume. We investigate the use of three-dimensional magnetic nanowire networks (3DNNs) as a highly efficient, long-lasting, and lightweight solution [1-3]. The magnetic performance of such 3DNNs strongly depends on the potentially novel magnetic states emerging from the interaction between longitudinal and transverse nanowires. However, a precise understanding of the magnetic performance of these 3DNNs [3-4] remains elusive due to the computational difficulty of modeling 3DNNs of several tens of micrometers with tens of transverse nano-networks. In this work, we will present preliminary results on the characterization of 3D-nano-networks of various ferromagnetic materials with a range of transverse number of interconnections. We conducted a systematic computational study using a realistic micromagnetic model. We looked at different structural factors to get the first magnetization curves and hysteresis loops. This helped us figure out the magnetic anisotropies that are at work in these 3DNNs. Further, we have explored the suitability of these 3DNNs for environments with extreme temperatures by investigating their magnetic properties for a range of temperatures, from 5 K to 350 K. Moreover, we have initiated the first tests of radiation effects on these types of nanostructures. To summarize, we are studying the suitability of these 3D magnetic systems for space applications combining experimental research on scalable fabrication methods, magnetic characterization, advanced computational approaches, and temperature resilience. In future studies, we will concentrate on the radiation tolerance of these 3DNNs.-[1]J. Martin et al., Nature Communications 5 (2014) 5130 [2]A. Ruiz-Clavijo, et al., Adv. Elect. Mat. 8 (2022) 2200342 [3]A. Ruiz-Clavijo et al., Phys. Status Solidi RRL 13 (2019) 1900263. [4]A. Ruiz-Clavijo, et al. 2023 IEEE International Magnetic Conference - Short Papers (INTERMAG Short Papers), Sendai, Japan, 2023, pp. 1-2,

Submission number: 247

ULTRASENSITIVE DIRECT DETECTION OF NFL IN CIRCULATORY BODY FLUIDS FOR NEURODEGENERATIVE DISEASE DIAGNOSIS

SONG, Qingting; Li, Hung Wing*

Keywords: Nanosensors and Nanoactuators; Nanomaterials; Nanomagnetics

Neurodegenerative diseases (NDs) are getting more prevalent in most countries because of the increasing life expectancy and are posing considerable burden to the society and economy. The most common form of NDs includes Alzheimer’s disease (AD) and Parkinson’s disease (PD). However, there is still no treatment that can cure most of these diseases. Early diagnosis and intervention are the best approach to alleviate the symptoms and delay the NDs progression. Therefore, we here develop an ultra-sensitive and direct assay to detect one emerging biomarker, neurofilament light chain (NfL) protein, in body fluids for early diagnosis of NDs. We employ capture antibody modified magnetic nanoparticles to specifically capture the target and a tailor-made protein turn-on fluorophore to label the immunocomplex, showing a remarkably concentration-dependent fluorescence enhancement upon binding. The magnetic nanoparticles served as preconcentration and purification platform. Our immunoassay-based method consumes only minute sample and simplifies the detection process by skipping the use of detection antibody as compared to commercial ELISA Kit. The detection limit of our assay can reach fM level. This assay used for real sample analysis and differentiated the AD patients and healthy people by determination of the serum NfL, which shows the potential for NDs screening in clinics.

Submission number: 248

TAU-TARGETING MANGANESE NANOFLOWER WITH ENHANCED MR IMAGING FOR ALZHEIMER'S DISEASE DIAGNOSIS

Chen, Pinyou; Li, Hung Wing*

Keywords: Nanomaterials; Nanosensors and Nanoactuators; Nanobiomedicine

Alzheimer's disease (AD) is the most prevalent neurological disorder among elderly but efficient and accurate diagnosis method for AD have not established yet. Widely used technique magnetic resonance imaging (MRI) only show brain shrinkage of brain regions in later stages of AD [1]. Tau deposition in the brain is one of the hallmarks of AD and thus serves as a crucial biomarker of AD that can be utilized in MRI for prognosis and diagnosis [2]. However, significant challenges including limited blood-brain-barrier penetration (BBB), poor targeting of tau neurofibrillary tangles and unclear MR imaging still remain. Herein, tau-targeting T807-NH2 covalently conjugated on folic acid-fabricated manganese dioxide nanoflower (MnO2-FA) is developed. The results show that NFs-T807 provides high binding affinity and targeting ability to tau, enhanced penetration of BBB and good T1-weighted contrast effect for MRI. This platform is envisioned as a promising strategy for future AD diagnosis.

Submission number: 249

THE SOUND OF MUSIC AT THE NANOSCALE – EXPLORING THE NANOSCALE WORLD WITH NEMS RESONATORS BASED ON LOW DIMENSIONAL NANOMATERIALS

Wang, Max Zenghui*

Keywords: Nano-Acoustic Devices, Processes, and Materials; Nanoelectronics

The advent of low-dimensional nanostructures has enabled a plethora of new devices and systems. Among them, nanoelectromechanical systems (NEMS) offers the unique capability of coupling the exquisite material properties found in these atomically-defined nanostructures with their mechanical degree of freedom, opening new opportunities for exploring exotic phenomena at the nanoscale [1]. In particular, as these devices driven into mechanical vibration—just as musical instruments—they become essentially nanoscale guitars, drums, tuning folks, etc. By studying the infinitesimal mechanical vibrations in these nanoscale “music instruments”, i.e., listening to the “sound of music” at the nanoscale, researchers can study a number of fundamental physical processes such as absorption, phase transition, anisotropy, and nonlinear processes.-

References

[1]--B. Xu et al., ACS Nano 16 (2022) 15545.

Submission number: 250

METAL/POLYMER NANOCOMPOSITE COATINGS DEPOSITION BY USING AN ATMOSPHERIC PRESSURE PLASMA COMBINED WITH AN AEROSOLIZED PRECURSOR

Bizeray, Elene*; Berard, Remi; Belinger, Antoine; DAP, Simon; Fanelli, Fiorenza; Naude, Nicolas

Keywords: Emerging Plasma Nanotechnologies; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

Plasma technologies at atmospheric pressure offer interesting opportunities for the synthesis of nanocomposite coatings [1]. Atmospheric pressure processes present lots of advantages, such as cost reduction. However, they can lead to gas thermalization if they are not well controlled. A solution to avoid the transition to the arc regime is to use a dielectric barrier discharge (DBD) system, which is a robust and well-known solution to obtain a cold plasma at atmospheric pressure. As suggested in a previous work [2], a DBD can be combined with an aerosol of the solution of gold salt (tetrachloroauric(III) acid trihydrate, HAuCl4·3H2O) in a polymerizable solvent (isopropyl alcohol) to obtain a nanocomposite of gold nanoparticles embedded in an organic matrix. This avoids the need for handling nanoparticles since the gold salt reduction occurs in the plasma as the organic matrix grows [2]. Synthesis can thus be carried out in a single step, and this is what makes the process innovative. To deposit nanocomposite layers with a DBD at atmospheric pressure, it is common to use a dual-frequency excitation to control independently the growth of the matrix and the transport of the nanoparticles [3]. Indeed, the nanoparticles transport to the surface is mainly due to electrostatic forces. It is, therefore, necessary to have a low_x0002_frequency period (below 1 kHz) to avoid particles being trapped in the gas gap. The high-frequency period is used for matrix polymerization but also, in our study, for gold salt reduction. For this study, we combined a parallel-plate dielectric barrier discharge in nitrogen with an aerosol of gold salt dissolved in isopropyl alcohol. This aerosol is produced by pneumatic nebulization using a TSI® constant output liquid atomizer. The variation of the process parameters gives us the opportunity to modulate the properties of the resulting layers. For example, a modification of the duty cycle (DC), which can be defined as the duration of the low-frequency excitation over the duration of the complete cycle, changes the distribution of particles in the coatings. Morphology, optical properties, and chemical composition of the resulting coatings have been investigated using various techniques, such as UV-visible absorption spectroscopy, scanning electron microscopy, Fourier_x0002_transform infrared spectroscopy and X-ray photoelectron spectroscopy. Preliminary results have shown that we are able to synthesize nanocomposite coatings with the inclusion of gold nanoparticles in the matrix. Indeed, UV-Visible spectroscopy analysis shows a plasmonic peak at 540 nm in the thin films deposited, at the entrance of the discharge region. They provide new insights into the possibility of using a single-step plasma process assisted by aerosol to deposit nanocomposite thin film containing gold nanoparticles at atmospheric pressure. Acknowledgements The financial support from the Agence Nationale de la Recherche (PLASSEL Project, ANR-21-CE08-0038, France) is gratefully acknowledged.

References

[1] A. Uricchio, F. Fanelli, Processes 9 (2021) 2069.
[2] E. Nadal, N. Milaniak, H. Glenat, G. Laroche, F. Massines, Nanotechnology 32 (2021) 175601.
[3] P. Brunet, R. RincOn, Z. Matouk, M. Chaker, F. Massines, Langmuir 34 (2018) 1865.

Submission number: 251

PLASMONIC VIRUS-BASED NANOMATERIALS AS IN-SOLUTION SERS SENSORS

Ha Duong, Nguyet Thanh*; Khan, Haziq Naseer; Moreira de silva, Cora; Nguyen, Ha Anh; Boubekeur-Lecaque, Leila; Alloyeau, Damien

Keywords: Nanomaterials; Nanosensors and Nanoactuators; Nanobiomedicine

The ability to construct three dimensional architectures via nanoscale engineering is important for emerging applications of nanotechnology in sensors, catalysis, controlled drug delivery, microelectronics, and medical diagnostics. Because of their well-defined and highly organized symmetric structures, high robustness over wide ranges of temperature, pH, buffer, and in the presence of organic solvents, viral capsid proteins then provide a 3D scaffold for the precise placement of plasmon materials yielding hierarchical hybrid materials. In this study, we use two plant viruses with different shapes and morphologies: Turnip yellow mosaic virus (TYMV), and Tobacco mosaic virus (TMV). To obtain assemblies of nanoparticles onto capsids at room temperature, we used two different syntheses: grafting pre-formed nanoparticles or biomineralization. In the first part of this work, I will present the synthesis and characterization of new nano-bio-hybrid materials, which are soluble and stable in solution. Gold nanoparticles (AuNP) of different sizes (5, 10 and 20 nm) were grafted on icosahedral capsid (TYMV) according to two strategies or directly on rod-shaped capsid (TMV-C) presenting cysteine at its surface. After purification, the resulting nano-biohybrids were characterized by different technics (DLS, TEM, XPS...). In the second part, gold biomineralization experiments on TMV-wt and TMV-C will be described and compared. The size, morphology, monodispersity of AuNP and gold assembly on virus were studied according to the experimental conditions (concentrations of reactant, number of cycle, nature of reductant…) and in situ TEM observations directly in liquid media were also performed to unravel the nucleation and growth mechanisms. Finally, I will show some in-solution SERS experiments with these new nano-biohybrid materials as sensors.

Submission number: 252

3D INTERCONNECTED MAGNETIC NANOWIRE NETWORKS

Liu, Kai*

Keywords: Spintronics; Nanomagnetics; Quantum, Neuromorphic, and Unconventional Computing

Interconnected magnetic nanowire networks offer a promising platform for 3-dimensional (3D) information storage and integrated neuromorphic computing. Previously, in interconnected quasi-ordered Co nanowire networks, we have demonstrated interesting magnetization reversal mechanisms as well as discrete propagation of magnetic states driven by magnetic field and current, manifested in distinct magnetoresistance (MR) features [1,2]. In a complex network with many intersections, sequential switching of nanowire sections separated by interconnects was observed, along with stochastic characteristics. The pinning/depinning of the domain walls can be further controlled by the driving current density. More recently, we have also investigated the feasibility of utilizing random magnetic nanowire networks connected by multiple electrodes as neuromorphic computing elements [3]. Multiple discrete jumps (i.e. step-by-step switching) with each electrode pair showing unique MR feature are found. Utilizing this design, diverse programming of synaptic weights may be achieved by assigning different electrode pairs as inputs/outputs and controllably switching a certain subsection of the networks by applying current pulses of varying magnitudes, pulse-widths, or repetitions. Hence, these results illustrate the promise of such interconnected networks for non-Boolean computing devices such as spintronic memristors and synaptic devices.-This work has been supported in part by the NSF (DMR-2005108 and ECCS- 2151809).-[1] E. Burks et al, Nano Lett. 21, 716 (2021). [2] D. Bhattacharya et al, Nano. Lett. 22, 10010 (2022). [3] D. Bhattacharya et al, submitted.

Submission number: 253

TUNING THE PLASMONIC RESPONSE OF GOLD NANOSTARS THROUGH MORPHOLOGY MODULATION AND INTERFACE ENGINEERING

Fabris, Laura*

Keywords: Nanomaterials; Nanosensors and Nanoactuators; Nano-Energy, Environment, and Safety

Plasmonic nanomaterials can be employed in a wide range of applications, including, among others, sensors, diagnostic platforms, and optical devices. One of the most important properties of these nanomaterials is their ability to generate hot spots upon interaction with impinging radiation. At these locations the scattered electric field reaches its highest levels and energetic hot electrons can be generated and extracted. The enhancement of the scattered electric field is a fundamental process at the basis, for instance, of surface enhanced Raman scattering and surface enhanced fluorescence effects, while the generated hot electrons are implied in several technologies, among which photocatalysis. To fully benefit from these phenomena, however, it is fundamental to establish and realize very specific materials design rules, which hinge, in particular, on morphology modulation and interface engineering. In my talk I will discuss how we have approached hot spot optimization by devising novel colloidal methods for the synthesis of plasmonic nanostructures and by studying in detail the interfacial properties of these nanostructures in various environments, focusing especially on metal-molecule interactions. I will report on how we have holistically integrated computational and experimental approaches to understand the properties of the systems under exam and will present a few case studies in which fundamental discoveries have led to real applicability.

Submission number: 254

THE IMPACT OF DEVICE TECHNOLOGIES ON THE DESIGN OF NON-VOLATILE CONTENT ADDRESSABLE MEMORIES

Moon, Sabrina Hassan; Dutta, Prayash; Khorrami, Parsa; Bhanja, Sanjukta; Reis, Dayane*

Keywords: Nanoelectronics; Quantum, Neuromorphic, and Unconventional Computing; Spintronics

Content Addressable Memories (CAMs) are employed in the design of computing-in-memory (CiM) accelerators for data-intensive applications due to their ability to perform massively parallel searches. This paper presents a study of different device technologies, i.e., resistive RAMs (ReRAMs), ferroelectric field-effect transistors (FeFETs), and magnetoresistive random access memory (MRAMs) that are leveraged in the development of dense and energy-efficient non-volatile content addressable memories (NVCAMs). Through experiments done in existing work, as well as SPICE simulations, we present a comprehensive evaluation of different NVCAMs and compare their power consumption, area efficiency, speed, and reliability with respect to CMOS-based CAM counterparts. Additionally, we explore potential application scenarios that correspond to the unique strengths of the various NVCAMs. Our discussion highlights pathways for future research on the application mapping of NVCAM designs for CiM architectures.

Submission number: 255

EFFECT OF MXENE NANOSHEETS ON THE DIFFERENTIATION OF SH-SY5Y CELLS INTO MATURE NEURONS

celik, Dogantan*; sanjiv, dhingra; Acelya, Yilmazer

Keywords: Nanobiomedicine; Nanomaterials

The effect of conductive surfaces on cell differentiation of neuronal origin is well described in literature[1]. Electrical conductance is related to ion channels in the plasma membrane, which are responsible for triggering signaling pathways between neurons and neural development[2]. Based on this information, it is hypothesized that MXene nanosheets, which are known to be biocompatible and conductive, could be used in surface coating during a neural differentiation protocol. In order to coat the surface, MXenes were mixed with matrigel. The cell line for the differentiation study was selected as SH-SY5Y, which is generally used in disease modeling and drug studies [3]. SH-SY5Y cells have a stable karyotype and can be differentiated from a neuroblast-like state to mature human neurons[4]. Brain-derived neurotrophic factor (BDNF) and retinoic acid were used to differentiate SH-SY5Y cells into mature neuron cells in addition to the gradual reduction of serum from the media. At the end of 12 days, the cells were differentiated into mature neurons, the differentiation of cells confirmed by immunofluorescent staining. Following the process of differentiation, the seahorse xf device was used to measure mitochondrial respiration. According to the results, cells differentiated in the presence of MXene nanosheets showed higher metabolic activity. Although the study provides preliminary data on the effect of MXenes on cell differentiation, results suggested the importance of oxygen consumption during MXene dependent neuronal differentiation. This provides new perspectives for neuronal differentiation protocols.

Submission number: 256

ENERGY-EFFICIENT ADIABATIC MTJ/CMOS-BASED CLB FOR NON-VOLATILE FPGA

Tanavardi Nasab, Milad; Yang, Wu; Thapliyal, Himanshu*

Keywords: Spintronics

High flexibility, infinite reconfigurability, and fast design-to-market of FPGAs make them a promising platform for modern applications, such as IoT, medical, and automotive applications. Energy and area limitations are challenging in these applications since many of these applications have limited power and hardware resources. Accordingly, the energy- and area-efficient design of FPGAs is of great importance. In this paper, an adiabatic non-volatile hybrid CMOS/MTJ logic-in-memory-based configurable logic block (CLB) has been proposed and compared to its state-of-the-art counterparts. The simulation results show that the proposed design has 98%, 98%, 97%, 97%, 96%, and 92% lower energy consumption compared to CMOS counterparts for frequencies of 1, 2.5, 5, 10, 20, and 40 MHz. Also, compared to its adiabatic counterparts, the proposed design has at least 74%, 70%, 69%, 69%, and 46% lower energy consumption for frequencies of 1, 2.5, 5, 10, and 20 MHz, respectively. Also, the proposed design has at least 74% fewer transistors compared to its counterparts. Furthermore, the energy saving of the proposed design for different tunnel magnetoresistance (TMR) is almost consistent. In addition, the proposed design keeps its superiority in energy saving over its counterparts for different power supply voltages.

Submission number: 260

DEPTH PROFILING OF DEFECT REGIONS WITH NANOMETER DEPTH RESOLUTION AT SEMICONDUCTOR INTERFACES USING LOW-ENERGY MUON SPIN SPECTROSCOPY

Prokscha, Thomas*

Keywords: Nanomaterials; Nanoelectronics

Defects and structural changes at semiconductor interfaces are of fundamental importance for the performance of semiconductor devices. The control and characterization of these defects is the key to optimizing device efficiency. While a variety of characterization methods exist for the investigation of process-induced defects (DLTS, C-V, I-V), most of these techniques cannot resolve the depth distribution of defects close to the device interfaces with nanometer resolution, an information which is important to better understand the relation between these defects and the observed limitations in device performance. Transmission electron microscopy and electron energy loss spectroscopy can provide information about non-stoichiometric regions at semiconductor interfaces. However, there is a large spread of experimental data in the range of tens of nanometer, and an unambiguous interpretation of the structural information is not always possible. Muon spin spectroscopy (muSR) is a sensitive local probe technique to study structural, magnetic, and electronic phenomena in magnetic systems, superconductors, semiconductors, and insulators. The availability of low-energy positive muons at PSI with tunable energies between 1 and 30 keV enabled the extension of the muSR technique to low-energy muSR (LE-muSR), with which investigations of thin films and heterostructures at tunable mean depths of a few nanometers up to about 200 nm became possible. Here we show how LE-muSR can be used as a powerful tool to study the distribution of defects created during the manufacturing process with unprecedented nanometer-scale depth resolution in technologically relevant semiconductor heterostructures. The technique is based on the measurement of the influence of defects and free charge carriers on the formation probability of hydrogen-like muonium (Mu) states. We used proton irradiated Si and 4H-SiC to measure the effect of well-defined defect concentration profiles on the formation probability of Mu states, and we demonstrate the power of LE-uSR for the identification and characterization of defect regions in technologically relevant SiO_2/Si and SiO_2/4H-SiC device structures

Submission number: 261

IMPROVING RELIABILITY OF STT-MRAM-BASED SMART MATERIAL IMPLICATION

Lanuzza, Marco*; Moposita, Tatiana

Keywords: Nanoelectronics; Spintronics

Logic-in-Memory (LIM) architectures, particularly those based on Spin-Transfer Torque Magnetic Random-Access Memory (STT-MRAM), offer a promising solution to overcome the von-Neumann bottleneck of traditional computing platforms. The smart material implication (SIMPLY) LIM scheme has been proposed to execute computations efficiently within memory units. This paper presents reliability enhanced STT-MRAMbased SIMPLY and sFALSE operations, assessing improvements in read margin (RM) and bit error rate (BER). Furthermore, the energy efficiency of the SIMPLY scheme is evaluated for the implementation of some logic operators such as NAND, XOR, and XNOR. Simulation results show that SIMPLY+ scheme results to be energy efficient, while assuring a 3.7× larger RM as compared to the conventional SIMPLY.

Submission number: 263

ANALYSIS OF SPACE CHARGE ACCUMULATION AT METAL/DIELECTRIC INTERFACE BY KELVIN PROBE FORCE MICROSCOPY

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Keywords: Nano-Metrology and Characterization

The phenomena occurring at metal/dielectric interfaces, like charge injection and trapping, are crucial for devices performance and reliability, though it remain only partially understood, due to the lack of characterization tools with spatial resolution compatible with the scale at which the mechanisms occur. A direct probing of space charge accumulation and induced electric field distortion at nanoscale is then necessary to improve our understanding. In this study, surface potential measurements performed by Kelvin Probe Force Microscopy (KPFM) and data processing using Finite Element Method are used to quantify densities of space charge accumulated at metal/dielectric interfaces.

Submission number: 264

TAILORING OPTICAL PROPERTIES IN CORE-SHELL SILVER NANOWIRES

Lech, Agnieszka*; Psarski, Maciej; Celichowski, Grzegorz

Keywords: Nanomaterials; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

The phenomenon of plasmon resonance is one of the most interesting properties of silver nanowires. The resonance of silver nanowires strongly depends on the structure's geometry (including diameter, length, etc.) and the dielectric constant of the chemical environment [1]. Covering AgNWs with a tin oxide coating allows to achieve multiple effects - increasing colloid stability, increasing environmental resistance, and optimizing maximum absorption [2,3]. The presented work describes a method for producing silver nanowires coated with tin (IV) oxide using chemical reduction in polyol solutions and an optimized method for coating with tin oxide in an aqueous medium. This synthesis procedure allows for precise control of the thickness of the resulting tin oxide layer. This, in turn, allows the creation of an AgNWs@SnO2 system with different absorption maxima in the range of (376 – 411 nm) presented in Fig1. [4]. The created system made it possible to align the maximum absorption with the length of light emitted by a standard blue laser. This system allows for photothermal energy delivery using a semiconductor laser (405nm). The system allows for remote energy supply and local temperature increase. One possible application is remote surface de-icing [4].-The research was financially supported by a grant from the National Science Centre, Poland (Opus 15 no. 2018/29/B/ST8/02016)-

References

[1] NiedziO-322;ka-Jönsson J., Mackowski S., Materials 12 (2019), 1418
[2] A. Baranowska-Korczyc, G. Celichowski, RSC Advances, 11, (2021), 4174-4185;
[3] A. Baranowska-Korczyc, G. Celichowski, RSC Advances, 10, (2020), 38424–38436
[4] M. Psarski, A. Lech, G. Celichowski, Nanotechnology, 33, (2022), 465205

Submission number: 265

TANNIC ACID MODIFIED METALLIC NANOPARTICLES FOR ANTIVIRAL APPLICATIONS

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Keywords: Nanobiomedicine; Nanomaterials

Silver nanoparticles (AgNPs) exhibit broad-spectrum of unique properties, including: virucidal, antibacterial and antifungal activity [1]. The wide application spectrum of AgNPs results from its size, shape, and the type of ligands present on the surface of the nanoparticle surface, because they are responsible for the direct interactions of nanoparticles with the biological environment [2]. The literature reports that the use of compounds of natural origin in the synthesis and functionalization of metallic nanoparticles increases their biological activity, especially towards Herpes Simplex Viruses (HSV) type 1 and 2 [3-4]. One of the interesting compounds of natural origin is tannic acid, which exhibit anti-inflammatory properties and supports the wound healing process [4-5]. However, due to its chemical structure and the presence of hydroxyl groups in the molecule structure, this compound is susceptible to the oxidation processes. Therefore, a very important aspect is the study of the characterisation of colloidal systems containing compounds of natural origin and the monitoring of changes occurring during their storage conditioning. In this work, the characterization results of tannic acid-modified silver nanoparticles will be presented: i) the nanomaterial characterisation (based on the UV-vis, DLS, STEM and Zeta potential techniques) and the chemical structure of compounds present on the surface of nanoparticles as well as in the colloid (based on the following techniques (Folin-Ciocalteu method, FT-IR and TLC). The precise characterisation of AgNPs functionalized with natural origin compound allow the deeper understanding of nanoparticles interactions with the biological environment. Acknowledgements This work was supported by the National Science Center, Poland (UMO 2018/31/B/NZ6/02606).

References

[1]Krzy-380;owska M., et al., Microorganisms 2022, 10(1), 110
[2]Tomaszewska E., et al. Int. J. Mol. Sci. 2022, 23(21)
[3]Or-322;owski P., et al., Viruses 2018, 10(10), 524
[4]Ranoszek-Soliwoda K., et al., J. Nanopart. Res., 19: 273, 2017
[5]Ranoszek-Soliwoda K., et al., Colloids Surf. B 177 (2019) 19–2420

Submission number: 266

SURFACE POTENTIAL BASED DEFECT QUANTIFICATION TECHNIQUE OF MONOLAYER MOS2 USING KELVIN PROBE FORCE MICROSCOPY

Hossen, Moha Feroz; Aravamudhan, Shyam*

Keywords: Nano-Metrology and Characterization; Nanomaterials; Nanoelectronics

Two-dimensional transition metal dichalcogenides (2D TMDCs) are the promising materials for next generation electronics and optoelectronics applications [1]. Among various the TMDC materials, molybdenum disulphide (MoS2) has attracted the most interest due to the availability of both transition metal and chalcogen precursors. Also, the layer dependent band gap falls within visible to near infrared region. For practical applications, MoS2 must be single crystalline and defect free. There are several synthesis techniques for MoS2 including chemical vapor deposition (CVD) [2], physical vapor deposition (PVD) [2], and metal organic chemical vapor deposition (MOCVD) [3]. The film quality and scalability of MoS2 in MOCVD is comparatively better than other techniques. Nevertheless, point defects emerge on the film surface during growth due to the lack of chalcogen atoms or desorption of chalcogen atoms at high temperature on the surface. Therefore, it is necessary to measure the film defect density to optimize growth parameters to reduce defects. Kelvin Probe Force Microscopy (KPFM) is a non-destructive defect quantification technique for 2D materials. This technique measures surface potential of monolayer MoS2. Surface potential is varied due to the change of carrier concentrations in the film. The change of carrier concentration of atomically thin film occurs due to the absence of chalcogen atoms [4]. Variation of carrier concentration shifts the fermi level towards either valence band or conduction band. Absence of chalcogen atoms increases the electron concentration in the film, shifting the fermi level to the conduction band and hence changing the work function of the material. In KPFM technique, the carrier concentration is calculated by measuring the work function of the film. The half of the carrier concentration indicates the total number of defect present in the film [5]. In this work, we have quantified point defects in MOCVD grown monolayer MoS2 films using kelvin probe force microscopy by measuring the position of the fermi level that is shifted in the presence of defects in MoS2.

Submission number: 267

ORGANOMETALLIC SYNTHESIS OF COLLOÏDALLY STABLE MOS2 SMALL NANOPARTICLES.

Aussonne, Alexis; Jakoobi, Martin; Krystianiak, Anna; Heintz, Olivier; Hierso, Jean-Cyril; Cavarroc, Marjorie; Clergereaux, Richard; L. Kahn, Myrtil*

Keywords: Nanofabrication; Nano-Metrology and Characterization

Molybdenum disulfide (MoS2) is an inexpensive transition metal dichalcogenides (TMDs) due to its natural abundance. Advantageously, this TMD exhibits properties of interest for electronics and chemical reactivity thanks to its layered structure [1]. Indeed, MoS2 usually forms sheets of Molybdenum atoms enclosed between two layers of Sulfur atoms. This material is a very promising catalyst for the production of hydrogen (Hydrogen Evolution Reaction) [2]. It is also investigated as catalyst for various organic reactions such as carbon bond formation [3] or transamidation [4]. In these examples, MoS2 is used as bulk material for heterogeneous catalysis. Bulk MoS2 can be obtained from vapor phase reactions at high temperature (800 to 900°C) [6] or from natural ore Molybdenite. It is also possible to prepare nano-MoS2 by exfoliation of bulk MoS2 in the presence of stabilizing agent [5] or from direct solvothermal synthesis [6] that allows crystallization of nano-objects such as nano-rods, nano-sheets or nano-dots. However, these syntheses require high temperatures (around 200°C) and days-long reactions. Moving from bulk material to nanoparticles, if possible stable in a colloidal form, would help improving the promising catalytic properties of this material. Colloidal stabilization of nanoparticles (NPs) can be achieved by introducing of stabilizing agent(s) in the reaction solution. Carboxylic acids, amines or other long alkyl chain molecules with one or multiple functional groups that can coordinate to the surface of the NPs have been already reported as good stabilizing agents [7]. Here we report a new synthetic procedure allowing obtaining colloidally stable nanoparticles of MoS2 in a one-step process at room temperature. The molybdenum bis toluene organometallic precursor [8] is mixed with a solution of metallic sulfur and stabilizing agents. Multiple combinations of solvents and stabilizing agents were tested to increase the stability of the colloid. MoS2 was characterized by various methods such as Raman and Infrared spectrometry, X-ray photoelectron spectroscopy (XPS), Energy Dispersive X-ray (EDX) and Wide-Angle X-ray Scattering (WAXS). Moreover, electron microscopy, atomic force microscopy and DOSY NMR measurements evidenced small nanoparticles from 2 to 8 nm. These colloids of small MoS2 nanoparticles, stable for months, appear to be very promising regarding organic reaction catalysis. Acknowledgements This work is supported by the French Ministere des Armees - Agence de l'innovation de defense and Safran.

References

[1] W. Choi, N. Choudhary, G.H. Han, J. Park, D. Akinwande, & Y.H. Lee, Mater. Today,

20 (2017) 116.
[2] H.G. Shiraz, X. Crispin, & M. Berggren, Intern. J. Hydrogen Energy, 46 (2021) 24060.
[3] X. Du, C. Zhang, & S. Liu, Dalton Trans., 51 (2022) 15322.
[4] F. Zhang, KL. Li, J. Ma, & H. Gong, Scientific Reports, 9 (2019) 2536.
[5] D. Sahoo, B. Kumar, J. Sinha, S. Ghosh, S.S. Roy, & B. Kaviraj, Scientific Reports, 10 (2020) 10759.
[6] S.V.P. Vattikuti, C. Byon, & C. Venkata, J. Mater. Sc., 50 (2015) 5024.
[7] Y. Coppel, G. Spataro, C. Pages, B. Chaudret, A. Maisonnat, & M.L. Kahn, Chem. Eur. J., 18 (2012) 5384.
[8] M.L.H Green, W. E. Silverthorn, Dalton Trans., 3 (1973) 301.

Submission number: 268

SYNTHESIS OF GOLD/POLYMER THIN FILMS IN AR AND AR/NH3 ATMOSPHERIC-PRESSURE DIELECTRIC BARRIER DISCHARGES

Perdrau, Alexandre*; Barros, Noemi; RincOn, Rocio; GLENAT, Herve; Fanelli, Fiorenza;

PLUJAT, Beatrice; Massines, Francoise

Keywords: Emerging Plasma Nanotechnologies; Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nano-Energy, Environment, and Safety

This study focuses on gold/polymer nanocomposite thin films made by Atmospheric-Pressure Plasma-Enhanced Chemical Vapor Deposition (AP-PECVD). An aerosol of tetrachloroauric acid (HAuCl4:3H2O) dissolved in isopropanol (C3H8O) is injected in a dual-frequency dielectric barrier discharge to synthesize nanocomposite thin films. Two carrier gases are used in this study: pure argon and a mixture of argon and ammonia (NH3) known as a Penning mixture. Two plasma frequencies are applied : a high one at 60 kHz which is used to polymerize the matrix and reduce the gold salt and a low one at 800 Hz which controls the transport of the nanoparticles onto the surface of the substrate. The size of the droplets produced is analyzed prior to the plasma entry. The optical properties of the thin films, such as plasmonic resonance, are characterized by UV–visible absorption spectroscopy. Its chemical composition is analyzed using X-ray Photoelectron Spectroscopy and Energy-Dispersive Spectroscopy. The morphology of the deposits is investigated by Atomic Force Microscopy and Scanning Electron Microscopy. Results show that the salt crystals are reduced in the plasma phase leading to gold nanoparticles embedded in a carbon-based matrix formed by isopropanol polymerization in pure argon. On the other hand, the addition of NH3 in the plasma hinders the formation of gold nanoparticles. The presence of chlorine and the absence of plasmonic response point to an incomplete reduction of the gold salt. Similar results are obtained with ammonium tetrachloroaurate (NH4AuCl4) confirming a possible reaction between NH3 and HAuCl4.

Submission number: 269

A NOVEL PECVD APPROACH FOR ACHIEVING HIGH DENSITY, LOW STRESS AMORPHOUS CARBON HARDMASK FILMS

Zhao, Jianping*; Carroll, John; Blankenmeyer, Gabriel; Ventzek, Peter

Keywords: Emerging Plasma Nanotechnologies; Nanomaterials

High aspect ratio etching such as in 3D NAND architectures requires deposition of a highly etch resistant hardmask that can withstand the longer etch time needed to achieve deep, uniform features. Advanced amorphous carbon hardmasks are being developed as a solution to achieve the higher etch resistance, but typically come at the cost of added wafer stress when increasing film density.- To meet the future sub-nano device nodes process request, one must find a novel solution to overturn the typical high density with high stress trend and achieve high density, low stress advanced hardmask films. With this goal in mind, a novel layered deposition method was developed that showed promising results for achieving high density and low stress films. While typical PECVD control knobs such as chamber pressure, gas chemistry, plasma power show the typical trend of increased stress along with increased density, carbon hardmask film properties using this new approach showed a break from the trend. The method employs a layered amorphous carbon deposition where a high-density, sp3 bond-rich film is deposited in one layer, and a lower density stress-relaxation film is deposited in the other. In theory, by sandwiching lower density layers in between higher density layers, the wafer stress induced by the high-density film is alleviated. The layered deposition was achieved by modulating a pulsed DC bias applied to the wafer. During the on-period where the pulsed DC bias is applied, a high-density film is deposited, and a lower density film is deposited during the off-period where the DC bias is removed. This novel PECVD approach opened a new way for generating advanced carbon hardmask films that are superior to its current form. A physical model is also proposed to elucidate the stress release mechanisms provided by the novel PECVD technology.

Submission number: 270

ENHANCED INFLUENZA DETECTION THROUGH SERS IMMUNODIAGNOSTIC BREAKTHROUGH WITH DIGITAL COUNTING ANALYSIS

Kang, Aeyeon; Lee, Hyun Kyung; Yoo, Euisang*

Keywords: Nanosensors and Nanoactuators; Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanomaterials

We present a pioneering surface-enhanced Raman scattering (SERS) immunosensor tailored for the precise detection of nucleoproteins (NP) associated with the Influenza A virus. A sandwich immunoassay was employed through immobilized anti-NP (AA5H, Abcam) on a gold substrate (Au-anti NP), while a gold nanoparticle (AuNP) probe was functionalized with anti-NP (C43, Abcam) and rhodamine B isothiocyanate (RITC). In this study, we meticulously prepared 490 samples, comprising 49 samples for each of the 10 distinct concentrations, utilizing a liquid handling robot (Notable, ABLE Labs). Subsequently, 10×10 SERS mapping was conducted to acquire 100 Raman spectra for each sample. For quantification, we used digital counting, a technique reported by the Brolo research group for quantifying single molecules [1]. This involved tallying the number of Raman spectra exhibiting a peak with higher intensity than a preset threshold, determined based on the intensity of samples devoid of the target molecule. Through this analysis of the correlation between NP concentrations and the counts acquired through digital counting using the median value, we reveal the capability of detecting NP within a low concentration range spanning from 100 pg/mL to 100 µg/mL. Our innovative SERS immunosensor can contribute a significant advancement, offering unparalleled sensitivity and specificity for diverse biomedical and clinical applications.-Acknowledgements This work is supported by EO-24-0004 (“Development of fiber-based technology for reduction of hazardous substances in the air”).

References

[1]--Albuquerque, C. D. L., Sobral-Filho, R. G., Poppi, R. J., Brolo, A. G., Anal. Chem. 90, 1248-1254 (2018).

Submission number: 271

FABRICATION AND CHARACTERIZATION OF COMPOSITE MATERIALS USING CNT SHEETS

Lee, Hyun Kyung; Yoo, Euisang*

Keywords: Nanomaterials; Nanofabrication

In recent times, there has been a growing demand for the development of lightweight composite materials with superior protective performance and wearability, achieved through the utilization of high-performance advanced materials. Lightweight protective materials need to be structured with appropriate layered arrangements of high-strength fabrics and cushioning materials to reduce weight and thickness while enhancing wearability. Although emerging high-performance materials exhibit excellent individual functionalities, they often face limitations in process ability and applicability, with varying deformation characteristics under impact for each material. Research on composite materials incorporating CNT sheets is actively pursued across various fields, aiming at exploring diverse applications and improving material properties. CNT materials offer superior strength-to-weight ratios, chemical stability, and unique morphological characteristics, enabling enhancements in the mechanical strength properties of polymer nanocomposite [1, 2, 3]. In this study, lightweight materials were developed by utilizing CNT sheets with various binder treatments, and these materials were further compounded with UHMWPE (Ultra high molecular weight polyethylene) to create lightweight and high-strength composite materials. The composite materials underwent investigations on weight, thickness, and tensile strength variations concerning changes in the concentration of five types of binders in the CNT sheets. Additionally, ballistic evaluations were conducted on these materials compounded with UHMWPE (Ultra high molecular weight polyethylene), confirming their potential as ballistic materials. The research findings demonstrate that composite materials utilizing CNT sheets offer a feasible approach for manufacturing lightweight, high-strength composite materials. These materials hold promise for diverse applications as impact-absorbing materials.-Acknowledgements This study has been conducted with the support of Institute of civil military technology cooperation as "Practical Use Technology Development of Hybrid-type Ultralight Soft Armor using CNT Sheet (21-PD-CO-02)".

References

[1] N. Hiremath, J. Mays and G. Bhat, Polymer Reviews, 5

Submission number: 272

ELECTRONIC CORRELATIONS IN MULTIELECTRON SILICON QUANTUM DOTS

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Keywords: Modeling and Simulation; Quantum, Neuromorphic, and Unconventional Computing; Nanoelectronics

Silicon quantum computing has the potential to revolutionize technology with capabilities to solve real life problems that are computationally complex or even intractable for modern computers by offering sufficient high-quality qubits to perform complex error-corrected calculations. Silicon metal oxide-semiconductor based quantum dots present a promising pathway for realizing practical quantum computers. To improve certain qubit properties, it is a common strategy to incorporate multiple electrons in the same dot in order to form qubits in higher confined orbital states. Theoretical modelling is an essential part of understanding the quantum behaviour of these electrons, providing a basis for validating the physical working of device models as well as providing insights into experimental data.-Hartree-Fock theory is an imperative tool for the electronic structure modelling of multi-electron quantum dots due to its ability to simulate a large number of electrons with manageable computation load. However, an efficient calculation of the self-consistent field becomes hard because dot formations in silicon are characterized by strong electron-electron interactions and conduction band valleys, besides the relatively high comparative effective mass, which add to create a behaviour dominated by repulsion between electrons rather than a well established shell structure. In this paper, we present a Hartree-Fock-based method that accounts for these complexities for the modelling of silicon quantum dots. With this method, we first establish the significance of including electron-electron interactions and valley degree of freedom and their implications. We then explore a simple case of anisotropic dots and observe the impact of anisotropy on dot formations.

Submission number: 273

ANODIC ALUMINUM OXIDE TEMPLATE MEDIATED FABRICATION OF DESIGNABLE NANOSTRUCTURES AND THEIR APPLICATIONS

Xu, Rui*

Keywords: Nanofabrication; Nano-Energy, Environment, and Safety; Nanoelectronics

Advanced devices play a critical role for sustaining the ever-growing demands of our society for energy, information, health care, etc. To achieve high performance, devices with nanoscaled features are attracting more and more attentions by virtue of their unique and promising effects emerging at nanoscale [1]. Structural design and engineering of materials provides a versatile platform to optimize the device performance and improve the commercial competitivity. Regarding the structural engineering, controlling the geometrical parameters (i.e., size, shape, hetero-architecture, and spatial arrangement) of nanostructures have been the central aspects of investigations and practical applications. Low-cost high-yield template-guided techniques have been a workhorse for nanostructure fabrication. Here we report designable anodic aluminum oxide templates with well-defined pore features within templates in terms of in-plane and out-of-plane shape, size, spatial configuration, and pore combination [2, 3]. By using designable anodic aluminum oxide template, we realize well-defined controlling of nanostructures over the size, in-plane/out-of-plane shape, spatial arrangement, and hetero-architecture. Integrating well-defined nanostructures into optoelectronic devices (e.g., photocatalysis [4], solar steam generator [5], surface enhanced Raman spectroscopy [2]) and magnetic devices [6], the device performance can be obviously enhanced.-

References

[1]--R. Xu et al., Adv. Energy Mater. 11 2021) 2001537.
[2]--R. Xu et al., Nat. Commun. 13 (2022) 2435.
[3]--L. Wen et al., Nat. Nanotech. 12 (2017) 244.
[4]--R. Xu et al., Adv. Funct. Mater. 30 (2020) 2005170.
[5]--R. Xu et al., Nano Energy 58 (2019) 543.
[6]--R. Xu et al., Nat. Commun. 13 (2022) 6587.

Submission number: 275

TARGETED DELIVERY AND APOPTOSIS INDUCTION OF CDK 4/6 INHIBITOR LOADED 4-CARBOXY PHENYL BORONICACID CONJUGATED PH SENSITIVE CHITOSAN LECITHIN NANOPARTICLES IN THE MANAGEMENT OF BREAST CANCER

Rajana, Naveen*

Keywords: Nanobiomedicine; Nanomaterials; Nanofabrication

Over the past few decades, anti-cancer drugs have been suffering from off-target toxicity and non-specific effects in preclinical, and clinical setups; targeting the specific cancer tissue is the main approach to triumph this burdensome. Recently, many receptors are known to be overexpressed in cancer and are explored as docking sites for targeting tumor tissues. In the current research, we aim to design and develop a novel 4-carboxy phenyl boronic acid (4- CPBA) conjugated Palbociclib (PALB) loaded pH-sensitive chitosan lipid nanoparticles (PPCL). The objectives of the study are to synthesis of 4-CPBA conjugated chitosan, overcome the drawbacks and to facilitate the targeted delivery of PALB, enhance the anti-cancer efficacy of the PALB in in-vitro cell line studies by loading into 4-CPBA conjugated chitosan lipid nanoparticles. 4-CPBA was conjugated to chitosan by carbodiimide chemistry and formation of conjugate was confirmed by 1HNMR, ATR-FTIR spectroscopic techniques. Ionic-gelation method was used for the fabrication of PPCL and particles size, PDI, zeta potential was found to be 226.5 ± 4.3 nm, 0.271± 0.014 and 5.03 ± 0.42 mV. Presence of pH-sensitive biological macromolecule, i.e., chitosan in the carrier system provides pH-senstivity to PPCL and sustainedly released the drug upto 144 h. The PPCL exhibited approximately 7.2, 6.6, and 5- fold reduction in IC50 values than PALB in MCF-7, MDA-MB-231 and 4T1 cells. Receptor blocking assay concluded that the fabricated nanoparticles were internalized into MCF-7 cells might be through sialic acid-mediated endocytosis. PPCL caused extensive mitochondrial depolarization, enhanced ROS generation, apoptosis (DAPI nuclear staining, acridine orange/ ethidium bromide dual staining), and reduced % cell migration than pure PALB. Thus, it reported that delivering PALB by 4-carboxy phenyl boronic acid conjugated chitosan lipid nanoparticles provides an optimistic approach to treatment of breast cancer.

Submission number: 276

SPECTROSCOPIC CHARACTERIZATION OF THE INTERACTION OF STILBENE MOLECULES WITH THE SURFACE OF HEXAGONAL BORON NITRIDE

Halimski, Ivan; Pashnev, Daniil; Talaikis, Martynas; Dementjev, Andrej; Karpicz, Renata; Kašalynas, Irmantas; Urbanovi-269;, Andžej; Lamberti, Patrizia; Shundalau, Maksim*

Keywords: Nanomaterials; Nano-Metrology and Characterization

The unique properties of 2D materials are considered to be promising for a variety of applications including optoelectronic systems, photonics, and others. Hexagonal boron nitride (hBN) nanosheet is a structural and isoelectronic analogue of graphene, but in contrast to the latter, hBN is an electrical insulator and does not absorb in the visible region. It has also high chemical stability as well as thermal conductivity and stability. Therefore, ultra-thin hBN is successfully applied as the dielectric layer in field effect transistors, protective cover in devices, buffer layer in film growth, etc. The properties of hBN nanosheets can be modified using the functionalization of their surface by molecular architectures. Non-covalent functionalization of 2D hBN provides a way to modify the physical properties without violating its structure. Adsorbed molecules interact with surfaces due to relatively weak van der Waals interactions. Downsizing of 2D hBN nanosheet allows to production of hBN quantum dots, which have unique photophysical properties and are biocompatible that determines their promising application in biomedicine for the diagnosis of various diseases, bioimaging and targeted drug delivery. Although the functionalization of graphene and some other 2D materials is well established, the functionalization of 2D hBN has not been extensively studied, partly due to its inert nature. Apparently, the hBN surface can form -960;–-960; staggered stacking interactions with organic molecules containing aromatic rings. The complex of the trans-stilbene (TST) molecule with hBN as a promising system for non-covalent functionalization of the hBN is synthesized and characterized using THz, FTIR, Raman, CARS, and photoluminescence spectroscopy, as well as DFT-based calculations. The spectroscopic features of the weak interaction of the TST with the surface of the hBN have been revealed.

Submission number: 277

IMAGING NUCLEIC ACID NANOSTRUCTURES WITH IONIC CURRENTS IN NANOPORES

Keyser, Ulrich*

Keywords: Nanosensors and Nanoactuators; Nanobiomedicine; Nanofabrication

Nanopore sensing has been transformative in nucleic acid sequencing. However, the analysis of non-canonical structures like the G-quadruplex or even double-stranded nucleic acids remain challenging with commercial platforms. Here, I will discuss how the combination of solid-state nanopores and nucleic self-assembly allows the study of non-canonical structures in nucleic acids. After introducing the nanopore sensing platform I will discuss the analysis of G-quadruplex folding on designed DNA molecules and their folding kinetics. Using glass nanopores with diameters below 5 nm we show that structures can be localized along DNA molecules with a few nm precision. The origin of the ionic current signal is studied with a range of different DNA structures. Based on the localization of structures using nanopore signals, we develop a strategy for the rapid identification of RNA isoforms without reverse transcription or amplification. In the future, our technology will enable to identify nucleic acid structures and may allow mapping of RNA binding proteins.

Submission number: 278

SELF-FOLDING SHELL ELECTRONICS FOR 3D NEUROMORPHIC DEVICES

Acha, Chris; George, Derosh; Gracias, David*

Keywords: Nanoelectronics; Nanofabrication; Nanosensors and Nanoactuators

One of the limitations of present-day neuromorphic devices is their inherent two-dimensional layout based on existing layer-by-layer VLSI fabrication and E-test probe stations capable only of planar electrical testing. Self-folding is a process that can be used to transform layered lithographic patterns into three dimensions by out-of-plane curving, folding, and buckling based on differential stress, pre-strained materials, surface tension, and swelling. This talk will discuss self-folding shell electronic interfaces capable of on-chip integration with wiring and sensors in 3D contours. Of note are self-folding shells in spherical, cubic, and related polyhedral geometries of broad relevance as next-generation interfaces for truly 3D neuromorphic devices composed of organoids and synthetic organoids. The self-folding shells utilize a differentially crosslinked SU8 bilayer capable of self-folding in biological media and is biocompatible. As discussed in this talk, the shells can permit not only 3D recording and stimulation in 3D geometries but also have the capacity for electrical, electrochemical, and chemical functionalities. By leveraging the high resolution of planar lithography, wiring, contact pads, and even microfluidic channels and biosensors can be integrated within the 3D contour of the shell to enable spatiotemporal mapping of the activity of brain and synthetic organoids in 3D. Potential applications for Organoid Intelligence (OI) and Synthetic OI will be discussed.

Submission number: 279

ENABLING ANALOG COMPUTE-IN-MEMORY NEUROMORPHIC DEVICES WITH STANDARD SILICON CMOS VLSI TECHNOLOGIES

Strangio, Sebastiano*; Catania, Alessandro; Iannaccone, Giuseppe

Keywords: Quantum, Neuromorphic, and Unconventional Computing; AI for Nanotechnology; Nanoelectronics

Neuromorphic chips exploiting analog in-memory computing are providing solutions to overcome fundamental limitations of classical processors, especially for in sensor edge computing where the processing efficiency is a critical limiting factor. As opposite to emerging material and device platforms proposed for neuromorphic applications, standard silicon CMOS platforms benefit from great know-how, low cost and excellent reliability: all these features are well exploited in mainstream digital microprocessors, while analog processing units are very rare, also due to the lack of reliable analog memories.-We have conceived analog neuromorphic chips based on a low-cost single-poly CMOS process technology exploited beyond its normal application domain, benefiting from floating-gate multi-level memory cells not included in the standard cell package. Our neuromorphic accelerators are based on analog vector-matrix multipliers, implemented with either current-mirror (current mode) or miller-integrator (charge mode, time domain) approaches. To the purpose, three terminal or miniaturized two terminal floating-gate memory devices have been conceived to store the weights of the neuromorphic core.-Simple two-layer feed-forward neural networks have been trained for the recognition of handwritten digits captured in low resolution conditions (derived from the MNIST dataset). A high classification accuracy, comparable to the one reached by a software implementation of the network operating in floating-point precision, has been achieved by our analog CMOS classifiers for a 50°C temperature range (10 °C – 60 °C) by exploiting a dynamic voltage compensation technique.

Submission number: 280

ADVANCES IN MULTISCALE MODELLING OF MAGNETOELASTIC PHENOMENA

Nieves Cordones, Pablo*; Arapan, Sergiu; Korniienko, Ievgeniia; Fraile, Alberto; Iglesias Pastrana, Roberto; Legut, Dominik

Keywords: Modeling and Simulation; Nanomagnetics; Nanosensors and Nanoactuators

Magnetoelastic interactions couple the motion of atoms in a magnetic material with atomic magnetic moments, allowing to transfer mechanical and thermal energies between phonon and magnon subsystems. Precise control of magnetization through a mechanical excitation of the motion of atoms in magnetic materials, and vice versa, has enabled the development of a wide range of technological applications such as sensors and actuators. Presently, there are still many open questions about possible ways to model magnetoelasticity at different spatial and time scales. Starting at the smallest spatial scale, the aim is to perform a quantum mechanical characterization of the magnetoelastic constants of the material at zero temperature. For instance, this task can be done through our recently developed software MAELAS[1] in an automated way. These intrinsic magnetic properties are used as inputs to build coarse-grained classical atomistic models that allow to simulate the material at larger spatial and time scales, including temperature and pressure effects, as well as other features. Here, the coarse-grained modelling of atom and spin motion via spin-orbit coupling represents a key bottleneck. Recently, we proposed a methodology to construct such spin-lattice models capable to account for magnetoelastic properties based on the Neel model[2], finding quite encouraging preliminary results on the magnetoelastic effects on sound velocity and temperature dependence of magnetoelasticity. Finally, at the macroscopic scale, all this information can be used to construct reliable finite-element models that include magnetoelastic features, as well as material geometry, microstructure, etc. For instance, we successfully applied this type of model to study the influence of grain morphology and orientation on the saturation magnetostriction of polycrystalline Terfenol-D. We believe that consistent combinations of all these different methodologies within a multiscale approach could be successfully exploited in the development of technological applications based on magnetoelastic and magnetocaloric phenomena.[1] P. Nieves et al. Comp. Phys. Comm. 264 (2021) 107964.[2] P. Nieves et al. Phys. Rev. B 103 (2021) 094437.

Submission number: 281

HYBRID MEMBRANE-COATED NANOMOTOR FOR IMMUNOTHERAPY AND CHEMOTHERAPY OF BREAST CANCER

Lee, Man Lung; Li, Hung Wing*

Keywords: Nanobiomedicine; Nanosensors and Nanoactuators

Cancer cells adhesion and extracellular matrix penetration are important for drug delivery in cancer treatment. However, it is reported that coating nanoparticle surface with tumor-recognizing ligands can only achieve 0.7% delivery to solid tumors in preclinical animal models.[1] The major reason for low delivery efficiency is due to the blockade by extracellular matrix (ECM) in tumor microenvironment (TME). Here, we proposed a membrane coated NO driven mesoporous silica iron oxide drug carrier ([RBC-MDA]-GDL-MSN@Fe3O4) for drug delivery. Red blood cells (RBCs) membrane coating can prevent the immune clearance of nanoparticles by expressing “don’t eat me” signal, thus prolonging the blood circulation time.[2] Mesoporous silica iron oxide is loaded with Doxorubicin (DOX) and L-arginine(L-arg) for chemo/immunotherapy and starvation therapy. Through the conversion of L-arg to nitric oxide (NO) bubble in reactive oxygen species (ROS) overexpressed tumor microenvironment (TME), drug carrier can be propelled by the generation of nitric oxide gas to penetrate the extracellular matrix, thus enhancing the accumulation of nanoparticles in tumor site. Besides, the magnetic Fe3O4 core can be directed to tumor site by manipulating magnetic field, which further promotes the tumor adhesion of nanoparticles. The release of nitric oxide is also reported to exhibit a promising antitumor effect at high concentration and combine with ROS to generate more cytotoxic substance peroxynitrite (ONOO-). Synergizing with immunotherapy, [RBC-MDA]-GDL-MSN@Fe3O4 holds excellent potential to kill cancer without causing strong side effects.

Submission number: 282

THERMOELECTROMECHANICAL CHARACTERIZATION OF LASER-INDUCED GRAPHENE NANOCOMPOSITES

Jacquin, Tom; Wanstall, Simon; Lim, Theodore; Amjadi Kolour, Morteza*

Keywords: Nanotechnology in Soft Electronics; Nanomaterials; Nanoelectronics

The demand for flexible electronic devices is rapidly growing across various fields, notably in biomedical studies and prosthetics. Soft strain sensors have emerged as a promising solution for the real-time monitoring of biomedical signals due to their conformability and resilience to different strain levels. Nonetheless, these sensors encounter limitations, including hysteresis introduced by the polymer matrix and susceptibility to external factors like temperature and humidity, which can impede their functionality. In this talk, we introduce a novel strategy to tackle these challenges by fine-tuning the temperature sensitivity of Laser-Induced Graphene (LIG)/Polydimethylsiloxane (PDMS) composite soft strain sensors. The controlled manipulation of laser parameters governs the carbonization process and the formation of interconnected networks, endowing the sensors with unique electromechanical and electrothermal responses. The experimental results showcase a remarkable tunability of temperature sensitivity, ranging from 0.4%/°C to 0.85%/°C. Moreover, the design and fabrication of nearly temperature-insensitive soft strain sensors are detailed, underscoring their potential application in environments prone to temperature fluctuations. Specifically, we highlight the suitability of these sensors for applications such as hot-cold grasping and Joule effect-activated grippers. Our findings contribute to enhancing the performance of soft strain sensors, thus opening avenues for their utilization in diverse biomedical applications. This study not only addresses critical challenges in sensor technology but also emphasizes the importance of tailored approaches in advancing flexible electronic devices for biomedical purposes.

Submission number: 283

IMPACT OF TEMPERATURE VARIATIONS ON THE ELECTROCHEMICAL PERFORMANCE OF BATTERIES WITH CYRENE-BASED, SPRAY-PRINTED NMC CATHODES

Nguyen, Hai Harry; Valikangas, Juho; Hannila, Esa; Molaiyan, Palanivel;

Keski-Korsu-Piekkari, Paula; Lassi, Ulla; Fabritius, Tapio; Sliz, Rafal*

Keywords: Nano-Energy, Environment, and Safety

This study examines the effects of temperature influence, ranging from +20°C to -10°C, on the electrochemical performance of lithium-ion batteries with nickel manganese cobalt (NMC) cathodes that have been spray-printed using a sustainable solvent. In the cathode fabrication process, Cyrene—a sustainable, dipolar aprotic solvent—was used as a replacement for N-methyl-2-pyrrolidone (NMP) to enhance the eco-friendliness and safety of battery manufacturing. Blade-coated Cyrene-based NMC cathodes were used as a reference. The morphological and structural attributes of the spray-printed and blade-coated NMC cathodes were assessed using scanning electron microscopy and optical profilometry. Electrochemical performance was evaluated through cyclic voltammetry, varied C-rate charge-discharge cycling, and electrochemical impedance spectroscopy under different temperature conditions. Our results demonstrate that the Cyrene-based, spray-printed NMC cathodes exhibit electrochemical performance comparable to their blade-coated counterparts. Although performance degradation was observed at sub-zero temperatures—attributed to increased electrolyte viscosity and reduced lithium-ion mobility—the spray-printed cathodes maintained performance parity with those fabricated by blade-coating. This study offers significant insights into how temperature affects the operational efficiency of lithium-ion batteries with NMC cathodes fabricated via different methods, indicating that spray printing is a viable and sustainable alternative for producing NMC cathodes.

Submission number: 284

NANOSCALE OPTICAL AND DIELECTRIC RESPONSES OF THIN PROTEIN LAYERS ADSORBED ON SOLID SILICA SURFACES

Villeneuve-Faure, Christina; Rima, Maya; Boudou, Laurent; Roques, Christine; Makasheva, Kremena*

Keywords: Nano-Metrology and Characterization; Nanobiomedicine; Nanomaterials

Microbial adhesion on solid surfaces represents the preliminary step in the development of biofilms, which in some cases can be considered responsible for nosocomial infections in the biomedical domain and may lead to septic complications and lethal issues, and entail large economical losses for the health-care systems. Among other parameters, the electrostatic interaction between the adhering cell and the surface is the one governing the microbial adhesion. It is intrinsically linked to the presence of a conditioning layer created by adsorption of proteins on the solid surface. It is therefore appropriate to reveal the optical and dielectric responses of these soft materials organized in a conditioning layer at nanoscale. An essential step consists of studying the dielectric properties of proteins because their presence on the surface or in the surrounding liquid medium plays a major role in the mechanisms behind the microbial adhesion and the subsequent biofilm formation. Such approach will also open the possibility of design and synthesis of tailored antimicrobial surfaces.

Submission number: 285

NANOWIRE STRAIN SENSOR-BASED WORD RECOGNITION FOR SPEECH-IMPAIRED USERS

Zhang, Eric*; Wu, Shuang; Shen, Alex; Syed, Zahid; Zhu, Yong; Shen, Xipeng

Keywords: Nanotechnology in Soft Electronics; AI for Nanotechnology; Nano-Acoustic Devices, Processes, and Materials

Millions of people around the world grapple with speech loss due to various medical conditions. This significantly hinders their ability to communicate and express themselves. To address this challenge, our research delves into cutting-edge nanomaterial-based high-performance strain sensors designed specifically to detect intricate human facial muscle movements associated with speech. The strain sensor is soft and flexible, which makes it a good candidate for integration into wearable devices. Our experiments reveal that the strain sensors can pick up distinct signal patterns during the articulation of words and sentences. Furthermore, we discerned and interpreted these signals as words with modern time series machine learning algorithms. By testing 21 popular words, our findings revealed promising outcomes, showing recognition accuracy ranging from 47.4% to 80% across 10 speakers using the K-Neighbors Time Series Classifier. In addition, we compared the classification accuracy of five popular time series machine learning algorithms. Three random forest classifiers showed comparable accuracy with the K-Neighbors Time Series Classifier, while the Time Series Support Vector Classifier showed lower performance. These findings pave the way for a future where individuals with speech impairments can regain a powerful mode of communication through this innovative technology.

Submission number: 286

A SPATIO-TEMPORAL-BASED CONCEPT FOR ASSOCIATIVE MEMORY MODELING WITH MEMRISTORS

Chatzipaschalis, Ioannis*; Tompris, Ioannis; Stavroulakis, Emmanouil; Chatzinikolaou, Theodoros Panagiotis; Fyrigos, Iosif-Angelos; Fraidakis, Pantelis; Calomarde, Antonio; Goma, Rafael; Sirakoulis, Georgios; Rubio, Antonio

Keywords: Quantum, Neuromorphic, and Unconventional Computing

Spatio-temporal encoding in neural systems refers to the representation of information through the combined spatial and temporal patterns of neuronal activity and plays a fundamental role in various brain biological functions, such as higher cognitive processes, including the memory effect. Memory is an intricate process in human cognition and this bio-inspired function can be replicated by novel hardware components. Memristors can imitate the memory effect as they appear to have non-volatile characteristics, and they can also constitute the switching component of memristive-based oscillators acting as neurons for designing complex network structures in order to replicate the human brain behavior. In this paper, a spatio-temporal encoding scheme is being evaluated under a hardware-oriented concept integrating memristive novel devices, aiming to replicate the way associative memory works, and paving the way for novel approaches in brain-inspired computing systems.

Submission number: 287

MYCELIUM-BASED ELM EMULATION UTILIZING MEMRISTIVE OSCILLATING CELLULAR AUTOMATA

Chatzinikolaou, Theodoros Panagiotis*; Tompris, Ioannis; Chatzipaschalis, Ioannis; Fyrigos, Iosif-Angelos; Tsompanas, Michail-Antisthenis; Adamatzky, Andrew; Sirakoulis, Georgios

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Modeling and Simulation

Engineered Living Materials (ELMs) represent a novel class of materials that possess intrinsic properties and capabilities inspired by living organisms. Among ELMs, fungal mycelium stands out due to its low-cost manufacturing process, ubiquity in nature, and significant environmental benefits owing to its biodegradability. Modeling mycelium's complex behaviors challenges scientists due to its intricate natural phenomena, leading to the adoption of digital twins for accurate simulations and deeper insights. Memristors, with their unique state-transition capabilities and non-volatility, emerge as promising for implementing a low-power, efficient digital twin of mycelium, demonstrating versatility across various applications beyond conventional hardware limits. This paper explores the use of memristive nanoelectronic circuits to simulate the evolution of biological mycelium hyphae, introducing a novel computational approach, Memristive Oscillating Cellular Automaton (MOCA), to model the dynamic behavior of mycelium. The MOCA design mirrors the activator and suppressor processes observed in reaction-diffusion systems, thus simulating mycelium tip growth and branching patterns. The simulation results demonstrate the successful propagation of oscillating signals across a MOCA grid, reflecting the biological pathways within mycelium.

Submission number: 288

PIEZOELECTRIC MECHANICAL RESONATORS AS SENSITIVE ELEMENTS FOR GAS SPECTROSCOPY AND SENSING

Sampaolo, Angelo*

Keywords: Nano-Acoustic Devices, Processes, and Materials; Modeling and Simulation;

Nanosensors and Nanoactuators

The main advantage in employing laser-based sensors for gas spectroscopy is their capability to target gas species with high selectivity and detection sensitivity. Most of the spectroscopic techniques rely on multi-pass absorption cells or resonant optical cavities to enhance the interaction pathlength between the laser radiation and the absorbing molecules. In both cases, such sensors can be bulky and require the use of optical detectors, characterized by limited bandwidths and limited usability in harsh environments, where temperature can change sharply. In this context, we introduce piezoelectric mechanical resonators as low-cost, mass-production sensitive elements for in situ and real time laser-based sensors. The first embodiment is quartz-enhanced photoacoustic spectroscopy (QEPAS). In this spectroscopic approach, a quartz tuning fork (QTF) is employed as a high quality-factor optoacoustic transducer detecting soundwaves photo-acoustically generated by the target molecule. In this case, the required gas sample is as small as few cubic centimeters, the interaction pathlength needed is smaller than 3 cm but the tuning fork is exposed to the gas sample. This, together with the photoacoustic signal dependence on the energy relaxation efficiency, makes the QEPAS detection sensitive to gas matrix fluctuations. An alternative embodiment of QTFs as sensitive elements is light-induced thermo-elastic spectroscopy, in which the residual light downstream an absorbing gas sample is focused upon the surface of a QTF. A photo-thermo-elastic conversion of the light absorbed within the resonator structure induces mechanical motions and, consequently, a piezo-current proportional to the gas molecule concentration is generated. In this case, the sensitive element is not necessarily exposed to the gas sample, but the interaction pathlength needed is larger with respect to QEPAS. In both cases, QTFs allow a wide range of operation in terms of pressure, temperature and excitation wavelengths. These features of mechanical resonators set the basis for the design and development of chip-size sensing platforms where the laser sources, waveguides, optical resonators can be integrated for in situ and real time detection.

Submission number: 289

THEORETICAL ASSESSMENT OF DIRECT COULOMB EXCHANGE IN SPIN QUBITS

Kotlyar, Roza*

Keywords: Modeling and Simulation; Quantum, Neuromorphic, and Unconventional Computing; Nanoelectronics

Semiconductor quantum dot-based technology is a natural venue for scaling towards fault tolerant quantum computing that is taking a full advantage of the advanced semiconductor process manufacturing. Qubits are encoded using spins in individual quantum dots (Loss-DiVincenzo encoding), or various many-electron states in multiple quantum dots (for example, Exchange Only encoding) [1]. Electron exchange between two dots is utilized for gate operations for all considered encodings. An exchange gate is accomplished by hybridizing electron wavefunctions of electrons in individual dots [2], [3]. This is akin to a formation of an artificial quantum dot molecule from two dots. Similar to natural molecules, the exchange energy consists of two parts – a positive kinetic exchange and a negative direct Coulomb exchange. I had developed a Python based quantum dot simulator that includes the full exchange Hamiltonian and studied the role of direct Coulomb exchange on spin qubits performance. I will discuss the limiting role of direct Coulomb exchange to achieve the maximal exchange in qubit systems, and its impact on sensitivity to noise.- [1] Semiconductor spin qubits, Guido Burkard, Thaddeus D. Ladd, Andrew Pan, John M. Nichol, and Jason R. Petta, Rev. Mod. Phys. 95, 025003 (2023). [2] R. Kotlyar and S. Das Sarma, Phys. Rev. B 56, 13 235 (1997). [3] R. Kotlyar et al., IEDM Tech Dig., pp. 8.4.1-8.4.4 (2022).

Submission number: 290

FIRST-PRINCIPLE ANALYSIS OF ELASTIC CONSTANTS OF -946;-(ALXGA1-8722;X)2O3 FOR HETEROGENEOUS INTERFACE APPLICATIONS

Lim, Hyokyung; Kong, Byoung Don*

Keywords: Nanomaterials

Monoclinic -946;-Ga2O3, with its wide bandgap, shows great potential for high-power electronics, offering high critical electric field strength for FETs and tunability through alloying with Al for enhanced performance. Determining the elastic constants for (AlxGa1-8722;x)2O3 is crucial, as it enables the prediction of material properties, including piezoelectricity, thereby broadening the potential for advanced device applications. This study investigates the piezoelectric properties of -946;-(AlxGa1-8722;x)2O3, focusing on the analysis of elastic constants. The structural stability and piezoelectric properties of -946;-(AlxGa1-8722;x)2O3 alloys for compositions from x=0.25 to 0.5 have been meticulously investigated. First-principle calculations is employed to identify the most stable configurations by analyzing inter-atomic distances between aluminum atoms, pinpointing the optimal aluminum positions within the crystal structure. The foundation of understanding the material's structural integrity facilitates an in-depth exploration of its piezoelectric characteristics through the calculation of six essential elastic constants C11,C22, C33, C12, C23, and C13. These calculations reveal the material's mechanical and electrical responses under stress, offering critical insights into the trends and behaviors of these elastic constants.

Submission number: 291

EXPANDING THE SCOPE OF BIOMOLECULAR SENSING: LEVERAGING CASCADE EFFECTS IN MEMBRANE-INTEGRATED DNA NANOPORES FOR ENSEMBLE MEASUREMENTS

Manda, Swathi*; Gopinath, Ashwin

Keywords: Nanosensors and Nanoactuators; Nanoelectronics; Nanobiomedicine

In the realm of bioelectronic interfaces, achieving-efficient information transfer often requires leveraging-inherent amplification mechanisms. Previous approaches-primarily utilized membrane-integrated DNA nanopores for-single-molecule readouts, which limited their utility in-achieving broader biomolecular sensing capabilities.-Traditional approaches, such as aptamer-redox probe-configurations or antibody-field effect transistor systems,-exhibit subtle changes in response to single binding events,-thereby constraining their effectiveness in multiplexed-biomolecular detection. By contrast, our innovative approach-integrates membrane-spanning DNA nanopores with-bioprotonic contacts, thereby capitalizing on inherent-amplification phenomena. This integration enables a cascade of-events initiated by a single binding event within the DNA-nanopore interface, akin to the amplification observed in-processes such as enzyme turnover or the generation of-multiple photons in GFP from a single binding event in an ion-channel. Through ensemble experiments, we explore the-kinetics of these interactions, paving the way for facile-electronic measurement and quantification of biomolecules in a-multiplexed manner. This paradigm shift from single molecule-readouts to ensemble measurements unlocks new opportunities-for advancing the frontier of bioelectronic technologies.

Submission number: 292

AN AREA-EFFICIENT LOW-POWER FULLY NON-VOLATILE FULL-ADDER USING RECONFIGURABLE LOGIC

Shen, Zhongkun; Deng, Erya*; You, Jiaqi; Hu, Qingting; Wang, You; Gong, Yu; Wu, Bi; Liu, Weiqiang

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Spintronics

The miniaturization of CMOS results in high static power consumption in traditional computer system. Logic-in-memory (LIM) architecture based on emerging non-volatile memory (NVM) can significantly reduce static power consumption by embedding computing and logic functions into NVM. Magnetic tunnel junction (MTJ) is considered as one of the most promising candidates for LIM circuits owing to its high speed, nearly infinite endurance, and 3D back-end integration technology. This paper introduces a reconfigurable LIM circuit integrating spin transfer torque based MTJs (STT-MTJs). Unlike the conventional non-volatile full-adders (NV-FAs) that perform the "Sum" and "Co" operations with two sub-circuits, the proposed circuit can perform both operations. Simulation results based on 28 nm CMOS process design kit and a perpendicular STT-MTJ compact model show that the proposed NV-FA has the advantages of small area and low power consumption.

Submission number: 293

DEVELOPMENT OF TRIBOELECTRIC NANOENERGY AND NANOSYSTEM (TRIBO-NENS)

Lee, Chengkuo*

Keywords: Nanotechnology in Soft Electronics; Nanosensors and Nanoactuators; AI for Nanotechnology

Recent progress on Triboelectric Nanoenergy and Nanosystems (Tribo-NENS) provides a new possibility for realizing low-power smart electronics in the 5G and Internet of Things (IoT) era. Focusing on energy harvesting from natural and human activities, triboelectric nanogenerators power smart systems for various applications, including human-machine interfaces, robotic perception, and smart homes, showcasing versatility and efficiency. Covering advancements in wearable tech, robotic perception, and smart living spaces, the review navigates through current innovations, applications, and future prospects, underlining the critical role of Tribo-NENS in evolving sustainable, intelligent technologies for everyday life.

Submission number: 294

25 YEARS OF DEVELOPMENT— FROM ESOTERIC QUANTUM TRANSPORT THEORY TO WIDE ADOPTION IN ATOMISTIC DEVICE SIMULATION

Klimeck, Gerhard*

Keywords: Nanoelectronics; Modeling and Simulation; Nanomaterials

The quantum device modeling field has changed a lot in 30+ years. In the 90s, there was no consensus on which theory, basis sets, algorithms, user interfaces, and dissemination methods to use. The NEMO development began in ‘94 at Texas Instruments, continued at NASA/JPL from ‘98, and Purdue since 2004. Today, advanced quantum transport modeling tools that use 3D atomistic representations of the physical device are widely used to explore the design space of nano-scale transistors. NEMO methods of the NEGF theory with atomic tight-binding basis are the benchmark for quantitative and predictive simulation. Most device modeling research groups use this approach. In 2015, Intel bought an in-house supercomputer ranked in the top-100 to run NEMO5 for design explorations and integrated it into their in-house design suite. Silvaco commercialized since in 2018 and other industry leaders such as Samsung and TSMC created their own solutions based on NEMO. NEMO’s ability to model crystal orientations and strain in a realistic system enabled the development of Texas Instruments' rotated substrate technology in 2004, which had a significant impact on chips used in billions of cell phones. Today’s 3D FinFETs or nanosheet transistors have the same 5nm central length features as 1D RTDs. The quantitative and predictive modeling of 1D RTDs (‘94-97) defined the standards needed for today’s 3D transistors. Quantum Well, Quantum dot and few impurity modelling were steps towards full 3D quantum transport modelling in realistic devices. These systems helped understand single and correlated electron physics in realistically sized systems where crystal orientation, atomistic composition & disorder, strain, confinement, and electron-electron interactions matter. Over 25,000 users on nanoHUB.org, the first end-to-end user scientific computing cloud platform, have studied various nanoscale devices such as nanowires, ultra-thin-body transistors, and quantum dots using the easy-to-use NEMO/OMEN tools. Over half of nanoHUB's simulation users learn about device exploration and modeling concepts in formal classroom settings across 180 institutions worldwide, where they use these apps. nanoHUB hosts 700+ apps and tools and over 170 full courses.

Submission number: 295

POROUS ALUMINA ASSISTED ANODIZING OF TI/NB LAYERS

Hoha, Aliaksandr; Poznyak, Alexander; Pligovka, Andrei*

Keywords: Nanofabrication; Nanoelectronics; Nanomaterials

The three-layer Al/Ti/Nb system onto Si substrates was magnetron sputter-deposited. The titanium/niobium layers in 0.2 M oxalic, orthophosphoric and tartaric solutions were alumina assisted 100 and 200 V potentiostatically anodized and galvanostatically reanodized in 0.5 M boric solution. Titanium oxide (TiO2), niobium oxide (Nb2O5) and their mixture were obtained. The current–time and voltage-time response, morphology and composition were investigated.

Submission number: 296

NEUROMORPHIC TECHNOLOGY INSIGHTS IN SPAIN

Xabier, Iturbe*; Camunas-Mesa, Luis; Serrano-Gotarredona, Teresa; BargallO Gonzalez, Mireia; Campabadal, Francesca; Margarit-Taule, Josep Maria; Serra-Graells, Francisco; Teres, Lluis; Lanillos, Pablo; Lopez Dominguez, Victor; Bisquert, Juan; Guerrero, Antonio; Lopez-Vallejo, Marisa; Ituero Herrero, Pablo; Otero, Andres; Rubio, Antonio; Rodriguez-Montanes, Rosa; Picos, Rodrigo; Miranda, Enrique; Sune, Jordi; Sort, Jordi; Roldan, Juan; Jimenez-Molinos, Francisco; DUEnAS, SALVADOR; CASTaN, HELENA; Marsal, Lluis F; Basterretxea, Koldo; Astarloa, Armando; Francisco, Barranco; Goma, Rafael; Del Ser, Javier; Rodrigues, Serafim; Torres, Elias; BOFILL-PETIT, ADRIA; Turchetta, Renato; Goossens, Stijn; Jonuzi, Tigers; Estebanez, Irene; Artundo, Inigo; Sainz, Unai; Erramuzpe, Asier; Ruiz, David; Gonzalez-Arjona, DAvid; Regada, Raul; Pedro Puig, Marta; Lara-Rapp, Oscar

Keywords: Nanoelectronics; Modeling and Simulation; Spintronics

This paper provides an overview of the main research activities carried out by Spanish organizations in areas related to neuromorphic technologies, spanning physical, materials, circuitry, and architectural levels. It also discusses the potential of these technologies to create competitive advantages for the Spanish industry, and to enable new applications and business opportunities via deep-tech startups, especially related to novel neuromorphic sensing modalities (e.g., Dynamic Vision Sensors).

Submission number: 297

LIGHT MANAGEMENT THROUGH GRADUAL DIAMETER-MODULATION OF WAVE-SHAPED SIDEWALL SILICON NANOPILLAR

Choi, Minkeun; Park, Ju Hong; Baek, Chang-Ki*

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanoelectronics; Nanofabrication

Near-infrared (NIR) detection is a key enabling technology for future applications. In particular, NIR light in the 700 - 1,000 nm spectral range is highly desirable for biomedical devices, ethernet communications, and light detection and ranging applications [1]. For these practical applications, photodiodes with high NIR response and tunable broadband wavelength are preferred. Silicon NIR photodiodes (PDs) have attracted significant attention for their low-noise and highly cost-effectiveness. However, a relatively large bandgap of silicon limits its NIR response. To enhance the NIR response, various nanostructures have been suggested, inducing optical resonances. In our previous work, we reported the wave-shaped sidewall silicon nanopillar (WS-SiNP) structures with highly enhanced NIR responsivity (R-955;) compared to the straight sidewall SiNP [2]. This enhancement comes from increased effective absorption path by WS boundary. This sidewall boundary not only improve the horizontal component of the vertically incident light, but also induce whispering gallery mode (WGM) resonances. Here, we explore the diameter modulation dependence of the resonant frequency with enhanced NIR R-955; to achieve the tunability of broad wavelengths. Symmetric WS (S-WS), tapered WS (T-WS), reversely tapered WS (RT-WS) SiNPs PDs were fabricated and evaluated, compared with cylindrical SiNP (C-SiNP) PDs. These three types of WS-SiNP devices have higher R-955; than C-SiNP devices in the overall NIR spectrum. Notably, at 720 nm wavelength, T-WS devices were improved by 17.4 %, S-WS devices were improved by 14.5 % at 865 nm, and RT-WS devices were improved by 32 % at 1000 nm. S-WS devices consist of a constant diameter, so WGM resonance occurs at an 865 nm. T-WS and RT-WS devices have a continuum of diameters from top to bottom, allowing for resonant wavelengths to be continuously excited within a single pillar. These asymmetric structures have different resonant wavelengths because of their geometry differences. T-WS devices have higher R-955; in the range of 720-840 nm since shorter resonant wavelengths are coupled to the smaller cavity. RT-WS devices have higher R-955; in the range of 900-1,000 nm since the longer resonant wav

Submission number: 298

HOLISTIC, RELIABLE AND PRACTICAL CHARACTERIZATION FRAMEWORK FOR GRAPHENE-FAMILY MATERIALS, A CORRELATED APPROACH INCLUDING IMAGING-BASED TECHNIQUES

Fernandez Poulussen, Daniel*; Drobne, Damjana; Menendez Velazquez, Amador

Keywords: Nano-Metrology and Characterization; Nanomaterials; Nano-Energy,

Environment, and Safety

ACCORDs is an EU funded project working in the development of an imaging-based characterization framework for the holistic correlative assessment of Graphene Family Materials (GFMs) as a representative of 2D nanomaterials (NMs) to assess and predict 2D NMs health and environmental risks, involving key activities on synthesis, characterization, data collection, standardisation and efficient workflows for industry. The ACCORDs framework will operationalise safe and sustainable by design (SSbD) strategies proposed in past or ongoing H2020 projects or within OECD by correlating low-, medium-, and high-resolution physico-chemical-biological imaging-based methods with non-imaging methods in a tiered approach. ACCORDs will deliver the framework and user guidance, new imaging-based characterisation methods, reference in vitro tests, new reference 2D NMs for different matrices, a new minimum information reporting guideline for FAIR data sharing and reuse of images as well as an atlas with reference images for diagnostics of compromised safety of GFMs / GFM products. The new guidelines and standard proposals will be submitted to standardisation bodies to allow creation of regulatory ready products. The novelty of ACCORDs is in translating the principles of medical imaging-based diagnostics to 2D material hazard diagnostics. ACCORDs will accelerate industrial sectors in the area of aviation, marine construction, drone production, flexible electronics, photovoltaics, photocatalytics and print inks-based sensors. The value ACCORDs proposes to the graphene industry are practical, easy, imaging-based tools for GFM quality monitoring next to the production line with a possibility to be correlated with advanced high-resolution imaging characterization methods in case hazard i.e. deviation from controls (benchmark values) are diagnosed. The ACCORDs framework and tools will contribute to the European Green Deal by addressing the topic: “Graphene: Europe in the lead” and to a “new European strategy on standardisation”. This project receives funding from the European Union’s Horizon Europe Research & Innovation Programme under grant agreement no. 101092796.Funded by the European Union.

Submission number: 299

FUNDAMENTAL PROPERTIES AND DEVICE APPLICATIONS OF SQUARE SNO2 NANOTUBES

Allen, Martin*

Keywords: Nanomaterials; Nanofabrication; Nanoelectronics

Tin dioxide (SnO2) is a technologically-important transparent semiconducting oxide. Its wide (3.5 eV) bandgap combined with a strong n-type electrical conductivity makes SnO2 well-suited for ultraviolet optoelectronic devices and transparent electronics, while other interesting properties such as a high surface electron density and donor-like oxygen vacancies enable a wide range of gas sensing and electrocatalytic applications. We have recently developed a highly-scalable method of growing perfectly-square SnO2 nanotubes on Au-nanoparticle covered sapphire, quartz, and silicon substrates using mist chemical vapour deposition. These square nanotubes have a unique 90° geometry, exhibit high single crystallinity, and can be controllably doped with Sb with no loss in structural quality. X-ray diffraction measurements and transmission electron microscopy show that they adopt the rutile structure growing in the [001] direction with (110) sidewalls, while synchrotron x-ray photoelectron spectroscopy has revealed the presence of an unusually strong 2-dimensional surface electron gas (2DEG). This 2DEG is created by donor-like states produced by the hydroxyl termination of the SnO2 surface on exposure to atmospheric conditions. Unlike other oxide semiconductors, the 2DEG is sustained at high temperatures by the formation of donor-like in-plane oxygen vacancies. This persistent high surface electron density is expected to prove useful in gas sensing and catalytic applications of these remarkable structures. In this work, we also report on electronic devices based on these square nanostructures. Single square SnO2 nanotube Schottky diodes and field-effect transistors (FETs) were fabricated with large on/off current ratios of up to 107 and very low leakage currents, representing an important step towards utilising these structures in optoelectronic and gas sensing applications. Interestingly, these FETs exhibit very large gate hysteresis effects which may be useful in SnO2 memristor-like devices. We have also recently fabricated a range of electrolytically-gated square nanotube FETs intended for neuromorphic and bio-sensing applications.

Submission number: 300

PROGRAMMABLE SPIN LOGIC BASED ON MAGNETIZATION SWITCHING IN A FERRIMAGNET VIA SPIN ORBIT TORQUE

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Keywords: Spintronics; Nanomagnetics

With traditional semiconductor-based logic approaching its limits with respect to size and power efficiency, an active search for possible alternatives that replace or complement these established technologies is currently in progress. Spin based logic, which utilizes both the charge as well as the spin of the electron, has shown promise in this regard. By manipulating the effect of the spin orbit torque (SOT) on a magnetic material, we can realize different logic operations. In this work, we realize four logic operations, namely AND, OR, NAND and NOR, in a heavy metal (Pt)/ ferrimagnet (GdFe) bilayer via SOT driven magnetization switching. The lower and higher amplitudes of the applied longitudinal current define input 0 and input 1, respectively, while the negative and positive polarities of the measured Hall voltage define output 0 and output 1, respectively. The effect of the SOT on the magnetization is controlled by varying the external in-plane magnetic field. Such programmable SOT driven logic can be viable for use in logic-in-memory architectures, thus solving the size and energy constraints faced by conventional logic devices.

Submission number: 301

IN VIVO APPLICATION OF 3D BIOPRINTED SCAFFOLDS CONTAINING MXENE QUANTUM DOTS IN BREAST TISSUE REGENERATION AFTER MASTECTOMY

Alkaya, Damla; Ozgenc, Özge; ahmet, ceylan; EKIM, OKAN; sanjiv, dhingra; Acelya, Yilmazer*

Keywords: Nanomaterials; Nanobiomedicine

It is known that stem cells play a role in tissue repair and regeneration [1]. Emerging technologies developed for tissue engineering, such as 3D bioprinting, hold promising applications in breast cancer treatment [2]. Additionally, MXene-based nanomaterials are effectively and widely used in cancer treatments [3]. The aim of this study was to assess the influence of 3D bio-printed scaffolds containing stem cells and MXene quantum dots (MQDs) on breast tissue regeneration and cancer recurrence through in vivo transplantation after mastectomy in mice models. The fluorescent staining showed that the viability of embedded cells within the 3D printed scaffolds was greatly preserved. Subsequently, we performed mastectomy in mice models which was followed by transplantation of cellular or acellular 3D bioprinted scaffolds with and without MXene. Clinical examination after 7 days of transplantation revealed better outcomes in terms of adhesion and complication rates in acellular MXene-containing scaffolds. Immunohistochemical staining of tissue sections taken from mice on the 7th and 14th days was performed to understand breast tissue regeneration and tumor recurrence. Remarkably, no tumor formation was observed on the 14th day in the acellular MXene-containing scaffold group. Furthermore, based on increased expression of CK14 and TGF-b, we observed a higher regeneration rate in post-mastectomy tissue in our mice mastectomy models. In conclusion, in this study, we developed a hydrogel-based scaffold design containing MQDs for post-mastectomy transplantation in breast cancer surgery. Furthermore, our study demonstrated a dual effect that could support regeneration while preventing tumor recurrence, thus supporting surgical practice. These findings suggest that our approach could be considered as a feasible and innovative treatment option in breast cancer therapy in the future.

Submission number: 302

NOVEL AND QUICK MAGNETIC METHODOLOGY FOR IN SITU MONITORING REDOX REACTIONS IN THE LIQUID PHASE: REVISITING THE PROPERTIES OF FE-CR SPINELS

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Keywords: Nanomagnetics; Nano-Energy, Environment, and Safety; Nano-Metrology and Characterization

The pollution of water bodies with heavy metals is a major public health concern. In this regard, while Cr(III) has been proposed to be an essential nutrient, hexavalent chromium Cr(VI) is mainly a man-made by-product classified as Group A (known human carcinogen) [ref. 1]. Therefore, novel methodologies are required to remediate and monitor its concentration in drinking water. Building on our previous work [ref. 2], this study aims to determine the adsorption mechanism of Cr(VI) onto the surface of Fe_3O_4 nanoparticles. To this end, we employed a bunch of techniques such as X-ray photoelectron spectroscopy, chemical analysis, and temperature-dependent transport measurements. Parenthetically, we also explored the potential of AC magnetometry for monitoring the reaction kinetics. In doing so, we surmised the oxidation of Fe^{2+} ions to Fe^{3+} ions triggers rapid reduction of Cr(VI) onto magnetite nanocrystals, giving rise to a passivation $Fe_{3-x}Cr_xO_4$ spinel. An initial reduction of the lattice parameter (see figure) results from the replacement of ‘large’ Fe^{3+} cations by smaller Cr^{3+} at the octahedral sites, while the subsequent gradual recovery is due to Fe^{2+} ions being forced into the tetrahedral sites. The figure shows kinetic data of Cr(VI) uptake by magnetite nanoparticles. The Freundlich fit of the adsorbent capacity evaluated by measuring the residual Cr(VI) concentration after treatment is compared to the variation of coercivity on increasing immersion time, measured at 100 kHz. Additional information can be obtained from the deviation of Vegard’s law for the Fe_3O_4–$FeCr_2O_4$ system. A clear signature of the lattice constants is found by following the concentration-dependence of the hysteresis area as a proxy for the magnetic anisotropy. In summary, our work suggests that changes in lattice parameters appreciably influence the magnetic anisotropy of the resulting core-shell nanocrystals. Consequently, the combined use of ferrite nanoparticles as an adsorptive agent and AC magnetometry allows the detection of Cr(VI) at mg/L concentration levels and evaluation of adsorption performance.

Submission number: 303

THEORETICAL STUDY OF LI ATOM DIFFUSION IN SI AND SIC NANOSTRUCTURES

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Keywords: Nanomaterials; Nanoelectronics; Modeling and Simulation

In this work, we present a density functional theory study of the chemical reaction path or diffusion of a Lithium (Li) atom in bulk crystalline, monolayer and nanowire silicon (Si) and Silicon Carbide (SiC) structures, by the Dmol3 module incorporated in the Materials Studio software. The model considers an initial and final positions where the reaction occurs. For the bulk material the choose places are two equivalents Td sites, which are the centers of the tetrahedra formed by four atoms in the diamond structure. For the nanowire the reactant site is a Td on the surface of the nanowire, and the product site is an equivalent Td site in the structure of the nanowire. Likewise, for the Si monolayer the react and product site corresponds to two equivalents hexagonal sites over the monolayer, while for the SiC monolayer both sites correspond to top site over one Si atom. Figure 1 depicts the initial and final position of the Li atom for all studied structures. The results indicate that the diffusion path is symmetric for the Li atom for the Si bulk structure, and the monolayer one, as result of only one atomic specie in the structure. In contrast, the path for the SiC bulk is asymmetric due to two atomic species. The surface effects are more evident in the SiC monolayer where the reaction path is symmetric, and for both SiC and Si nanowires the asymmetry of the diffusion path is the result of the environment of the Li atom. These results reveal the effects of the dimensionality and atomic species in the diffusion of Li atoms, such as the values of the potential barrier due these restrictions. Else the results allow understanding the process during the charge or discharge cycle in electrodes of one battery.

Submission number: 304

CONDITIONAL AND MULTI-LEVEL WRITE OPERATIONS ON CURRENT-CONTROLLED MEMRISTIVE DEVICES FOR NEUROMORPHIC APPLICATIONS

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Keywords: Nanosensors and Nanoactuators; Modeling and Simulation

The analog response of memristive devices makes them suitable for various applications, such as multi-level memory and neuromorphic computing. When the devices are voltage-driven, resistive switching is associated with voltage thresholds, representing the minimum required voltage to trigger a SET or RESET. Most simulation models correspond to voltage-controlled memristive devices, and multi-level tuning in such cases can be achieved via a controlled voltage-driven SET process. However, when current drivers are used instead of voltage drivers, a proper assessment of device performance should also consider models of current-controlled devices whose response adheres to current thresholds. To this end, here we provide both the voltage- and the current-controlled version of a behavioral model of memristive devices in a readily available netlist for simulation in LTSpice. We present simulation results using both model versions and show that, to achieve multi-level tuning of current-controlled devices when current-driven, a current divider circuit can enable a controlled RESET process. Finally, we provide experimental results for the controlled switching response of Self-Directed Channel (SDC) bipolar memristive devices by Knowm Inc. Overall, we demonstrate the feasibility of conditional and multi-level switching of current-controlled memristive devices, towards the design of current-based multi-level drivers and in-memory logic based on the conditional switching response triggered via current stimuli.

Submission number: 305

INVERSE EMULSION TECHNIQUE TO PRODUCE FLEXIBLE ASYMMETRIC LIPOSOMES FOR GENETIC MATERIAL ENCAPSULATION.

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Keywords: Nanomaterials; AI for Nanotechnology; Nanobiomedicine

During decades different nanocarriers for pharmaceutical delivery have been explored. Of these-nanocarriers, liposomes have gained importance, because of their improved characteristics, such as-biodegradability and low toxicity [1]. Liposomes are artificial spherical shape vesicles composed of lipid-bilayers [2]. There are different types of liposomes, the symmetric ones have the same lipids composition in-the inner and outer layers. In the other side, asymmetric liposomes have different lipids in the inner and outer-parts of the bilayer. This feature gives the asymmetric vesicle advantages such as optimizing the charges [3][5],-encapsulation efficiency and a reduction of drug leakage[6][7]. Transdermal delivery of liposomes is also-attractive to the pharmaceutical industry [8][9], and represents a viable alternative for optimizing problems as-poor biodistribution, off-target side effects, and a short circulation time [10]. Also, these vesicles have the-capacity of encapsulating and protecting molecules as nucleic acids [11][12] giving them importance in the-molecular medicine field. A suitable carrier with a high nucleic acid loading capacity is required and currently,-no stable vehicle has been designed for transdermal delivery of nucleic acids. Asymmetric liposomes, promise-to be a viable alternative for loading genetic material, but their use as transdermal drug delivery systems has not been explored yet. For this reason, the purpose of this study was to develop a flexible asymmetrical-liposome capable of loading a high percentage of nucleic acids in a stable way. The synthesis of asymmetric liposomes is still in development, during the present work, asymmetric
flexible liposomes for nucleic acid encapsulation were designed through the inverse emulsion technique,-expecting that these liposomes could be applied by the transdermal route, which is why components as span-80 and ethanol were used to make them flexible and capable of passing through the stratum corneum of the-skin. The inverse emulsion technique had some modifications, especially to protect the genetic material-through the synthesis process. Six different liposome formulations were synthesized using a cationic lipid-(DOTMA and DOPE) for the inner layer and a neutral lipid (DSPC) for the outer layer, changing the added-components for flexibility (ethanol and span 80 surfactant) and stability (cholesterol). Each formulation was-characterized by transmission electron microscopy (TEM), particle size distribution, encapsulation efficiency (%EE) and flexibility index through extrusion method.-The characterization by TEM shows notable changes in the shape of the liposome, when the more
flexibility components are in the formulation, the bilayer tends to lose its round shape and

is less defined.-Otherwise, the addition of cholesterol showed a spherical shape with well-defined asymmetric bilayers, and a-reduction in vesicle diameter. The particle size distribution shows that the vesicles are found in sizes between-25 (for formulations with cholesterol) and 120 (for formulations with Span 80) nanometers, sizes that, being less than 200 nanometers, are ideal for transdermic administration. According to these results, the average-diameter varies depending on the bilayers components. For encapsulation efficiency, 440 ng of pDNA were used per synthesis, and results show that formulations with span 80 and ethanol obtained the highest %EE-(94%), and the formulation with less %EE was the one with lipids and ethanol with a 73%. Symmetrical-liposomes were used as a control (DSPC liposomes by thin film hydration technique) and obtained a 43% which indicates that the asymmetry of the bilayers improves the %EE. Flexibility index was measured by extrusion and shows that formulations containing ethanol and span 80 separately have the highest flexibility indexes, these being 0.6 and 0.4 respectively, the liposomes with no-flexibility components had an 0.11 flexibility index. As future expectations, the evaluation of these liposomes-will continue through cytotoxicity and transfection techniques in fibroblast cell line. Flexibility will be further-characterized through the parallel artificial membrane technique. Based on these results, we conclude that-asymmetric liposomes with flexibility components have high %EE of nucleic acids, as well as good flexibility-indexes. As a result, they can be used in the pharmaceutical industry as transdermic nucleic acid delivery.

References
[1] S. Bhatia, "Nanoparticles Types, Classification, Characterization, Fabrication Methods and Drug Delivery Applications," in Natural Polymer Drug Delivery Systems, Cham: Springer International Publishing, 2016, pp. 33-93. doi: 10.1007/978-3-319-41129-3-2.
[2] L. Van Der Koog, T. B. Gandek, and A. Nagelkerke, "Liposomes and Extracellular Vesicles as Drug Delivery Systems: A Comparison of Composition, Pharmacokinetics, and Functionalization," Adv. Healthc. Mater., vol. 11, no. 5, p. 2100639, Mar. 2022, doi: 10.1002/adhm.202100639.
[3] B. Li and E. London, "Preparation and Drug Entrapment Properties of Asymmetric Liposomes Containing Cationic and Anionic Lipids," Langmuir, vol. 36, no. 42, pp. 12521-12531, Oct. 2020, doi: 10.1021/acs.langmuir.0c01968.
[4] L. Zangi et al., "Modified mRNA directs the fate of heart progenitor cells and induces vascular regeneration after myocardial infarction," Nat. Biotechnol., vol. 31, no. 10, pp. 898-907, Oct. 2013, doi: 10.1038/nbt.2682.
[5] A. Komin, M. I. Bogorad, R. Lin, H. Cui, P. C. Searson, and K. Hristova, "A peptide for transcellular cargo delivery: Structure-function relationship and mechanism of action," J. Controlled Release, vol. 324, pp. 633-643, Aug. 2020, doi: 10.1016/j.jconrel.2020.05.030.
[6] Y. N. Al Badri, C. S. Chaw, and A. A. Elkordy, "Insights into Asymmetric Liposomes as a Potential Intervention for Drug Delivery Including Pulmonary Nanotherapeutics," Pharmaceutics, vol. 15, no. 1, p.

294, Jan. 2023, doi:
10.3390/pharmaceutics15010294.
[7] A. Hussain, S. Singh, D. Sharma, T. Webster, K. Shafaat, and A. Faruk, "Elastic liposomes as novel carriers: recent
advances in drug delivery," Int. J. Nanomedicine, vol. Volume 12, pp. 5087-5108, Jul. 2017, doi:
10.2147/IJN.S138267.
[8] B. D. Kurmi, P. Tekchandani, R. Paliwal, and S. R. Paliwal, "Transdermal Drug Delivery: Opportunities and
Challenges for Controlled Delivery of Therapeutic Agents Using Nanocarriers," Curr. Drug Metab., vol. 18, no. 5,
pp. 481-495, May 2017, doi: 10.2174/1389200218666170222150555.
[9] D. Ramadon, M. T. C. McCrudden, A. J. Courtenay, and R. F. Donnelly, "Enhancement strategies for transdermal
drug delivery systems: current trends and applications," Drug Deliv. Transl. Res., vol. 12, no. 4, pp. 758-791, Apr.
2022, doi: 10.1007/s13346-021-00909-6.
[10] P. Chaurasiya, E. Ganju, N. Upmanyu, S. K. Ray, and P. Jain, "Transfersomes: a novel technique for transdermal
drug delivery," J. Drug Deliv. Ther., vol. 9, no. 1, pp. 279-285, Jan. 2019, doi: 10.22270/jddt.v9i1.2198.
[11] A. I. S. Van Den Berg, C.-O. Yun, R. M. Schiffelers, and W. E. Hennink, "Polymeric delivery systems for nucleic
acid therapeutics: Approaching the clinic," J. Controlled Release, vol. 331, pp. 121-141, Mar. 2021, doi:
10.1016/j.jconrel.2021.01.014.
[12] M. B. C. De Matos et al., "Liposomes with asymmetric bilayers produced from inverse emulsions for nucleic acid
delivery," J. Drug Target., vol. 27, no. 5-6, pp. 681-689, Jul. 2019, doi: 10.1080/1061186X.2019.1579819.

Submission number: 306

BOSCH-ETCHED NANOJUNGLE BLACK SILICON AND ITS APPLICATIONS

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Keywords: Nanofabrication; Nanomaterials; Hydrophobic, Oleophobic and/or Icephobic nanostructured surfaces

Black silicon (b-Si) is a class of silicon materials featuring nanostructures that enable remarkable light absorption within the visible spectrum, earning it the designation “black” silicon. Its distinctively rough and nanostructured surface makes it suitable for various applications such as water-repellent surfaces and optoelectronics. Superhydrophobic surfaces derived from b-Si hold potential applications in industries like aviation and electronic packaging. Additionally, its light-diffusing characteristics broaden its utility to fields like IoT and solar energy harvesting, enhancing absorption within the visible spectrum.-Traditional b-Si, shown as nanograss b-Si in Figure 1a, is typically produced through cryo deep-etching with a depth limit of 4-5 -956;m. Our new method using Bosch etching has created nanojungle b-Si, also in Figure 1a, with depths over 10 -956;m. This advancement expands b-Si applications, including durable superhydrophobic surfaces and near-infrared light diffusion.-The durability of nanojungle b-Si was confirmed via a sand blasting abrasion assessment. In this experimental arrangement, a certain amount of sand was directed to impact samples positioned at a 45-degree angle from various heights. Figure 1b demonstrates that nanojungle b-Si maintained its superhydrophobic characteristic at heights reaching up to 40 cm, while nanograss b-Si ceased to exhibit this property beyond 20 cm.-The distinctive architecture of nanojungle b-Si grants it remarkable proficiency in diffusing near-infrared (NIR) light. Illustrated in Figure 1c, nearly 100% of the transmittance within the NIR spectrum is diffused. Consequently, haze values were calculated and compared with those of nanograss b-Si. In the case of nanograss b-Si, the haze was noted to be marginally below 60%.

Submission number: 307

ACCURATE DETERMINATION OF SIZE DISTRIBUTION OF NANOMATERIALS: PROBLEM OF TRADITIONAL SIZING METHODS AND NOVEL TECHNOLOGY OF SIZING

Kato, Haruhisa*; Nakamura, Ayako

Keywords: Nano-Metrology and Characterization; Nanomaterials; Nanobiomedicine

Reduction of the size of materials could induce nano-enable specific characteristics, the research of nano-sized materials has been increasing. Considering the relationship between material size and functional/application characteristics, the size determination of nanomaterials is therefore crucial for developing nanoscale technologies. Since the nanomaterials were used in various areas such as cosmetic, ink, and food; nanomaterial product in liquid phase; the accurate sizing techniques of nanomaterials is significant in such fields. On the other hands, the European Commission has declared that a “nanomaterial” is a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50% or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm–100 nm. According to this definition, not only averaged size but also the size distribution of nanomaterials in is an important characteristic for nanomaterial industrial field. There are various techniques of sizing of nanomaterials; however, users have been confusing to select appropriate sizing methods on nanomaterials. In the past few decades, dynamic light scattering (DLS) and particle tracking analysis (PTA) have been widely used for determining the sizes of Brownian nanoparticles in nano- and submicron-scale bio-colloidal suspensions. However, the apparent sizes of nanoparticles over a wide size distribution depends on the particular analytical algorism. While electric microscope (EM) is effective method to obtain the primary particle information visually, however; it requires counting a large number of materials for ensemble characterization. In contrast to such traditional characterization methods, recent characterization methods such as field-flow fractionation (FFF) and flow particle tracking (FPT) have given more accurate sizing results. Hybrid method to combine two characterization method (FFF-EM) will give not only sizing information but also shape distribution information. Although all methods have good/weak points, one of the answers of the selection of appropriate sizing method will be introduced in this presentation.

Submission number: 308

GREEN SYNTHESIS OF COLLOIDAL GOLD-BASED ANISOTROPIC NANOSTRUCTURES AND THEIR APPLICATION AS ACTIVE SERS SUBSTRATES FOR THE DETECTION OF ORGANIC DYES

Garcia Garcia, Maria Paula*; Cholula-Diaz, Jorge L.

Keywords: Nanomaterials; Nanosensors and Nanoactuators; Nano-Optics,

Nanophotonics, and Nano-Optoelectronics

Surface-enhanced Raman spectroscopy (SERS) has had recent relevance as an analytical technique due to its high sensitivity in the detection of several types of molecules. A major breakthrough has been the use of noble metal-based anisotropic nanostructures as SERS substrates due to the possibility to tune their localized surface plasmon resonance (LSPR) in the visible and near infrared regions, which enhances consequently the SERS response. However, the development of an environmentally responsible synthesis of anisotropic nanostructures with a defined morphology and size presents major obstacles that needs to be investigated further.- In the present work, a green synthesis of anisotropic gold nanostructures (Au-NSs) as colloids was proposed, following a modified seed mediated method [1], using starch-capped bimetallic gold/silver nanoparticles (Au/Ag-NPs) as seeds, followed by a growth step carried out at low temperatures (10-15ºC) and neutral pH, using hydrogen peroxide (H2O2) as a reducing agent. Finally, a purification step by centrifugation for shape separation was included, to obtain Au-NSs with a "nanorod"-type morphology.- In the application of these colloidal nanostructures as SERS substrates for the detection of methylene blue (MB), crystal violet (CV) and malachite green oxalate (MGO) in aqueous solutions, an analytical enhancement factor of the Raman signal of 5.8x10^5 for MB, 6.3x10^8 for CV and 1.8x10^7 for MGO was obtained, as well as detection limits of 1x10^-7 M for MB and 1x10^-9 M for CV and MGO, which is relevant to the application of the Au-NSs for quantitative analysis of organic pollutants. Currently, the potential use of the anisotropic Au-NSs to detect relevant biomolecules, such cysteine or ascorbic acid, is under investigation.

Submission number: 309

GREEN SYNTHESIS OF METAL-BASED NANOSTRUCTURES AND THEIR BIOMEDICAL APPLICATIONS

Cholula-Diaz, Jorge L.*

Keywords: Nanomaterials; Nanobiomedicine; Nanofabrication

Nanotechnology has been recognized as a reliable strategy to respond to the global challenges related to the environment and healthcare issues of modern societies. However, the nanoscale has its own drawbacks, particularly those related to the sustainable production of nanomaterials. Thus, green nanotechnology has emerged as a new discipline in the synthesis of nanomaterials following the principles of green chemistry. Therefore, green nanotechnology has been conceived to target the synthesis of nanomaterials by using plant extracts, biomolecules, bacteria and viruses, natural waste materials or environment-friendly physical methods that either decrease or remove the need for harmful substances, such as toxic solvents or reducing and capping agents [1]. In terms of the biomedical application of nanostructures, green-synthesized metal-based nanomaterials have exhibited great potential as active antimicrobial, antiviral and anticancer agents [2]. In this talk, the green synthesis of metal-based nanostructures and their use in biomedical applications, specifically as bioactive anticancer agents against human breast cancer cells, will be covered.- Acknowledgements The author thanks Acciones Bilaterales de Movilidad Conjunta, Modalidad B, program (ref. BILTC22001) for financial support and the School of Engineering and Sciences at Tecnologico de Monterrey for access to laboratories and characterization equipment.-

References

[1]--D. Lomeli-Marroquin et al., Int. J. Nanomedicine 14 (2019) 2171-2190.
[2]--A. Nieto-Argüello et al., Nanomaterials 12 (2022) 779.

Submission number: 310

VARIOUS DISPLAY APPLICATIONS OF GREEN INP QUANTUM DOTS WITH P(DEA)3 AS P PRECURSOR

Park, Jae Hyung; Oh, Min Suk; Kim, Yong-Hoon; Yang, Heesun; Kim, Hyeok; Kim, Jiwan*

Keywords: Nanomaterials; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

Colloidal quantum dots (QDs), as semiconductor nanoparticles, exhibit distinctive electrical and optical properties. Due to the quantum confinement effect, QDs have huge benefit on color-tunability through particle size control and excellent color gamut. These advantages make QD electroluminescence (EL) devices, using QDs as the emission layer (EML), get significant attention as a next-generation display technology. In the past, QLEDs with high brightness was mainly developed using cadmium (Cd) QDs as the EML. However, the usage of Cd QDs has been restricted due to the Restriction of Hazardous Substances in Europe. Therefore, indium phosphide (InP) QDs are of great interest as a potential alternative to replace Cd based QDs with a broad visible emission range. Currently, InP QDs using tris(trimethylsilyl)phosphine (P(TMS)3) as the P precursor have a high photoluminescence quantum yield (PL QY) and a narrow full width at half maximum (FWHM). However, the use of P(TMS)3 in the synthesis of InP QDs is very cautious because it is explosive, toxic, and even expensive. Thus, various less reactive P precursors have been attempted to impede InP core growth. Tris(diethylamino)phosphine (P(DEA)3) is the one of the strong candidates satisfying the above conditions.[1] In this work, we present the synthesis of green-emitting InP/ZnSe/ZnS quantum dots using P(DEA)3, zinc chloride, and indium (III) iodide as precursors. The adoption of an InP/ZnSe/ZnS heterostructure effectively reduces the lattice mismatch between the InP core and ZnS outer shell. Thus, interfacial strain and PL QY were effectively improved by inserting additional inner shell with oleic amine ligands. Optimization of various synthetic conditions, including temperature, reaction time, and the ratio of P and I precursors, resulted in green InP QDs with an impressive PL QY of 87% and a narrow FWHM of up to 39 nm. Both EL and PL applications of green InP QDs were manufactured successfully. Figure 1 shows the blue to green color conversion by QD-PMMA composites. Additionally, bright InP based QD EL devices with an inverted structure were fabricated and showed a maximum luminescence of about 500 cd/m2.

Submission number: 311

DEVELOPMENT OF AN ULTRASENSITIVE NANOZYME-BASED IMMUNOCHROMATOGRAPHIC PLATFORM FOR QUANTITATIVE DETECTION OF NT-PROBNP USING V2(SN0.8PT0.2)C MAX PHASE

Tan, Huiling; Zhu, Shuairu; Zhuang, Weihua; Hu, Walter*

Keywords: Nanosensors and Nanoactuators; Nanomaterials

N-terminal pro-brain natriuretic peptide (NT-proBNP) has been demonstrated to be as a sensitive and specific biomarker for the heart failure (HF) management, while the development of timely and accurate point-of-care testing methods for frequent quantitative monitoring of NT-proBNP remains challenging [1]. Nanozymes are gaining increasing attention as an alternative to natural enzymes for colorimetric lateral flow immunoassay (LFIA). However, the development of nanozymes with high catalytic activity and colorimetric signal amplification still poses challenges [2]. Herein, we develop a novel nanozyme system with peroxidase (POD)-like activity by incorporating Pt into the A layer of V2SnC MAX phase. V2(Sn0.8Pt0.2)C MAX displays enhanced brightness in colorimetric signal and remarkably high peroxidase mimicking activity (2542.9 U mg-1), which contributes to the improvement of LFIA sensitivity through catalytic amplification. Density functional theory (DFT) calculations reveal that the presence of Pt effectively lowers the energy barrier for H2O2 adsorption at the A site in V2SnC. Specifically, V2(Sn0.8Pt0.2)C-immunolabeled LFIA strips were developed for the detection of NT-proBNP, exhibiting an unprecedented limit of detection at 0.0016 ng mL-1 , which is remarkably enhanced by 1437-fold compared to conventional Au nanoparticles-based LFIA methods. Furthermore, these LFIA strips also demonstrated excellent performance in detecting human plasma-containing samples with a sensitivity of 0.02 ng mL-1 within a linear detection range of 0.02-71.64 ng mL-1 . These findings suggest that V2(Sn0.8Pt0.2)C holds great potential as a signal reporter for the development of highly sensitive LFIA assays aimed at accurately monitoring HF progression and prognosis.

References

[1] Khan, M. S, Greene, S. J, DeVore, A. D, JACC Heart Fail. 12 (2024), 488-491.
[2] Cheng, N, Song, Y, Zeinhom, M. M. A, Chang, Y. C, Sheng, L, Li, H, Du, D, Li, L, Zhu, M. J, Luo, Y, Xu, W, Lin, Y,
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Submission number: 312

PLASMA BASED METHOD FOR SYNTHESIS OF IRON-CONTAINING NANOPARTICLES AND THEIR PROTECTION THROUGH INCORPORATION IN ORGANOSILICON MATRIX

Berard, Remi*; Gaboriau, Freddy; Sabbah, Hassan; Joblin, Christine; Makasheva, Kremena

Keywords: Nanofabrication; Nanomaterials; Emerging Plasma Nanotechnologies

Iron, iron oxide (Fe_2O_3, Fe_3O_4) or iron carbide (Fe_3C) nanoparticles, called hereafter FeNPs, are of interest for applications in catalysis, electronic devices or biomedicine. Nowadays, most of the FeNPs are oxides, synthesized by chemical methods, but when performed in a liquid medium aggregation might be an issue. Furthermore, Fe- or FeCx-nanoparticles are more difficult to synthesize and stabilize due to efficient oxidation processes. Incorporation of FeNPs into a matrix during the synthesis process can be a way to overcome both aggregation and oxidation stability issues.-In recent years, we have studied and demonstrated the possibility of embedding pure crystalline, non-oxidized, silver nanoparticles (AgNPs) in organosilicon (SiOxCy:H) or silica (SiO_2) matrices by using an asymmetric radio-frequency capacitively-coupled discharge. The vector gas is argon (Ar). The asymmetry of the plasma reactor leads to the build-up of a self-bias voltage on the powered electrode and to the acceleration of ions from the plasma toward it. Thus, a hybrid plasma process, which combines physical vapor deposition (PVD), by sputtering of a metallic target, and plasma enhanced chemical vapor deposition (PECVD), using pulsed injection of the precursor, hexamethyldisiloxane ($Si_2O(CH_3)_6$, HMDSO), is promoted. The working hypothesis is therefore based on the possibility of designing similar nanocomposite structures, but containing pure iron or iron oxide nanoparticles.

Submission number: 313

QUANTIFYING NANOPARTICLES USING ELECTROSPRAY-SCANNING MOBILITY PARTICLE SIZER

Kim, Jaeseok*

Keywords: Nanomaterials; Nano-Metrology and Characterization; Nanobiomedicine

Nanoparticles are used in various fields such as medicine, environment, food, and electronics [1]. Although accurate quantification of number concentration of colloidal nanoparticles is needed for evaluating safety of nanoparticles, it is quite challenging and there are also no certified reference materials (CRMs), yet. In this study, a scanning mobility particle sizer (SMPS) with electrospray was used to determine number concentration of gold nanoparticles. We compared a value with results calculated by size and mass concentration measured by transmission electron microscope (TEM) and inductively coupled plasma-optical emission spectrometer (ICP-OES), respectively. Number concentration of 90 nm gold nanoparticles (KRISS 301-01-004) is (4.62±0.73)×109 #/mL. It is similar to the value derived by TEM and ICP-OES. It suggests that the SMPS technique with electrospray is one of candidates for quantification of nanoparticles.

Submission number: 314

SPIN-ORBIT TORQUE ENGINEERING BY TI ALLOYING IN BETA W-BASED HETEROSTRUCTURES

Lee, Jiyoung; Nguyen, Quynh Anh T.; Kim, Doowon; Lee, Jeong Kyu; Rhim, Sonny H.;

Kim, Young Keun*

Keywords: Spintronics; Nanomagnetics; Nanomaterials

Magnetoresistive Random Access Memory (MRAM) is garnering attention as a potential candidate for the next generation of memory devices. Among the various writing mechanisms of MRAM, spin-orbit torque (SOT) offers advantages in terms of rapid operation speed and power efficiency [1]. To enable the commercialization of SOT-based MRAM, it is essential for the device to utilize materials compatible with semiconductor fabrication processes and exhibit stability under thermal annealing at 300oC. In this study, we explored the properties of SOT in -946;-W-Ti/CoFeB heterostructures. Through first-principles calculations, we assessed the spin Hall conductivity and phase stability while adjusting the composition of Ti in the -946;-W-Ti alloy. Subsequently, we fabricated the -946;-W-Ti/CoFeB/MgO/Ta structure and subjected it to post-annealing at 300oC for 1 hour under a 6 kOe of external magnetic field. Analysis via Rutherford backscattering spectroscopy (RBS), Transmission electron microscopy (TEM) and X-ray diffraction (XRD) verified the composition of Ti in -946;-W-Ti alloys and the dissolution of Ti in -946;-W matrix. Vibrating sample magnetometry (VSM) measurements confirmed the perpendicular magnetic anisotropy (PMA) of the samples after annealing process. Additionally, we observed lower resistivity in -946;-W-Ti (~149 -956;-937;·cm) at 11.5 atomic percent of Ti compared to -946;-W (~200 -956;-937;·cm) samples [2]. SOT efficiency was evaluated through harmonic Hall voltage measurements on samples exhibiting PMA. The sample with 11.5 at% of Ti displays the highest damping like torque (DLT) efficiency (0.54) and spin Hall conductivity (-1811 (-8463;/e) -937;-1cm-1) aligning with theoretical calculations. Furthermore, to assess magnetization switching current, we utilized PMA samples to 6 x 6 -956;m2 ferromagnet island on the center of the Hall bar structure. At 11.5 at% of Ti exhibits the lowest switching current density of 15 MA/cm2.

Submission number: 315

PAN NANOFIBER-BASED RADIATIVE COOLING SHEET WITH DUAL-MODAL OPTICAL PROPERTIES

LEE, Tae Yoon; son, soomin; Kim, Young Keun*

Keywords: Nano-Energy, Environment, and Safety; Nanomaterials

Global warming is leading to an increase in Earth's average temperature, resulting in a higher demand for energy in cooling systems for buildings, vehicles, and other objects. There is a growing need for the development of new materials that can cool these structures and vehicles without consuming energy. Radiative cooling materials are among the solutions being explored to address this challenge. This research discusses the potential of such materials in breaking the vicious cycle of energy consumption and global warming by offering a sustainable cooling alternative. Radiative cooling materials must possess two key optical properties to be effective.[1] First, they should maximize thermal emission in the 8 to 13 micron wavelength range, allowing thermal energy to escape into space. The second optical property is a high reflectivity in the 0.2 to 2 micron wavelength range. Since solar heat significantly impedes the cooling of objects.[2] The radiative cooling material was synthesized by electrospinning PAN(Polyacrylonitrile) polymer along with Al_2O_3 and SiO_2 nanoparticles. The primary difference between this material and existing ones lies in its capability for property transformation. Radiative cooling materials can be broadly categorized into two types: selective emitters and broadband emitters. A selective emitter exhibits high emissivity only in the 8-13 micron wavelength range, while a broadband emitter maintains high emissivity not only in the 8-13 micron range but also across all wavelengths. Previously researched materials couldn't simultaneously exhibit both characteristics. However, the material developed in our study can possess both properties depending on the substrate used. PAN exhibits high transmittance except in the solar spectrum, and we observed that its overall optical properties vary depending on the substrate. On a metal substrate, it behaves as a selective emitter polymer, while on a ceramic substrate, it exhibits broadband emitter properties. High cooling efficiency of 89.51 W/m^2 was also confirmed.

Submission number: 316

A RADIO FREQUENCY STUDY OF MAGNETIC NANOPARTICLES DEPOSITED ON SOLIDS FOR SENSING APPLICATIONS

Fraile Aguirre, Leyre*; MARQUES, JOSE LUIS; PILATI, VANESSA; SALVADOR, MARiA; MARTiNEZ-GARCiA, JOSe CARLOS; RIVAS, MONTSERRAT

Keywords: Nanosensors and Nanoactuators; Nanobiomedicine; Nanomagnetics

Magnetic nanoparticles are excellent candidates for labeling and detecting biomarkers in rapid diagnostic tests such as lateral flow immunoassays [1]. However, this type of test requires a good capillary flow of the bioconjugates along the membrane, thus limiting the size of the nanoparticles and the bioconjugates. A study of magnetic nanoparticles deposited on solid substrates could open the door for developing static immunoassays such as an ELISA. Therefore, bigger-sized magnetic nanoparticles could be used, contributing to a larger sensitivity and binding range. It could also be used for the measurement of magnetic nanoparticles inside cells. In this work, we designed and optimized a new measurement system using a refractometry and radiofrequency sensor [2]. We synthesized magnetic biofunctional nanoparticles based on manganese ferrites using the hydrothermal coprecipitation method. Finally, we deposited the synthesized magnetic nanoparticles in a solid substrate and quantified their signals. We obtained calibrations with a R^2 of 0.9995, and with a very big signal-to-noise ratio for this type of measurement. Therefore, our results support the promising use of this new measurement system for sensing applications.

Submission number: 317

THICK ELECTRODES FOR HIGH-CAPACITY LI-ION BATTERY USING CARBON NANOTUBE FILM

Cakmakci, Nilufer; Jeong, Youngjin*

Keywords: Nanomaterials

The escalating demand for high-capacity lithium-ion batteries as energy storage, driven by environmental-concerns stemming from fossil energy usage, necessitates innovative manufacturing approaches,-especially for mobile electronic devices and vehicles. Increasing the active material amount by thickening-the electrode stands out as a viable strategy to enhance the energy density of the battery. Thick electrodes-can be manufactured with conventional methods such as slurry casting and drying, meaning that they can-be fabricated without any additional technique. However, during the drying of the thick electrodes, several-challenges occur due to the delamination of the current collector and low adhesion between the electrode materials, resulting in microcracks. As a result of this, electrode deterioration occurs, and it notably-augments internal resistance due to extended lithium-ion diffusion pathways. Addressing this issue, we-present a novel solution by fabricating a bifunctional carbon nanotube-based thick electrode (BCTE) using-a straightforward method involving stacking of LiFePO4-casted carbon nanotube (CNT) sheets. The CNT-sheet has a porous three-dimensional network structure and can contribute to superb ionic and electronic-transport, making it a suitable electrode material. BCTE achieved a remarkable loading capacity of 135-mg cm-2 of LiFePO4, delivering an impressive areal capacity of 20.2 mAh cm-2 at a current density of 1-mA cm-2. Furthermore, BCTE exhibited superior rate performance, boasting high efficiency. According-to the electrochemical performance results, it was found that the CNT film acts as a conduit for lithium_x0002_ion transport within the thick electrode, effectively mitigating resistance and thus elevating the energy-density of lithium-ion batteries. Overall, this study presents that CNT sheet has remarkable potential for-thick electrode production

Submission number: 318

CARBON-SUPPORTED NI NANOPARTICLES: SYNERGIZING OF MAGNETISM AND ADSORPTION FOR ADVANCED WATER DECONTAMINATION

Mahmoud Fadel Abdel aziz, Mona*

Keywords: Nanobiomedicine; Nanomagnetics; Nanostructures for extreme environments

Water, a fundamental life-giving resource, is frequently threatened by industrial activities. The motivation for this work is to develop an effective method for decontaminating wastewater from industries. A promising approach is to use magnetic nanoparticles (NPs) exhibiting adsorption functionalities, allowing for easy removal through magnetic separation. Nickel (Ni) NPs have excellent catalytic activity and ferromagnetic behavior, facilitating efficient magnetic separation [1]. Coating Ni NPs with activated carbon is an ideal strategy for this purpose thanks to its low density and large porosity [2]. The samples were obtained following a two-step procedure to produce Ni@C catalysts. It consists of (i) the synthesis of nickel–imidazole MOF (NiOF) by a simple method in an aqueous medium and (ii) a thermal treatment at different carbonization temperatures to obtain a hybrid material formed by Ni NPs embedded in a carbon matrix. This work focuses on the production and analysis of carbon-supported Nickel NPs derived from nickel-organic frameworks, NiOFs (see Fig. 1). The microstructure, morphology, and magnetic properties of NPs with various sizes from 5 nm to 50 nm synthesized at different carbonization temperatures (400 to 1000 ºC) were investigated. Our findings indicate that Ni NPs are surrounded by graphite-like layers, providing natural protection against oxidation. Additionally, a continuous transformation of the metastable Ni phase with hexagonal (HCP) crystal structure to the stable cubic (FCC) with raising carbonization temperature is accompanied by a rise of the value of a saturation magnetization increment from 5 to 48 emu/g-Ni. Adsorption experiments show excellent performance in the removal of noble metal (Chromium) and a dye (Methylene Blue) from water. I will showcase the most promising Ni NPs for water decontamination in this presentation

Submission number: 319

INK-JET PRINTED GRAPHENE-SILICON SCHOTTKY DIODES

Grillo, Alessandro*; Peng, Zixing; Pelella, Aniello; Di Bartolomeo, Antonio; Casiraghi, Cinzia

Keywords: Nanoelectronics; Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanomaterials

Integration of graphene (Gr) in silicon-based technology is of crucial importance for enabling the next generation electronics, photonics and sensors [1]. Although numerous works have reported devices based on Gr-Si junctions, the integration process relies on the use of high-quality Gr produced by Chemical Vapour Deposition (CVD), making the fabrication steps expensive, time consuming and by limiting the large-scale devices' reproducibility. In this work we show that inkjet-printing enables simple and scalable integration of Gr into Si-technology [2]. We developed a simple fabrication procedure, based on the mechanical or chemical etching of the SiO2 layer from a standard Si wafer, followed by the inkjet printing of water-based printable Gr inks [3] on the exposed area. The obtained devices exhibit typical diode behavior, showcasing an ON/OFF ratio of about three orders of magnitude when measured in air at room temperature. Various theoretical models have been employed to analyze the transport mechanisms of the junction and to estimate key diode parameters like the Schottky barrier height and ideality factor. Additionally, we investigate the device behavior under different temperatures and light irradiation conditions. Notably, a significant photovoltaic effect is observed, rendering the diode suitable for advanced optoelectronic applications, particularly long-wavelength photodetectors. Within this context, we present a device composed of a network of printed diodes on the same substrate, functioning as a spatially selective photodetector. This allows for the identification of irradiated areas on the chip through variations in current measured by different diodes. Lastly, to demonstrate scalability and compatibility with silicon technology in a back-end-of-line process, we fabricate the same diode on a pre-patterned silicon substrate, selectively removing oxide layers using standard clean-room etching techniques. Our results demonstrate that inkjet printing is a cost-effective and scalable method, which is also compatible with back-end-of-line fabrication processes for the integration of graphene in the modern Si-technology.

Submission number: 320

A STRETCHABLE AND CONDUCTIVE SILVER NANOWIRE-ELASTOMER NANOCOMPOSITE FOR WEARABLE ULTRASONIC TRANSDUCER ARRAYS

Lu, Pengda; Gao, Shaowei; Peng, Chang*

Keywords: Nano-Acoustic Devices, Processes, and Materials

Over the past decade, with the rapid growth of microelectronics and soft materials, wearable ultrasound devices have been extensively developed for imaging internal organs and evaluating various physiological features in biomedical applications including monitoring blood pressure [1], [2], long-term monitoring of cardiac tissue [3], and imaging diverse organs [4]. To provide access to deep tissue and organ functions, wearable ultrasound devices are commonly fabricated with piezoelectric elements embedded in a flexible and stretchable substrate that is constructed by silicone-based elastomers. While adopting an elastomer-based substate can provide improved wearability compared to conventional ultrasound probes, wearable ultrasound devices lack backing layers that are essential for absorbing the backward traveling waves generated by the piezoelectric elements, leading to internal reverberations of the element after attachment on the back side of piezoelectric element and narrow bandwidth. In this study, we present the fabrication, characterization, and application of a silver nanowire (AgNW) elastomer nanocomposite for use as a backing layer in wearable ultrasonic transducer arrays (Fig. 1). Salt particles are first mixed with a small amount of water to slightly melt the particles, compressed into the desired shape, and dried to serve as 3D interconnected template. The template is then dip coated in an AgNW/ethanol solution, and the solvent is evaporated. Ecoflex precursors are poured into the AgNW/template, degassed to allow the liquid Ecoflex to infiltrate into the pores of the template, and cured at room temperature. The cured Ecoflex/AgNW/template is then immersed in hot water to dissolve the salt. After drying, the completed 3D interconnected porous AgNW/Ecoflex nanocomposites are cut into desired shapes (Fig. 1). The AgNW/Ecoflex nanocomposites are fabricated with an acoustic impedance of 3.8 MRayl and high stretchability (> 100% strain). The average resistance value of the nanocomposite is < 10 -937;, demonstrating its good conductivity. In the next step, the stretchable AgNW/Ecoflex backing layer will be integrated with a wearable ultrasonic transducer array to demonstrate its acoustic performances.

Submission number: 321

OPTIMIZATION OF MICROBUBBLE-ENHANCED MILD HYPERTHERMIA FOR TARGETED TUMOR THERAPY IN PORCINE LIVER

Lu, Pengda; Pu, Cong; Fu, Ben; Peng, Chang*

Keywords: Nano-Acoustic Devices, Processes, and Materials

Mild hyperthermia, which is defined as a sustained temperature of 39-45 °C for 30-60 minutes, has been combined with temperature sensitive nanodrugs, offering on-demand drug release for increased drug bioavailability and enhancing antitumor response [1], [2]. Ultrasound has been used as a modality to induce hyperthermia and is found to be advantageous over other thermal sources for its non-invasiveness and penetrating ability into deep tissues [3]. While high intensity focused ultrasound (HIFU) has been shown to be a valuable tool for eliciting focal thermal elevations at variable depths within tissues, it may not be favourable for inducing mild hyperthermia for treating tumors since the focal volume (i.e., treated volume) can be small compared to a tumor’s volume. In order to overcome this limitation, studies have shown that heating with microbubbles can enhance ultrasound’s heating capability by reducing the amount of energy needed for equivalent temperature rise [4]. Therefore, this study proposes to use microbubbles with HIFU to induce mild hyperthermia for a large heating volume in order to reduce treating time. The experiment setup for microbubble-enhanced mild hyperthermia study mainly consists of a custom-made single-element focused ultrasound transducer with a working frequency of 1.0 MHz, a motorized 3-axis stage to control the motion of the transducer, and a fresh porcine liver that is fixed at a holder. The thermocouple is positioned in the liver such that its tip is at the focus of the transducer. SonoVue microbubbles are introduced to the liver via local injections with a 19G needle at the transducer focus, which is also at the tip of the thermocouple. The measured variations in focal temperature in ex vivo liver tissue as a function of time for different focal pressures are illustrated in Fig. 1. The results indicate that HIFU with microbubble injections lead to greater tissue temperature elevations compared to HIFU-only treatment. The acoustic pressure is a critical parameter to affect the temperature elevation. In the next step, the effects of microbubble concentration and other sonication parameters on the temperature elevation will be explored.

Submission number: 322

SPIN NONLINEARITY FACILITATED BY DEFECT-ENABLED SPIN FILTERING IN A NON-MAGNETIC SEMICONDUCTOR NANOSTRUCTURE

Huang, Yuqing; Polojärvi, V; Aho, A; Isoaho, R; Hakkarainen, T; Guina, M; Buyanova, Irina; Chen, Weimin*

Keywords: Spintronics; Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanomaterials

Nonlinear effects and dynamics are found in a wide range of research fields. In magnetic materials, nonlinear spin dynamics enables ultrafast manipulation of spin, which promises high-speed nonvolatile information processing and storage for future spintronic applications. However, a nonlinear spin response is not yet demonstrated in a nonmagnetic material that lacks strong magnetic interactions. Dilute nitride III-V materials, e.g., GaNAs, have the ability to amplify the conduction-electron-spin polarization by filtering out minority spins via spin-polarized defect states at room temperature [1]. By coupling to such a spin filter, electron and exciton spin polarization from adjacent quantum-dots (QDs) (e.g. InAs QDs) can exceed 90% at room temperature – the highest value ever reported in a semiconductor [2]. Here, by employing coupled rate equations, we theoretically demonstrate the emergence of a nonlinear spin response in such a defect-enabled room-temperature spin amplifier. We experimentally showcase the proposed spin nonlinearity in a GaNAs/InAs-QD coupled all-semiconductor nanostructure, by closely examining the higher-harmonic generation, which converts the modulation of excitation polarization into the second-, third-, and fourth-order harmonic oscillations of the QD exciton density and spin polarization that can be directly measured by photoluminescence intensity and polarization. The observed spin nonlinearity originates from defect-mediated spin-dependent recombination that can be conveniently tuned with the defect density and an external magnetic field. The demonstrated spin nonlinearity can readily operate at a frequency exceeding 1 GHz in the studied GaNAs/InAs nanostructure at room temperature, with the potential of approaching THz [3]. Furthermore, we provide a guideline for rational design and optimization of the proposed spin nonlinearity in nonmagnetic semiconductors with simultaneously achievable higher operation speed and nonlinear response. This may help to extend the functionality of current semiconductor-based electronic and photonic technologies and could pave the way for nonlinear spintronic and spin-photonic device applications based on nonmagnetic semiconductor nanostructures.

Submission number: 323

ENHANCEMENT-MODE ALGAN/GAN HEMTS WITH DAMAGE-FREE NEUTRAL BEAM ETCHED GATE RECESS

Chen, Yi-Ho; Chu, FuChuan; Lee, Yao-Jen; Li, Yiming; Samukawa, Seiji*

Keywords: Nanofabrication; Nanoelectronics; Emerging Plasma Nanotechnologies

AlGaN/GaN HEMTs are third-generation semiconductor devices known for their high electron mobility and density of 2DEG, leading to depletion mode operation. However, achieving enhancement-mode (E-mode) HEMTs requires complex circuitry. Recess gate etching simplifies this process but must be carefully performed due to the delicate gate structure. Neutral beam etching (NBE) has been shown to achieve atomically flat and defect-free interfaces, making it ideal for recess gate etching. In this study, NBE was used to enable E-mode operation in GaN HEMTs. Device fabrication commenced with mesa isolation formation by Cl2-based gas dry etching. Following were the source/drain regions definition and Ti/Al/Ni/Au metal stacks deposition by e-gun. Ohmic contact was then formed through annealing at 850°C in an N2 environment. After the gate region was defined, recess etching was performed and the Ni/Au was deposited as the gate metal. The recess gate etching was performed by NBE with Cl2 gas at a flow rate of 40 sccm, a source power of 400 W, a bias power of 5 W, and a maintained pressure of 0.1 Pa. The damages caused by the conventional plasma, such as charged particles and UV photon irradiation, do not occur in NBE since charged particles and UV photons are almost blocked by the high aspect-ratio aperture, resulting in low-damage etching, which is desired in the recess gate etching. The etched surface roughness measured by the atomic force microscope (AFM) of the recessed sample was slightly increased than that of the as-grown sample, which indicates the low damage of the NB etching. The threshold voltage (VTH) of the device without etching was -4.24 V. After recess etching by NB, the thickness of the AlGaN barrier was reduced to 9 nm, resulting in E-mode operation of the HEMT with VTH of 0.45 V. Pulsed IV measurements were also carried out. The gate and drain lag were calculated as 13.1% and 8.1%, respectively. The density of state (Nit) was also extracted through 1/f noise analysis. In summary, an E-mode AlGaN/GaN HEMT was successfully fabricated using NB recess etching. The device performance was characterized, demonstrating the low damage of NB etching for the recess gate.

Submission number: 324

HETEROSTRUCTURE-BASED SELF-DRIVEN TWO-DIMENSIONAL PHOTODETECTORS: DEVICES AND APPLICATIONS

RAN, HUO; Zhang, Han; Duan, Yu; zhang, jiyuan; Xu, Haoxuan; Zhang, Yuanting; Zhou, Changjian*

Keywords: Nanoelectronics; Nanosensors and Nanoactuators; Nanofabrication

Two-dimensional materials exhibiting extraordinary electronic and optoelectronic properties possess great potential to realize emerging ultrathin flexible and wearable photodetectors. Various mechanisms including photoconduction, photovoltaic, and photothermal effects have been adopted to implement two-dimensional photodetectors ranging from ultraviolet to infrared range. However, it poses considerable challenges to build low-power or even self-driven photodetectors based on two-dimensional materials, as the conventional doping strategy cannot readily apply to atomic-thin two-dimensional materials. In this review, we summarize recent research works on the asymmetrical device structure for building self-driven photodetectors on various substrates. To avoid any interface contaminants, both the Au-WSe2 and the WSe2-Graphene contacts are formed by PDMS-mediated dry transfer techniques. Here, two asymmetrical van der Waals contacts are formed to yield the photovoltaic effect and enable the self-driven photoresponses. When the device is under illumination at a wavelength of 650 nm, a large photocurrent is measured. Further, an open-circuit voltage and a short-circuit current are observed, indicating the self-driven properties of the MSM photodetectors. In particular, this method has been successfully applied to the preparation of Au-WSe2-Graphene heterostructures on a flexible polyimide substrate and the overall thickness of the photodetector is less than 10 µm. The flexible photodetector could be attached to curved surfaces without degrading the photodetection performance. In another type of device structure (Au-WSe2-Au), the same type of Schottky barrier is formed while the contact lengths of the two Au-WSe2 junctions are carefully designed to be different to result in a net Isc. We also highlight our recent study on the synergistic effect of the two asymmetric structures for enhanced self-driven properties. This self-driven photodetector is a promising candidate for low-power or even powerless operation. Based on the wide spectra covered by various 2D materials, it is expected that the self-driven 2D-materials-based photodetectors can augment the mainstream silicon and compound semiconductor-based photodetors.

Submission number: 325

ASTABLE TUNNED OSCILLATOR FOR QUANTIFICATION OF MAGNETIC NANOPARTICLES

Marques Fernandez, Jose Luis*

Keywords: Nano-Metrology and Characterization

The quantification of magnetic nanoparticles (MNP) in meager amounts has growing applications as a new generation of rapid diagnosis tests [1]. Numerous developments are trying to provide an affordable and compact solution to measure magnetic rapid diagnosis tests (MRDT). Based on a recent quantification technique called radiofrequency refractometry, we have developed a new, inexpensive technology capable of the sensitivity required by the MRDT. Radiofrequency refractometry uses an inductive sensor's self-resonant frequency (SRF) as a base for quantifying masses of magnetic nanoparticles [2]. Measuring the resonant frequency of an inductor can be achieved in different ways. The most cost-effective way is to use oscillators, which use the inductor as their resonant tank. Measuring the operating frequency of an oscillator can be achieved easily with simple digital circuits. The oscillator design plays an important role in measuring the inductive sensor's SRF. Previous designs use obsolete components or oscillator designs that can not leverage the full sensitivity of inductive sensors. We have designed a new oscillator architecture based on an astable oscillator whose emission spectrum marches the impedance curve of the inductive sensor. Our oscillator design uses modern components with a small footprint and high stability for a wide range of operating frequencies. Prototypes of this device have quantified 100 ng of magnetic nanoparticles, which is a lower mass than any previous sensor. We have measured signals of different magnetic and non-magnetic nanoparticle signals as the radio-frequency refractometry method predicted.

Submission number: 326

MAGNETIC NANOSTRUCTURES : LOCAL MAGNETOELASTIC CONTROL OF SPIN WAVES

CHALLAB, Nabil*

Keywords: Spintronics; Nanomagnetics; Modeling and Simulation

Since its discovery by Joule in 1847, magnetoelasticity has been the subject of continuous research, driven not only by its fundamental principles but also by its practical applications. These include flexible magnetic systems, usually consisting of thin or multilayer films, which can be nanostructured, deposited on a polymer substrate. These systems have applications in a wide range of fields, from everyday devices to aerospace equipment. During their use, these devices undergo significant and often complex deformations that can dynamically affect their magnetic properties [1]. To study the effects of strain on magnetic behaviour, two main aspects have been investigated: i) a numerical aspect, where a numerical code has been developed on COMSOL Multiphysics® to study the effects of magnetoelastic couplings in flexible magnetic systems [2], and ii) an experimental aspect, where magnetoelastic properties in nanostructured magnetic systems on flexible substrates have been studied. Together, these aspects shed new light on the relationships between the distribution of deformations and the static and dynamic magnetic properties.

Submission number: 327

PLASMONIC/DIELECTRIC NANOSTRUCTURED DEVICES EXHIBITING ULTRA-HIGH SENSITIVITY FOR BIOSENSING APPLICATIONS

Nocerino, Valeria; Miranda, Bruno; dardano, principia; De Stefano, Luca*

Keywords: Nanomaterials; Nanobiomedicine

In recent decades, metallic nanostructures have emerged as pivotal components in biosensing applications, leveraging their distinct properties as exceptional optical transducers [1]. Particularly, when these structures are significantly smaller than the operating wavelength, they exhibit the renowned phenomenon of localized surface plasmon resonance (LSPR), the spectral position of which is highly influenced by parameters such as nanoparticle size, shape, composition, and the refractive index of the surrounding medium. Notably, the integration of both bottom-up and top-down fabrication techniques has garnered increasing attention [2]. A novel approach proposes the large-scale fabrication of gold (Au) nanomushrooms (NMs) on glass and silicon substrates, presenting a promising platform for biosensing applications [3]. In this study, we advance the concept further by introducing hybrid plasmonic/dielectric materials to enhance the sensitivity of large-scale plasmonic arrays significantly. Specifically, we focus on optimizing the fabrication process of the AuNMs described in [3], by substituting the supporting pillar with dielectric Silicon Nitride. The fabrication process entails depositing a 100 nm layer of Silicon Nitride, followed by thermal evaporation of a thin gold film, and subsequent thermal annealing to induce the formation of gold nanoislands (AuNIs) (see Figure 1a). Subsequently, metal-assisted gas-etching is employed to create 80 nm-high pillars beneath the gold nanoislands, a crucial step that substantially enhances device sensitivity (as depicted in Figure 1b). To evaluate the performance enhancement, we conduct experiments where samples, both before and after etching, are exposed to solutions with varying refractive indexes, with LSPR redshift measured as a function of refractive index. Remarkably, etched substrates demonstrate unprecedented sensitivity, particularly promising for gas and biosensing applications. Moreover, the most sensitive AuNMs are subjected to rigorous testing, yielding highly encouraging results. Numerical simulations are also carried out to confirm the performance of the obtained nanostructured devices.

Submission number: 328

BIO-INSPIRED SYNAPTIC DEVICE BASED ON 2D MOSE2 MEMTRANSISTOR

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Keywords: Quantum, Neuromorphic, and Unconventional Computing; Nanoelectronics; Nanofabrication

The emergence of artificial intelligence and machine learning has led to an increased demand for computing systems that are high-performing and low-powered. The traditional CMOS based computing devices employing the Von Neumann architecture are reaching their limits in terms of performance parameters termed as Von Neumann Bottleneck. The brain-inspired computing systems have emerged as a promising approach to overcoming the limitations. Synaptic devices based on two-dimensional materials have demonstrated significant potential in developing neuromorphic systems that are efficient in terms of power consumption and speed and are capable of emulating the learning and plasticity processes of biological synapses. Several 2D material based synaptic devices have been reported. Molybdenum diselenide (MoSe2) a 2D transition metal dichalcogenide possesses several remarkable properties such as good chemical stability heterostructure integration bandgap tunability and high carrier mobility. However despite its excellent properties single channel 2D MoSe2 based three terminal synaptic devices are yet to be explored. Here we report a 2D MoSe2 based non-volatile three-terminal gate-tunable memory device that can be tuned using the back-gate. The MoSe2 flakes were transferred through mechanical exfoliation on a SiO2/Si substrate. The source-drain contacts were patterned using standard photolithography and deposited via sputtering. Figure 1a depicts the schematic of the device. Electrical measurements are performed at room temperature. Its functionality involves trapping and de-trapping of charges in response to applied gate voltage which results in exceptional memory properties as shown in transfer characteristics of the device (figure 1b). Repeatability is observed for 100 cycles without any degradation in the memory property and retention is studied for 3 hours. Figure 1c shows the long-term potentiation and long-term depression characteristics of the synaptic device. Furthermore other synaptic functions like spike rate-dependent plasticity spike magnitude-dependent plasticity and short-term to long-term memory conversion are also observed in the device. The synaptic behaviour in our device highlights its importance

Submission number: 329

TIO2 NANOSTRUCTURES FOR WASTEWATER REMEDIATION

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Keywords: Nano-Energy, Environment, and Safety; Nanomaterials; Nanofabrication

In the last decade, there has been an increasing demand for clean water sources. Water cleaning and sanitizing is indeed considered the sixth goal to be reached in the Sustainable Development Agenda of the United Nations, aiming “by 2030, achieve universal and equitable access to safe and affordable drinking water for all”. In this context, our research group has been working since 2014 on the development of nanostructured TiO2 able to purify and disinfect water through photocatalytic processes. Significant efforts have been dedicated to the development of two kinds of nanostructures: NanoParticles (NPs) and NanoWires (NWs). In the first part of the present lecture, an overview of the photo-electro-chemistry properties of a wide band gap semiconductor such as TiO2 is provided. The aim is to establish the rationale for use of the photocatalysis as a new strategy for wastewater remediation. The second part will focus on the production, properties, and use of TiO2 NPs which are synthesized using an environmentally friendly, versatile, cheap and scalable methodology known as the “laser ablation in liquids”. The nanoparticles exhibit a log-normal size distribution with a few tens of nm in size. They demonstrate excellent stability and high purity. Notably, these nanoparticles display significant photocatalytic activity and exhibit antibacterial properties when tested against Escherichia coli. Although the nanoparticles exhibit a very high exposed surface and photoactivity, they are dispersed into water and must be removed before water usage, posing a challenge due to their extremely small size. A way to circumvent this issue is to fabricate nanostructures firmly anchored to the substrate. Following this idea, we devised a new, straightforward and affordable method for synthesizing TiO2 NWs on a Ti substrate by using “gold nanoparticle-assisted thermal oxidation”. The NWs underwent comprehensive characterization. They were also doped with transition elements to enhance the photocatalytic efficiency within the visible spectrum.-- The relevance of the obtained results will be discussed, with particular attention to the application of these materials in photocatalysis for wastewater remediation.

Submission number: 330

THERMAL SCANNING PROBE LITHOGRAPHY WITH THE NANOFRAZOR: EXPLORING PATHS FOR SCALE-UP AND AUTOMATION

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Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanoelectronics; Nanofabrication

The NanoFrazor employs thermal scanning probe lithography (t-SPL) to simultaneously read and write nanoscale structures as well as direct laser sublimation (DLS) for the hybrid lithography of nanodevices. The technology has proven its value as an enabler of novel ultra-high-resolution nanodevices and an asset for improving the performance of existing device concepts. This hybrid lithography process addresses complex fabrication challenges with markerless overlay, sub-nanometer precise 3D grayscale lithography, and inert atmosphere integration. Automation of NanoFrazor lithography is essential for expanding its application space, ensuring reliable workflows, and serving as a training tool for novice users. The upcoming multi-tip version, the Decapede, enables scaled-up t-SPL while maintaining resolution, enhancing reproducibility, and minimizing overhead time. This talk will cover the working principle of the NanoFrazor, successful use cases of multi-tip patterning with the Decapede, and examples of integrating grayscale patterning with automatic overlay for nanophotonic device creation. These advancements pave the way to the scale-up and automation of t-SPL, enabling functional patterning in More-than-Moore applications, including nanophotonics, NEMS, and quantum computing.

Submission number: 331

INVESTIGATING LASER-INDUCED HEATING OF MNFE2O4 MAGNETIC NANOPARTICLES FOR POTENTIAL CANCER THERAPEUTICS

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Keywords: Nano-Metrology and Characterization; Nanomaterials; Nanomagnetics

In the past century, the imperative to address emerging healthy challenges has driven the development of nanotechnology-based approaches. Among these, nanomagnets have emerged as promising entities with unique physical properties poised to address these demands. Their appeal lies in their reduced size (from few nanometers to tens of nanometers), comparable to those of proteins, nucleic acids, or viruses, allowing promising interaction with biological systems. Second, the magnetic nature of the nanostructures grants their manipulation by external magnetic fields. All of this makes magnetic nanostructures excellent candidates to be used as therapeutic agents in cancer treatments, specifically in magnetic hyperthermia [1] or photothermia [2]. These techniques are designed to debilitate or eradicate cancer cells by administering heat. By inducing a targeted temperature elevation of approximately 4 - 7 °C in the treatment area, cancer cells undergo apoptosis while preserving the integrity of healthy cells. In magnetic hyperthermia nanomagnets heat up and disperse the heat in response to an alternating magnetic field while photothermia is based on the response to exogenously applied laser light. While magnetic hyperthermia has gained approval in Europe as an adjunctive cancer therapy [3], the underlying heating mechanisms in photothermal applications remain less understood, with research primarily confined to preclinical models and early-phase pilot trials [4]. This study delves into laser-induced heating of model $MnFe_2O_4$ nanoparticles coated with citric acid in water suspension, revealing a strong dependence of the specific absorption rate (SAR) on extrinsic parameters such as the experimental setup, laser characteristics, and sample concentration. The infrared molecular absorber IRA 980B, a standard probe for SAR measurements [5], was concurrently characterized to enable comparison across different laboratories, yielding the ratio SARMnFe2O4/SARIRA980B to compare different measurements performed in different laboratories. The photothermal platform incorporates an 808 nm infrared laser diode and a sensitive photothermal camera, all positioned on an optical bench designed for magnetic nanostructure measurements.

Submission number: 332

NEXT-GENERATION ATR-IR DEVICES FOR MONITORING CHEMICAL PROCESSES

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Keywords: Nanofabrication; Nanosensors and Nanoactuators; Modeling and Simulation

In this work, we show the fabrication of a microreactor consisting of a single-bounce attenuated total internal reflection (ATR) accessory coupled with a microfluidic channel to achieve spatially and temporally resolved kinetic information of an ongoing chemical reaction. Compared to our previous device[4], micromixers are added to the microfluidic channels to establish homogenously mixed liquids, enabling us to conduct reaction rate kinetic studies more easily. The device consists of a silicon part with the internal reflection element (IRE) for infrared (IR) spectroscopy and the first halves of the micromixers. The glass part of the device contains inlets and outlets and the second halves of the micromixers. To achieve efficient mixing, a rotational gradient micromixer was used, the design of which was inspired by F.T.G. van den Brink et al.[5]. The geometry was explicitly designed for use in shallow channels (h<<w) and operates so that after each unit, the concentration gradient undergoes a clockwise rotation due to strategically placed ridges next to where the connecting necks are located. This drastically increases the mixing performance of the device as the critical dimension affecting the diffusional mixing spans across the channel's height instead of the channel's width. To confirm the mixing efficiency of the devices, COMSOL simulations were conducted for flowrates ranging between 0.1 µL/min and 30 µL/min with varying diffusion coefficients (1·10-8 m2/s to 1·10-10 m2/s). It was determined that with 6 rotational units, 100% mixing efficiency could be achieved at the highest flow rate of 30 µL/min. Various optimizations in the process flow were also performed to successfully fabricate this device. First, the deep reaction ion etching (DRIE) recipe was optimized to 50 cycles with 5s etch time to achieve black-silicon-free channels. Second, two thermal annealing cycles of 75s at 1100-730;C followed by 1 min HF strip were performed to reduce bottom channel surface roughness, which could negatively affect the signal-to-noise ratio. The fabricated devices were then successfully used to monitor an SN2 chemical reaction.

Submission number: 335

THERMAL DEPENDENCE OF MAGNETIC ANISOTROPY IN SIZE-DISTRIBUTED FERRIMAGNETIC NANOPARTICLES

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Keywords: Nanomagnetics; Nanomaterials

The exploration of magnetic properties in nanostructured materials has gathered significant interest in the scientific community for potential high-performance technological applications. Particularly, nanoparticles (NPs) based on ferrimagnetic materials, such as spinel ferrites, have emerged as noteworthy candidates due to their tunable magnetic properties achievable through variations in chemical composition and crystalline structure. This study delves into the thermal dependencies of coercivity in ferrofluid samples comprising distinct sizes of core-shell CoFe2O4@-947;-Fe2O3 NPs. Synthesized via hydrothermal coprecipitation in an alkaline medium, the NP sizes were controlled by modifying the synthesis medium. Subsequent hydrothermal surface treatment with Fe(NO3)3 produced the maghemite shell. Characterization of chemical, structural, and morphological properties was performed using Atomic Absorption Spectroscopy, X-Ray Diffraction, and Transmission Electron Microscopy. Magnetic characterization involved measuring magnetization curves and zero-field cooled hysteresis loops as a function of temperature. The coercive field was analyzed within the Stoner-Wohlfarth model, considering size distribution and temperature dependence of magnetization and anisotropy constants influencing the transition from blocked to superparamagnetic (SPM) states. The proposed model[1] effectively fits experimental data, enabling predictions of the temperature-dependent anisotropy constant K. The model is then successfully applied to powder samples synthesized by thermal decomposition. For the ferrofluids samples, we carry out a comparison with values extracted from closure fields (Hirr) and first magnetization curves, using the Law of Approach to Saturation (LAS), providing meaningful insights into distinct sources of magnetic anisotropy arising from the ordered core and disordered shell, along with their temperature dependencies.-[1]--G. Gomide, R. Cabreira Gomes, M. Gomes Viana, A. F. Cortez Campos, R. Aquino, A. LOpez-Ortega, R. Perzynski, and J. Depeyrot, “Nanoparticle Size Distribution and Surface Effects on the Thermal Dependence of Magnetic Anisotropy,” J. Phys. Chem. C, vol. 126, no. 3, pp. 1581–1589, Jan. 2022.

Submission number: 336

MANUFACTURABLE ATOM-DEFINED SILICON DEVICES FOR ULTRA FAST AND EFFICIENT COMPUTING

Wolkow, Robert*; Pitters, Jason

Keywords: Nanoelectronics; Nanorobotics and Nanomanufacturing; Quantum, Neuromorphic, and Unconventional Computing

CMOS based computers cannot be made substantially more energy efficient or faster. Fast, low power computing schemes based on quantum dot ensembles have existed for some time but until now have not been physically realizable. In such an approach binary information is encoded in charge position. Available quantum dots had been too large, too irregular, and too prone to debilitating charge trap effects. By reducing the quantum dot to a single silicon atom, we have made the interaction energy among dots very large resulting in improved noise immunity while also gaining near perfect homogeneity of components and eliminating charge traps. These structures are absolutely stable to over 200 C. And crucially, the silicon atom printing process has been automated and rendered virtually error free. A new review article covers the decades of work bringing us to this point. We will discuss how the atom-scale circuitry works and why it consumes little power. Atom defined binary wires will be shown. These transmit information extremely rapidly and without the use of conventional current and as a result experience virtually no I2R heating. A working atomic binary logic gate will also be shown. Several applications will exemplify the advantages of this approach: We will explain how electrons confined within multi-well potentials can interact and spontaneously rearrange to embody a kind of Boltzmann machine. A common element in this and other projects is our 2 atom, 1 electron bit. Such a bit can be biased to set a desired occupation of one side or the other of the double well, thereby spatially mapping binary 0 and 1 states. The “bit energy” of ~100 meV is of ideal magnitude: information is thermally robust, yet not overly confined as it is in today’s computers, leading to wasted energy. Atom-defined SETs (single-electron transistors) of complete uniformity can transduce information represented as electron position to a current that can drive ordinary CMOS. Because competitive binary devices must be of vast complexity, the first products based on our technology platform will be quantum devices. I will sketch a portable quantum random number generator and a portable quantum magnetometer.

Submission number: 337

MESOPOROUS NANOCATALYSTS BASED ON PD FOR BIOORTHOGONAL CHEMISTRY

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Keywords: Nanobiomedicine; Nanomaterials

Coined in 2003 by the 2022 Chemistry Nobel Laureate Carolyn R. Bertozzi, the term “biorthogonal chemistry” refers to reactions that allow for the chemical alteration of intricate biological molecules within their natural surroundings. These reactions do not have natural equivalent and/or inherent reactivity with natural components [1], what makes them especially useful in the Nanomedicine field. It is here where the use of non-biotic Pd is on the rise, as its effectiveness for anticancer treatments based on the activation of prodrugs has offered promising in vitro results [2]. Nevertheless, it must be highlighted that despite its remarkable effectiveness, Pd typically suffers from biocompatibility, stability, or toxicity issues. Taking all this into consideration, in this research, firstly, SiO2 spherical cores were synthesized. With the aim of embedding the metal into them, the cores were functionalized with amine groups that strongly bond to the SiO2, creating SiO2@NH2 nanoparticles.--Next, Pd nanoparticles around 5nm size were embedded into the SiO2@NH2, resulting in the desired SiO2@Pd. In order to avoid toxicity due to the leakage of PdNPs, or the entrance of large biomolecules that could passivate the catalytic surface chemical groups or react with them, the Pd nanoparticles were encapsulated within a mesoporous silica shell leading to nanocatalysts SiO2@Pd@mSiO2. The resulting SiO2@Pd@mSiO2 nanoparticles have exhibited a pronounced catalytic activity for the deprotection of a fluorescence dye at low concentrations in physiological media.

Submission number: 338

INVESTIGATING LIGAND EFFECTS AND SOLVENT COMPATIBILITY ON CORE@SHELL NANOPARTICLES IONIC LIQUID-BASED DISPERSIONS FOR THERMOELECTRIC APPLICATIONS

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Keywords: Nanomaterials; Nanomagnetics; Nano-Energy, Environment, and Safety

In the ongoing pursuit of viable sustainable energy solutions, recent research has shown that magnetic charged nanoparticle (NP) dispersions in ionic liquids (ILs) present promising results for thermoelectric applications. In these systems, colloidal stability depends significantly on parameters such as ligand species, pH, temperature, and solvent type. Thus, the effect of these parameters on the dispersions of core@shell (CoFe2O4@-61543;-Fe2O3) magnetic NPs in ethyl-methylimidazoliumbistriflimide (EMIM/TFSI) was evaluated. The cobalt ferrite core provides relevant magnetic anisotropy, while the maghemite shell grants the NPs prolonged chemical stability and high surface tunability. The chosen IL presents high thermal and electrochemical stability, and low viscosity compared to other imidazolium-based ILs. Three ferrofluids (FFs) with different mean sizes of NPs (3.9, 7.4 and 13.4 nm) were synthesized by coprecipitation in an alkaline medium, followed by a surface treatment according to a well-known procedure. XRD, TEM, FAAS, and magnetization measurements were performed to characterize the FFs. Several surface ligands were tested: 1-Methyl-3-(4-sulfobutyl)imidazolium bis(trifluoromethanesulfonyl)imide (SBMIM±/TFSI-), 1-methyl-3-(butyl(or hexyl)phosphonic acid) imidazolium bromide (PAC4(or 6)MIM±Br-). The surface charge density of the NPs was tuned in the FFs in water before transferring the NPs toward the IL, through a wet route already tested. A multiscale analysis incorporating DLS and SAXS measurements was carried out to evaluate the colloidal stability of the samples, as well as aging and stability towards heating up to 200°C for the best samples. These latter were obtained with PAC6MIM±Br- as ligand, for which an adsorption isotherm was built to evaluate the surface coverage of the ions. The NPs are stable in the IL medium even at high temperature. However, the sample based on smaller NPs exhibits a clear phase separation overtime. Finally, the 7.4 nm NPs were successfully dispersed in mixtures of EMIM/TFSI with propylene carbonate (PC), showing a slight increase of the agglomerates while increasing the molar fraction of PC. Such agglomerates of few NPs are found in all samples.

Submission number: 339

WELL-ORDERED AUNP LAYERS AS UNIVERSAL LSPR SENSOR

Lednicky, Tomaš*; Borges, Joel; Bonyar, Attila; Fritzsche, Wolfgang

Keywords: Nanofabrication; Nanosensors and Nanoactuators; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

Many current biosensing solutions for healthcare and environmental applications are time-consuming, expensive, bulky, requiring skilled personnel and well-equipped laboratories. Consequently, it is unsurprising that critical services, such as disease diagnostics and water or air quality monitoring, are frequently disregarded due to economic constraints, thereby failing to prevent millions of casualties annually. Thus, even marginal reductions in diagnostic costs could significantly improve well-being in many places. This study presents a comprehensive fabrication technology for a sensor element that addresses critical challenges such as high cost and low sensitivity. The fabrication process involves the self-ordering growth of porous anodic alumina (PAA), followed by the template-assisted dewetting of thin gold films. This results in a 2D array of densely-packed, well-ordered sub-100 nm gold nanoparticles (AuNPs), which easily rival lithography techniques but at a fraction of their costs. Subsequently, the formed AuNP layers are transferred from aluminum to a transparent (SiO_2) substrate to leverage their optical colorimetric sensing properties based on the principle of localized surface plasmon resonance (LSPR). In prior studies, we showcased the biosensing capabilities of our nanosensors for DNA detection through simple transmission spectroscopy [1] and effective signal amplification for surface-enhanced Raman spectroscopy [2]. Furthermore, this study highlights recent progress in employing the same nanosensors for room-temperature gas sensing. LSPR-based nanosensors are emerging as promising candidates for various applications, given their broad tunability and the simplicity and compactness of their diagnostic instrumentation. Their versatility and potential for precise detection make them increasingly valuable in healthcare and environmental monitoring, marking a significant step forward in sensor technology.

Submission number: 340

DEVELOPMENT OF AN INNOVATIVE CARBON NANOTUBES-BASED NANOCONJUGATE FOR OVARIAN CANCER IMMUNOTHERAPY

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Keywords: Nanobiomedicine

Carbon nanotubes (CNTs) are becoming crucial in advanced nano-vaccine development due to their exceptional bioconjugation properties and cellular uptake [1]. In this study, we introduce an immunotherapeutic approach for ovarian cancer (OvCa) using CNTs conjugated with peptides from the overexpressed fucosyltransferase 4 (FUT4) protein [3], a hallmark of OvCa. Initially, predictive modeling identified high-affinity FUT4 epitopes binding with MHC-I and -II; after peptide synthesis (PEP37), CNTs were bioconjugated to create f-CNTs. Physicochemical analysis confirmed successful conjugation. Also, the not cytotoxic effect was demonstrated in vitro [2]. To evaluate f-CNTs potential as a nano-vaccine, we used the immunocompetent C57BL6/J OvCa mice model inoculated with transformed ID8 epithelial ovarian cells. FUT4 overexpression in ID8 cells was demonstrated, notably induced by ascites stimulation, and heightened in cells from C57BL6 mice compared to cells in culture media, affirming the tumor microenvironment (TME) influence on FUT4 expression. Subsequent immunization of mice with f-CNTs, f-CNTs plus adjuvant, or PEP37 plus adjuvant, followed by ID8 cell inoculation, revealed significant immunoprophylactic effects by f-CNTs. These included reduced tumor development, decreased ascites accumulation, and improved overall survival, with f-CNTs showing the most pronounced impact, followed by f-CNTs plus adjuvant and PEP37 plus adjuvant. In vivo experiments indicated changes in immune cell profiles within the OvCa TME, notably increased leukocytes, T lymphocytes, and cytotoxic T cells, alongside a shift from M2 to M1 macrophage polarization and reduced regulatory T cells (Tregs). Additionally, immunized groups significantly decreased immature myeloid cells. Furthermore, robust spleen cell proliferation was observed in mice immunized with f-CNTs, f-CNTs plus adjuvant, and PEP37 plus adjuvant, indicating the presence of T cells specific to the PEP37 antigen. In conclusion, our findings highlight f-CNTs' ability to modulate immune responses within the OvCa TME, mediated by cytotoxic T lymphocytes, M1 macrophages, and Tregs. This positions f-CNTs as a promising carrier system for exploration in OvCa immunotherapies.

Submission number: 341

HIGH QUALITY PHOTODETECTION IN THE MOS2 BASED FIELD EFFECT TRANSISTORS WITH SCHOTTKY CONTACTS AND EPITAXIAL FERROELECTRIC GATE DIELECTRICS

Niu, Gang*

Keywords: Nanoelectronics; Nanosensors and Nanoactuators; Nano-Optics,

Nanophotonics, and Nano-Optoelectronics

Nowadays the multi-functional integrated chips, which integrate multiple functions modularly, e.g., sensing, memories and filters etc. on the same low-cost silicon based platform, has become the hardware foundation for the "Internet of Things" and artificial intelligence applications. Photodetection is one of the vital functions for such multi-functional “More than Moore” (MtM) microchips. The further improvement of the performance of photodetectors faces various challenges including materials, fabrication processes and devices structures. 2D materials like transition metal dichalcogenides (TMDCs), represented by molybdenum disulfide (MoS2), are very promising channel materials for next-generation MOSFETs, thanks to their outstanding electrical and optoelectronic properties. Meanwhile, Ferroelectric gate dielectrics like (Hf, Zr)O2 (HZO) have been applied into novel low power consumption information devices like negative capacitance transistors, ferroelectric tunneling junction and FeFET memories etc. We firstly demonstrate MoS2 photodetectors with the nanoscale channel length and the back-gate device structure using SiO2 as the gate dielectric. With the optimized properties of mechanical exfoliated 6 monolayer-thick MoS2, the Schottky contact between source/drain electrodes and MoS2, high responsivity of 4.1×103 A W-1 and detectivity of 1.34×1013 cm Hz1/2 W-1 at 650 nm were achieved. The devices are also sensitive to multi-wavelength lights including 520 nm and 405 nm. The photoinduced Schottky barrier lowering (PIBL) was found to be important for the high performance of the phototransistor. Subsequently we show the results of the MoS2 phototransistor with epitaxial ferroelectric HZO as a gate dielectric layer. Gate-dielectric-polarization-dependent ambipolar behavior was observed in the FET, and relatively low power consumption and hysteresis-free loop were achieved in the FeFET. The anomalous negative photoconductivity has been observed as well. Possible reasons for such phenomenon have been clarified including the photogating effect originating from the interface traps and the polarization-dependent electric-field control through ferroelectric gating. The high responsivity of -8.44×103 A W-1 in the negativ

Submission number: 343

MAGNETIC PROPERTIES OF HOLLOW NANOARCHITECTURE

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Keywords: AI for Nanotechnology

In the nanometer-scale regime, the ratio of the surface area to the volume of a nanoparticle becomes significant, since a large portion of the atoms reside at the surface compared to those in the core of the nanoparticle. This large surface-to-volume ratio (R=S/V) in the nanoparticles is proving to be a key factor for the novel physical, chemical, and magnetic properties compared to those of the corresponding bulk material. An interesting possibility in the synthesis of nanostructures is the design of hollow nanoparticles that have both internal and external surfaces, which further amplifies the value of R [1]. Here, we present a comparative study of the morpho-structural and magnetic properties of full and hollow maghemite (-947;-Fe2O3) nanoparticles (NPs), characterized by a large surface to volume ratio, of corresponding sizes 5.0(5) nm and 7.4(7) nm. These systems have been thoroughly characterized by means of DC magnetization measurement and in field 57Fe Mössbauer spectrometry. The in-field hyperfine structure analysis suggested the presence of non-collinear structure for hollow NPs originating from the increased role of the surface due to the hollow morphology. Interestingly, an exchange bias effect was noted in the hollow structure, which is demonstrated by the shifted M(H) hysteresis loop recorded after field cooling. Monte Carlo (MC) simulations on ferrimagnetic hollow nanoparticles unambiguously corroborate the critical role of the surface. MC simulation results [2] show that the spins in the thicker external surface and at the interface are strongly exchange coupled. This strong exchange coupling enhances the antiferromagnetic character of the hollow particle leading to the decrease of its Ms. At the interface, this strong spin exchange coupling results in an exchange bias field and in the enhancement of the coercive field in agreement with experimental results.-[1]F. Sayed, N. Yaacoub, Y. Labaye, R.S. Hassan, G. Singh, P.A. Kumar, J.M. Greneche, R. Mathieu, G.C. Hadjipanayis, E. Agostinelli, D.Peddis. J.Phys.Chem.C. 122 (2018). [2]A. Lappas, G. Antonaropoulos, K. Brintakis, M. Vasilakaki, K.N.Trohidou, V.Iannotti, G. Ausanio, A. Kostopoulou, M.Abeykoon,I.K.Robinson,E.S.Bozin.Phys.Rev.X.9(2019)

Submission number: 344

IMPACT OF INITIAL IRON GLYCINATE COMPLEXES AS PHASE DIRECTORS ON RAPID MICROWAVE-DRIVEN SYNTHESIS OF IRON OXIDE NANOPARTICLES

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Keywords: Nanomaterials; Nanobiomedicine; Nanomagnetics

The production of magnetic nanoparticles for use in humans is subjected to stringent requirements by the regulatory authorities as part of their approval process. The relevant parameters and conditions to the synthesis are known – especially for iron oxides -, but parasitic phases appear at times even in reactions that are carried out using the most popular methods [1]. This entails additional post-production separation and purification steps, with the subsequent increase in economic and time costs. Utilizing an aqueous microwave synthesis approach for generating iron oxide nanoparticles, we introduce glycine as a crucial phase directing agent to inhibit the emergence of unwanted phases. This synthesis process not only facilitates the formation of nanoparticles but also prepare their surfaces for subsequent bioconjugation through a dual coating of glucose-fructose and glycine, achieved in a singular step at relatively low temperatures. Our findings illustrate that the rapid formation of iron glycinate complexes effectively blocks the appearance of unintended iron aquocomplexes or oxohydroxides. This strategy is especially effective in managing the Schikorr reaction, preventing premature chemical interactions during the mixing of precursors. Furthermore, glycine acts as a surfactant, curtailing the development of undesired clusters and enhancing the nanoparticles' bioconjugation potential, thereby supporting their use in theranostic applications.

Submission number: 345

A SYNAPTIC TRANSISTOR USING TITANIUM OXIDE TRAPS AT BACK CHANNEL FOR NEUROMORPHIC COMPUTING

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Keywords: Nanoelectronics; Quantum, Neuromorphic, and Unconventional Computing

Synaptic transistors have attracted great interest due to their huge potential for constructing neuromorphic computing architecture [1]. However, conventional synaptic transistors always use gate dielectric for charge trapping, which causes deterioration of device performance due to the Coulomb scattering indued by the charge traps in the gate dielectric [2]. To address the issue, this study proposes a novel synaptic transistor using titanium oxide (TiOx) related traps located at back channel for charge trapping, whose gate dielectric only works as a gate-controlled capacitance. Fig.1(a) shows the schematic diagram of the device. When electrical stimuli are applied on the bottom gate, electron trapping and detrapping will occur in the TiOx traps at the interface between Au/Ti top gate and InGaZnO (IGZO) back channel, thus changing the carrier density of the channel for conductance modulation. To induce TiOx traps at the Ti/IGZO interface, the post metal annealing (PMA) process is introduced to induce the interfacial reaction.-Fig.1(b) and (c) display the transfer and output characteristics of the synaptic transistor, respectively. Fig.1(d) shows a schematic illustration of an artificial synapse realized by the device. As seen in Fig.1(e), when a pair of gate voltage pulses are applied on the device, a short-term synaptic plasticity of paired-pulse facilitation (PPF) can be emulated. The PPF index (defined as A2/A1) decreases when the interval time between neighbouring two pulses increases, which can be explained as the retrapping of electrons in the channel by TiOx. Furthermore, as shown in Fig.1(f), potentiation and depression of channel conductance of the device are implemented by a series of positive or negative pulses as a result of electron trapping and detrapping in the TiOx traps. This characteristic can mimic long-term synaptic plasticity through conductance weight modulation, which reveals great potential of the device for application in neuromorphic computing.

Submission number: 346

ALTERNATIVE METALLIC FILLERS FOR THE PREPARATION OF CONDUCTIVE NANOINKS FOR SUSTAINABLE ELECTRONICS

Santana-Otero, Antonio*; SALVADOR, MARiA; Corrales-Perez, Belen; Diaz-Ufano, Carlos; Veintemillas-Verdaguer, Sabino; Beni, Valerio; Morales, Maria del Puerto

Keywords: Nanotechnology in Soft Electronics; Nanomaterials; Nanomagnetics

Zero net carbon emission electronics, achieved through the use of efficient and environmentally friendly materials and processes, is a major challenge. In this study we investigate alternative chemical methods to produce metallic conductive nanoparticles based on biodegradable materials. These nanoparticles are intended for long-term use as fillers in inks for inkjet printing applications. Specifically, we analyze the characteristics of nickel, ironnickel alloy and iron nanoparticles synthesized using highly adaptive and efficient solution-based routes, involving the use of water and polyols as reaction media, reducer and coating, and microwave as heating source. For comparison, commercially available metallic iron and nickel nanoparticles were coated with ethylene glycol. Conductivity tests were performed on nanoparticle pellets and nanoparticle strips drawn on glass surfaces. The study demonstrates that the nanoscale size of the particles facilitates sintering at lower temperatures, and the addition of coating agents prevents oxidation, making these nanoparticles promising candidates as conductive fillers in inks for printed electronic applications.

Submission number: 347

A READY SOLUTION FOR INTELLIGENT ORGANIC PHOTOELECTRONICS: LARGE-SCALE PHOTO-ACTIVATED FREE-STANDING FILMS OF PDA/RGO

Lukasiewicz, Zuzanna*; Szewczyk, Jakub; Krysztofik, Adam; Graczykowski, Bartlomiej; Wiesner, Maciej; Belaid, Habib; Bechelany, Mikhael; Coy, Emerson

Keywords: Nanomaterials; Nanosensors and Nanoactuators; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

Polydopamine free-standing film at the air/water interface forms through self-assembly of the dopamine oxidation products, resulting in large-scale, nanometrically thin films with extraordinary mechanical properties and 2D-like structure. This experiment aimed to create a PDA/rGO nanocomposite that can be freely transferred onto virtually any large surface. Our studies show unexpected electronic and photonic effects attributed to the unique structure and properties of these films. The one-pot synthesis method that was used in this experiment takes advantage of the antioxidation agent - boric acid - and is the first of its kind. A blend of 2D-like polymers - PDA and r-GO films - was obtained, whose morphology was analysed through XRD, SEM, AFM and chemistry through XPS, IR and Raman Spectroscopy. The boric acid improves PDA's mechanical properties and is also essential in the reduction of GO. The chosen synthesis method benefited from the synergy of those two processes. Super sensitive 4 Point Measurements showed that the conductivity of the PDA/r-GO films decreases under relatively weak irradiation with white and UV LED light. These changes are of reversible and quantified character. This can be explained by the structural and morphological changes upon light actuation. Time-resolved reflectivity was utilised to investigate the suspended film contraction and relaxation under the illumination on/off cycles. Interestingly, unlike PDA itself, PDA/r-GO nanofilms are stimulated primarily by thermal expansion rather than moisture adsorption/desorption. This response is much faster than for PDA, which allows generating an expansive and contractive film by a rather simple synthesis mechanism, which is crucial in their application and scalability. Finally, a complex electronic phase nanostructure was determined by conductive AFM measurements, namely, higher-conductivity domains surrounded by nanocomposite polymer filling that demonstrate lower, but significant, conductivity. Our studies, yet preliminary, undoubtedly show new opportunities for photosensors, phototransistors and memory devices. Additionally, they provide a unique view of the control of the intermolecular interactions of PDA towards composite materials.

Submission number: 348

UV-VIS SINTERING PROCESS OF COATINGS BASED ON NICKEL-SILVER CORE-SHELL NANOPARTICLES FOR FABRICATION OF PRINTED FLEXIBLE ELECTRONICS

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Keywords: Nanoelectronics; Nanomaterials

The large-scale manufacturing of printed flexible electronics requires low-cost substrates, such as papers or plastics. Unfortunately, those materials are thermally sensitive and require low-temperature sintering to obtain conductive tracks. Although the sintering methods of metal nanoparticles for the preparation of conductive coatings on heat-sensitive substrates have been frequently proposed in recent years, the search for a simple, fast, effective, and low-cost process of fabrication of flexible electronic devices is still required. Therefore, during the last years, growing interest has been observed in the field of sintering methods, which can be performed at a low temperature to avoid the destruction of heat-sensitive substrates. As a promising alternative to remediate the abovementioned detrimental thermal effects radiation-induced sintering methods were considered [1, 2]. Nanoparticles-based conductive inks are of particular importance in the field of printed flexible electronics, because of their low sintering temperature and micro-size processing capacity [3]. Therefore, our research was focused on the development of new methodologies for preparing printed conductive coatings based on nickel-silver core-shell nanoparticles (NPs) by using the UV-Vis sintering process as a promising alternative to thermal sintering. The method of the formation of Ni NPs and their stabilization by the formation of the silver shell to form Ni-Ag NPs was developed. Such nanoparticles with an average size of 220 nm were utilized for the preparation of conductive inks. The applicability of the UV-Vis irradiation for the sintering of the deposited ink composed of Ni-Ag NPs was investigated. The obtained results suggest, that UV-Vis irradiation is an effective method of sintering of Ni-Ag NPs, suitable for the fabrication of metallic coatings with good conductive properties. At the optimal UV-Vis irradiation conditions (400 nm wavelength and 90 minutes), the calculated value of resistivity of such films was low, about 24 µ-937;·cm, and corresponds to conductivity to 29% of that for a bulk nickel. To the best of our knowledge, it was the first time when coatings formed Ni-Ag NPs were sintered by UV-Vis irradiation and such lo

Submission number: 349

STUDY OF COULOMB INTERACTIONS IN A METAL QCA CELL USING GATE REFLECTOMETRY

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Keywords: Quantum, Neuromorphic, and Unconventional Computing; Nanosensors and Nanoactuators; Nanofabrication

Quantum-dot Cellular Automata (QCA) is a transistorless computing platform where binary information is encoded in a QCA cell through charge localization and electrostatic Coulomb interaction between quantum dots [1]. We experimentally study the interaction between electrons switching in the adjacent electrostatically coupled double-dots (DDs). A scanning electron micrograph (SEM) of functional four-dot metal QCA cell composed of two electrostatically coupled nanoscale DDs (D1D2 and D3D4) with four gates fabricated by Niemeier-Dolan technique [2] is shown in Fig. 1(a). At low temperature (T < EC/kB -8776; 10K, where EC =e2/2C and kB is Boltzmann constant) and no applied gate bias, both DDs are in Coulomb blockade. The DC bias applied to the gates forces electron tunneling within DDs, and this charge motion gives rise to dynamic capacitance that can be sensed by reflectometry. Here, we use a high quality factor (Q~550) -960; resonant network at gate-A to detect transport in both DDs. The change in dynamic capacitance results in measurable changes in the reflection coefficient (Fig. 1(b)). The change in charge configuration is more prominent in D1D2 due to its close coupling to the resonator, while the change in D3D4 is expected to result in weaker change due to a weaker coupling. A 2D map of the phase of the reflected signal acquired at 0.3K is presented in Fig. 1(c). Differential driving bias VIN = Vgate-C – Vgate-D is applied across gates C and D, while an offset bias, VT, is applied to Gate B with VA=0v. A faint set of nearly horizontal parallel lines in the data of Fig. 1(c) results from electron switching in D3D4. Another set of much stronger, more vertical lines in the data corresponds to charge transfer in D1D2. The crossings of these lines correspond to the regions where both DDs are interacting with one another, and one can clearly see that this interaction results in a strong suppression of tunneling due to Coulomb interactions between DDs. Experimental results are in excellent correlation with the theoretical calculations [3].

Submission number: 350

ICING TESTING AND EVALUATION OF ICEPHOBICITY

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Keywords: Hydrophobic, Oleophobic and/or Icephobic nanostructured surfaces

Icing causes many problems in cold climate conditions, where supercooled water droplets hit a surface, freeze and form an ice layer. This accreted ice can, e.g., hinder operations, cause safety problems and increase energy consumption. These, in turn, are causing problems in, e.g., aircraft, renewable energy and construction. Anti-icing and de-icing solutions are suitable ways to minimize these challenges. Furthermore, icephobicity is an important surface property and ice adhesion can be determined as a factor for it. When ice adhesion is low, icephobicity is high, meaning that ice can be removed easily from the surfaces. There are also some connections between icephobicity and surface properties such as wettability, surface topography and chemistry but a clear relationship has not been found because icephobicity depends on several factors and different surfaces have the different main influencing factors.-Icing testing is needed to evaluate the performance of the surfaces in different icing conditions and their icephobicity together with durability under environmental stresses. To mimic natural icing, icing testing should be designed to simulate ice accretion phenomena. An icing wind tunnel can be used to accrete ice in different icing conditions, which in turn, influence on ice adhesion. Ice adhesion can be tested with different testing methods. Tampere University has Ice Laboratory, where rime, glaze and mixed glaze ice can be accreted in the icing wind tunnel with the maximum wind speed of 25 m/s and the temperatures from - 0°C down to -35°C. For measuring ice adhesion, centrifugal and pushing type testers are available. For de-icing, electrothermal and gravity-based methods can be used and testing setups can be modified for different surfaces and sample geometries. It is important to understand icing testing conditions when comparing different researches because they are affecting strongly on the results. Icing is a very complex phenomena and therefore, development of icing testing to be more comparable with natural icing is further needed together with icephobic coating and surface development.-This research has partly done in the SOUNDofICE project (EU, H2020-FETOPEN-2018-2019-2020-01, GA nº: 899352).

Submission number: 351

SILICON SUBWAVELENGTH NANOSTRUCTURED MEMBRANE FOR BRILLOUIN OPTOMECHANICS

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Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics

Brillouin scattering, the nonlinear interaction between optical and mechanical fields, has led to remarkable developments in communications, sensing, and quantum technologies in the last decade. Four main mechanisms govern this interaction in nanoscale devices: photoelastic effect, electrostriction forces, moving boundary effect, and radiation pressure forces. Silicon-based devices have attracted significant attention owing to the strong optomechanical interaction therein and the compatibility with standard CMOS technology. Nevertheless, a considerable drawback of this platform is the challenging simultaneous confinement of optical and mechanical modes, a requirement for efficient Brillouin interactions, due to a strong phonon leakage towards the silica cladding. Here, we present and demonstrate a subwavelength silicon membrane yielding a large Brillouin interaction and good mechanical confinement. Suspended devices have been successfully shown to overcome this limitation. Subwavelength engineering of the longitudinal and transversal geometries allows for independent control of longitudinally propagating photonic and phononic modes in silicon nanostructures. Our geometry ensures the co-localization of the optical and mechanical modes in the core. We experimentally demonstrate a strong, narrow-linewidth optomechanical interaction, with a maximum on/off attenuation of 2 dB and gain of 1.5 dB for anti-Stokes and Stokes sidebands.

Submission number: 352

MR IMAGING EFFECT AND MAGNETIC HYPERTHERMIA OF GD3+DOPED MNFE2O4 NANOPARTICLES

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Keywords: Nanomagnetics; Nanobiomedicine; Spintronics

MnGdxFe2-xO4 nanoparticles (x = 0, 0.05, 0.10) encapsulated in amorphous SiO2 were prepared by a wet mixing method. Particle size was controlled to 18 nm by varying the annealing temperature. The composition dependence of the DC and AC susceptibilities were investigated, and it was found that Gd doping in MnFe2O4 with optimized Gd doping decreases the coercive force, indicating a superparamagnetic behavior. The temperature dependence of AC susceptibility shows that the imaginary part of AC susceptibility -967;”, which contributes to the heat generation due to the magnetic relaxation loss, has a peak at 310 K, which is close to the body temperature. It can be expected that this sample has shown a significant hyperthermia effect. We investigated the usefulness of the same material as an MRI contrast agent and measured MR signals. T1 and T2 relaxation measurements were performed by the spin-echo method, and the relaxation rates R1 and R2 were calculated. As a result, in T2 relaxation, the Gd-doped sample, which was highly effective in raising the temperature in AC magnetic field, showed higher relaxation rate in T2 relaxation than MnFe2O4 and iron-based oxides, which are commercially available contrast agent materials. Furthermore, in T1 relaxation, MnGd0.05Fe1.95O4 encapsulated with polyethylene glycol (PEG) showed a relaxation rate R1 comparable to that of Gd-DTPA currently used as a positive contrast agent (Figures 1 and 2), indicating that Gd doping promotes relaxation and that PEG-MnGd0.05Fe1.95O4 nanoparticles are effective as MRI contrast agents and heating media for magnetic hyperthermia, suggesting their potential for theranostics applications.

Submission number: 353

HIGH-SPEED VIDEOMICROSCOPY AND MAGNETORHEOLOGY UNDER TRIAXIAL UNSTEADY MAGNETIC FIELDS

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Keywords: Nanomaterials

The performance of non-Brownian magnetic suspensions (i.e. magnetorheological fluids) has been traditionally investigated exposing them to uniaxial steady magnetic fields. In that case, particles form string-like aggregates responsible for the suspension viscosity enhancement. Different structures, so far with unknown rheological properties, can be formed if an unsteady triaxial field is used instead. Here, we describe a custom-built device that is capable of superimposing this kind of magnetic fields on a sample at the same time that its microstructure is visualized using a high-speed camera and its rheological properties are measured with a commercial rheometer. The device reaches field strengths up to 5 kA·m-1, frequencies up to 4 kHz and its functionality is evaluated by testing magnetorheological fluids under steady shear flow and field transients. Striking differences are found at small Mason numbers by changing the field configuration. For high Mason numbers a cylindrical layered pattern is observed and analyzed using an image analysis code.

Submission number: 354

INITIATOR EFFECT ON OXYGEN-INFLUENCED POLYMERIZATION OF RESINS USED IN NANOIMPRINT LITHOGRAPHY

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Keywords: Nanomaterials; Nanofabrication; Nano-Metrology and Characterization

The present study focuses on investigating the influence of photoinitiators on resin polymerization in the presence of oxygen, emphasizing its significance in nanotechnology applications such as noimprint lithography, a low-cost technique for mass-producing nanostructures with the potential to replace expensive lithography processes, examining how this affects the nanofabrication process. We investigate how oxygen presence can inhibit or promote resin polymerization and how hybrid photoinitiators can enhance this process. The effect of different types of photoinitiators and their synergistic combinations on polymerization kinetics and the final properties of the UV resin, such as the improvement of the degree of conversion,is analyzed. Furthermore, we explore the use of hybrid photoinitiators to increase the efficiency of polymerization under UV radiation in the presence of oxygen. This study offers valuable insights into optimizing resin polymerization under challenging conditions, opening new possibilities for the development of advanced polymeric materials in the field of nanotechnology. The selection of photoinitiator plays a critical role in achieving optimal results in resin-based nanoimprint lithography. Modifications to the photoinitiator can have significant impacts, potentially leading to oxygen inhibition. This can affect various aspects of the curing process, including curing time, density, viscosity, solvents in roll-to-roll processes, and evaporation rates. Even though the photoinitiaors are crucial in UV resins used in nanoprinting, there have been limited detailed studies devoted to this topic. This gap in research highlights the importance of further investigation into the effects and optimization of photoinitiators in UV resin-based processes.

Submission number: 355

CONDUCTING-POLYMER NEURO/MORPHOGENESIS AS IN MATERIO COMPUTING MECHANISM: EVOLVING ELECTRONICS AT ALMOST NO COST

Pecqueur, Sebastien*

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Nanosensors and Nanoactuators; AI for Nanotechnology

Unlike living organisms, electronics is not metamorphic: devices are mass-produced in series, normalized with well-defined standards, aim at being highly stable during operation and are rebutted with poor recyclability when a better version of themselves can be deployed. Software can also be upgraded on the same hardware with no waste, but not the hardware. In nature, systems grow, evolve, copy, adapt to the environment they sense, scavenge only the least natural resources they need to operate and degrade to biomass. Very often, their degree of intelligence is associated to their plasticity and ability to adapt to an environment, proliferating on a substrate in the harshest conditions.-Today, electrochemistry can be a building block for a field of electronics which aims at mimicking natural intelligence by growing electro-conductive topologies as a learning mechanism. Specifically, electropolymerization allows on demand neurogenesis of sensitive inputs with chemospecific semiconductors, and morphogenesis of conducting polymer dendritic topologies. As bottom-up strategy, it is a mask-less patterning technique for microelectrodes and devices with high control of thickness/roughness. Like additive-manufacturing, it consumes only what it needs of the material resources available in an electroactive electrolyte environment, to manufacture semiconductors at various doping levels and bandgaps with no precious mineral and ore, and with low energy consumption manufactured in ambient. Fab-less, dynamic electropolymerization can be used as in operando mechanism to program the generation of sensing elements, the routing of array of devices, in a way brain cells, micellia or roots grow topologies on specific landscapes to achieve their purpose. In an era where new computing paradigms are needed, with manufacturing methods adopting the most care for the environment, electropolymerization inspires from nature to propose new ways hardware can form and embed new learning functionalities by physically evolving.

Submission number: 356

FROM TUNABLE DEVICES TO SELF-CALIBRATED MICRO-SPECTROMETERS: THE RISE OF COMPUTATIONAL OPTICAL SENSORS

Naveh, Doron*; Abu Hamam, Rana

Keywords: Nanoelectronics; Nanomaterials; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

The progress in spectral measurement of light is central to the advancement of scientific research and for future technologies. Spectrometers, optical devices that measure the spectral components of light, are important tools for modern applications including chemical sensing, spectral imaging, and light source characterization [1-3]. New archetype semiconductor devices utilize algorithms for driving and interpreting the I/O of photodetectors to resolve the optical spectrum. Distinct from conventional spectrometers, computational spectrometer devices necessitate bulky components or moving parts [4,5] and is based on compact semiconductor devices. Their resolution and dynamic range are subject to data sampling and electrical noise, rather than the diffraction limit of refractive optical systems. In this talk I will survey the topic of computational spectrometers and their future applications. The role of machine-learning algorithms and computational approaches will be discussed firefly as well as the importance of van der Waals materials and heterostructure devices.

Submission number: 357

A STUDY ON THE MICROSTRUCTURE FORMATION MECHANISMS AND FUNCTIONAL PROPERTIES OF NEW -946;-FESI2-BASED POLYCRYSTALLINE THIN FILMS FOR PHOTOVOLTAIC APPLICATIONS

Abu Muhfouz, Maram*; Zaefferer, Stefan

Keywords: Nanomaterials; Nanofabrication; Nano-Metrology and Characterization

Our research endeavors are directed toward developing sustainable materials that can tackle the challenges of current photovoltaic commercial structures. Amid the variety of potential materials, -946;-FeSi2 stands out as one of the promising materials for photovoltaics-based applications, because it is eco-friendly with a low-carbon footprint and based only on abundant elements. Also, it has an extreme optical absorption coefficient (-945; > 105 cm-1 above 1.0 eV) of more than one order of magnitude larger than that of Silicon and Gallium Arsenide. This enables the reduction of its absorption layer thickness below 1 µm, without affecting the optoelectronic performance of the solar cell.-In this work, we sputtered 800 nm thick -946;-FeSi2 thin films on stainless steel (SS) besides silicon (Si) and sapphire (Al2O3) substrates. This was carried out in controlled Direct Current (DC) and Radiofrequency (RF)-magnetron sputtering procedures. The phase formation for -946;-FeSi2 was monitored by electron backscatter diffraction (EBSD) and X-ray diffraction (XRD) measurements. EBSD mapping was applied to the cross-sectional and plane-view films to observe microstructure, spatial phase distribution, and texture. The analysis of the EBSD patterns using the classical Hough transform approach (HT) was challenging due to the following reasons: i) The complex crystallography of tetragonal and orthorhombic phases, ii) The small grain size (30 nm ± 10 nm), iii) The high defect density in the crystals. Therefore, a new approach to EBSD analysis, the so-called spherical indexing (SI), was utilized for accurate indexing of the EBSD patterns.-The results show that the -946;-FeSi2 thin films have a high-quality, and pore-free structure and a good adhesion to the SS substrate. We investigated in our work the correlation between DC sputtering parameters and both crystallographic phase fraction and texture evolution. Accordingly,-946;-FeSi2 films on top of SS substrates exhibit crystalline structure with a preferential orientation of the sputtering direction (substrate normal) towards [100] and [010]. Thus, the preferable phase distribution reveals the highest phase fraction, almost 90% of the beta phase, at 500°C and 1 Pa.

Submission number: 358

AN ATOMISTIC INVESTIGATION OF THE ELECTRONIC AND THERMAL TRANSPORT PROPERTIES OF CRYSTALLINE AND AMORPHOUS GERMANIUM

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Keywords: Modeling and Simulation; Nanoelectronics; Emerging Plasma Nanotechnologies

Germanium has been a crucial material in nanoscale technology ever since it was employed in the first-ever transistor. Although it was eventually supplanted by silicon as the preferred substrate in the semiconductor industry, Ge has recently attracted attention in several key nanotechnological applications. For example, the SiGe alloy enables next-generation gate-all-around nanosheet devices, while Ge itself shows promise in quantum information applications and in ultra-fast photodetectors. However, it is known that Ge might form non-ideal (i.e., either amorphous or polycrystalline) thin films, which might require a high thermal budget or complex engineering effort to recrystallize. To better understand the amorphization and crystallization processes in Ge nanodevices, it is important to study such systems from an atomistic point of view. Previously, the melting, amorphization, and recrystallization of Ge has been investigated through classical molecular dynamics with Stillinger-Weber-type potentials. Albeit this approach has been shown to adequately model melting temperatures, it is insufficiently accurate to determine the structure factor of amorphous Ge in comparison to density functional theory. To bridge this gap and better understand the structural properties of Ge, we perform studies of these materials based on both ab initio molecular dynamics and a computationally efficient machine-learning potential relying on non-von-Neumann molecular dynamics. Using CMD and NVNMD, we can calculate the specific heat capacity, as well as the thermal conductivity of Ge in its different phases. In addition, Ge is known to show an anomaly in its liquid phase density. Although this is captured by SW-type potentials, the required manual parameterization precludes a straightforward physical interpretation of this phenomenon. By employing the D3 correction in AIMD [9], we see evidence that such anomaly is at least in part due to longer-range dispersion interactions. Having adequate atomistic descriptions of both amorphous and crystalline Ge and by adding chemically inert platinum (Pt) electrodes, we calculate electronic transport properties using the quantum transmitting boundary method in the OMEN solver.

Submission number: 359

DESIGN AND BIOLOGICAL INTERACTIONS OF FUCOSYLTRANSFERASE-4 PEPTIDES BIO-CONJUGATED CARBON NANOTUBES IN MACROPHAGES AND OVARIAN CANCER CELLS

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Keywords: Nanomaterials; Nanobiomedicine

Ovarian cancer (OvCa) is one of the more lethal gynecological cancers in the world, ranking seventh cause of death globally. The lack of an early diagnosis method and resistance to treatment are factors involved in the high mortality. Several cancers, such as OvCa, overexpress proteins that could be targeted for nanovaccine development. It has been demonstrated that Fucosyltransferase-4 (FUT-4) is an overexpressed protein in OvCa [1]. Studies have shown that carbon nanotubes (CNTs) elicit a robust immune response in antigen delivery. This study aimed to design FUT4-derived peptides, bio-conjugate them with CNTs (f-CNTs), and analyze cytotoxicity and nanoparticle interactions on macrophages (J774A.1) and SKOV-3 OvCa cells. A multiepitope FUT-4 peptide was constructed using IEDB/NETMHC 4.0 and NetMHCII 2.3/IEDB, tested for MHC I/II docking, and enzyme-bioconjugated to CNTs [2]. The topographical characteristics of f-CNTs were performed using transmission and scanning electronic microscopy and atomic force microscopy. The structural quality, functional groups, and efficiency of bioconjugation of f-CNTs were determined by FTIR, X-ray photoelectron spectroscopy, and protein analysis, respectively. Results showed that cell viability was not affected by f-CNTs at concentrations < 6 µg/mL. Macrophage interaction with f-CNTs, unlike pristine or purified CNTs, induced activation-related morphological alterations and a time-dependent lysosome uptake. Also, f-CNTs induced M1-like cytokine production in macrophages, with upregulation of CD80, CD86, and MHC II and downregulation of ARG-1. These results demonstrate that FUT-derived peptide was recognized on f-CNTs, causing M1-like polarization in macrophages and without cytotoxic effects in both cellular types. These results allow us to propose f-CNTs as a peptide carrier system for macrophage activation, which is being explored in OvCa immunotherapies.
Acknowledgments Guzman-Mendoza is a CONAHCyT scholarship recipient.

References

[1]--N.P. Alvear-Hernandez, V.I. Hernandez-Ramirez, J.C. Villegas-Pineda, J. J. Guzman-Mendoza, et al., (2024) Cell Biology International.

[2]--J.J. Guzman-Mendoza, D. Chavez-Flores, S.L. Montes-Fonseca, et al.,

Nanomaterials. 12 (9) (2022).

Submission number: 360

NANODIAMOND-METFORMIN COMPLEX CYTOTOXICITY IN MCF-7 BREAST CANCER CELLS

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Keywords: Nanomaterials; Nanobiomedicine

Breast cancer is the most common neoplasm in women worldwide and one of the leading causes of death among women in Mexico. The primary treatment typically involves surgical resection of the lesion and administration of adjuvant chemotherapy, which are often highly aggressive.. Nanotherapy based on nanodiamond (ND) complexes functionalized with metformin (Met) is an innovative strategy for treating this disease. The ND-Met complex has shown low cytotoxic activity in highly aggressive triple-negative breast cancer cells MDA-MB-231 and HS578T. The aim of this project was to evaluate the cytotoxic effect of the ND-Met complex on the MCF-7 breast cancer cell line. MCF-7 is an estrogen and progesterone receptor-positive cell line belonging to the luminal A molecular subtype. For this purpose, cultures with 8,000 MCF-7 cells were exposed to 0, 5, 15, 25, and 250 µg/mL of the ND-Met complex and incubated for 24 hours. ND without functionalization, Met, and DMSO were used as controls at the same concentrations. Viability was determined using the resazurin assay. The results showed that the ND-Met complex significantly decreased MCF-7 cell viability in a dose-dependent manner at 24 hours. The IC50 calculated at 24 hours was 4.8 µg/mL, a significantly lower value than the IC50 of ND or Met (13 µg/mL and 2,500 µg/mL, respectively) (p-8804; 0.05, ANOVA-Tukey). However, the effect of the ND-Met complex was unable to inhibit cell proliferation at 48 and 72 hours. In the analysis of morphological alterations, cells treated with the ND-Met complex showed signs of apoptosis-induced cell death, such as cell shrinkage, nuclear condensation, and fragmentation. These results suggest that the cytotoxic effect of the ND-Met complex may be related to the induction of apoptosis. In conclusion, the results presented here demonstrate the therapeutic potential of the ND-Met complex in luminal A breast cancer, offering an innovative and promising approach to developing new effective therapies for this type of breast cancer.

Submission number: 361

NANODROPLETS MEDIATED HISTOTRIPSY WITH MINIATURIZED MULTI-ELEMENT ULTRASOUND TRANSDUCER: AN IN-VITRO STUDY

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Keywords: Nano-Acoustic Devices, Processes, and Materials; Nanomaterials

Ultrasound induced tissue ablation has diverse applications in medical procedures including treatment of uterine fibroids, neurological diseases, and tumors with either thermal or non-thermal effects. Non-thermal tissue ablation, also known as histotripsy, applied ultrasound burst with low-duty and high peak-negative pressure (>10MPa) for mechanical destruction of tissues through cavitation at the cellular level. Compared with thermal ablation methods, histotripsy avoided the heat sink effect and thermal spread limit, which has minimal injury to surrounding tissues. However, most existing histotripsy applications relied on external transducers or arrays with large aperture for high peak-negative pressure generation, which is limited by significant attenuation and aberration caused by biological tissues. Although most recent work has reported an endoscopic histotripsy array, the device showed relatively complex fabrication process and large ablation size. In this work, a miniaturized transducer was prepared for intracorporeal histotripsy. Considering the small aperture size of the transducer, stacked design was applied for higher pressure output and better electrical impedance matching with a thickness of 230 -956;m for each layer. Then, the transducer was characterized to have a center frequency of 5.5 MHz with an electrical impedance of 90 -937;. Under 300 Vpp input, the transducer showed a peak-negative pressure of 7.18 MPa with corresponding transmitting sensitivity of 0.024 MPa/Vpp. The capability of the transducer for histotripsy was validated through in-intro test with porcine kidney tissues. To decrease the threshold for histotripsy, 500 -956;L of nanodroplets were added with a concentration of 109/mL. For the in-vitro test, a 300 Vpp input was applied with a burst of 10 cycles and pulse repetition frequency of 200 Hz, corresponding to a low duty of 0.036% to avoid any thermal effect. A 7 MHz portable array was used for the nanodroplets cavitation and histotripsy imaging. After 5 min treatment, the in-vitro results showed a lesion region of 7×2 mm2 with NDs injection. The H&E histology and further statistic analysis over the lesion region will be included in the full paper.

Submission number: 362

SLOW ORDERING KINETICS OF MAGNETIC SKYRMIONS

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Keywords: Nanomagnetics; Nanomaterials; Spintronics

Magnetic skyrmions are topologically protected, nanoscale whirls of the spin configuration that tend to form hexagonally ordered arrays. As a topologically non-trivial structure, the nucleation and annihilation of the skyrmion, as well as the interaction between skyrmions, varies from conventional magnetic systems. Recent works have suggested that the ordering kinetics in these materials occur over millisecond or longer timescales, which is unusually slow for magnetic dynamics. The current work investigates the skyrmion ordering kinetics, particularly during lattice formation and destruction, using time-resolved small angle neutron scattering (TR-SANS). Evaluating the time-resolved structure and intensity of the neutron diffraction pattern reveals the evolving real-space structure of the skyrmion lattice and the timeframe of the formation. Measurements were performed on three prototypical B20 skyrmion materials: MnSi, (Fe,Co)Si, and Cu2OSeO3. To probe lattice formation and destruction kinetics, the system was prepared in the stable skyrmion state, and then a square-wave magnetic field modulation was applied. The measurements show that the skyrmions form ordered domains very quickly, with a significant distribution in lattice parameters, which then converge to the final structure; the results confirm the slow kinetics, with formation times between 10 ms and 99 ms. Comparisons are made between the measured formation times and the fundamental material properties, suggesting the ordering temperature, saturation magnetization and magnetocrystalline anisotropy may be driving the timeframes. Micromagnetic simulations were also performed and support a scaling of the kinetics with sample volume, an artifact which is caused by the reconciling of misaligned domains.

Submission number: 363

OPTICAL AND STRUCTURAL CHARACTERIZATION OF GOLD NANOCOLUMNS FABRICATED VIA GLANCING ANGLE DEPOSITION BY SPUTTERING

Garrido-Segovia, Maria*; Gonzalez, Maria Ujue; Galarreta-Rodriguez, Itziar; Navarro Palma, Elena; Espinosa, Ana; Garcia-Martin, Jose Miguel

Keywords: Nanomaterials; Nanofabrication; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

The utility of sputtering in manufacturing thin films is widely acknowledged, particularly within industrial contexts. This technique boasts considerable versatility, enabling the manufacturing of nanocolumnar films (NCs) from various materials through substrate tilting during atom deposition. Regarding Au NCs, they have been used for several applications: as black metal coatings in the visible spectrum [1], as bioelectrodes [2] and as templates for the identification of molecules with SERS, Surface Enhanced Raman Scattering [3,4]. The present work seeks to examine the presence of plasmons in these Au NCs, with the aim of leveraging them as a heat source via photothermal methods or as biosensor probes. This thermal effect is being investigated as a precursor in catalytic processes and for localized tumour treatment [5].-Diverse morphologies of Au nanostructures have been produced on silicon substrates in this work: i) a thin film, for the sake of comparison; ii) a vertical nanocolumnar film, and iii) a film featuring tilted nanocolumns. Morphological characterization of the samples was performed using atomic force microscopy (AFM) and scanning electron microscopy (SEM). Their crystalline and electronic structures were assessed through X-ray diffraction (XRD) and X-ray absorption spectroscopy (XAS) at the Au L3' edge (11919 eV). The latter two techniques were carried out at BM25 and BM30 beamlines, respectively, at the European Synchrotron Radiation Facility (ESRF, France). Finally, the optical properties of these films have been examined using an ellipsometer and a reflectivity measurement system custom-assembled within the laboratory. The different nanostructuring of the films will impart varying optical properties to them, facilitating the identification of those most suitable for the mentioned applications.-

References

[1] A. Vitrey et al., Beilstein Journal of Nanotechnology 8(1) (2017) 434.
[2] S. Mobini et al., Nanoscale 14(8) (2022) 3179.
[3] P. Diaz-Nunez et al., Scientific Reports 9 (2019) 13933.
[4] G. Barbillon et al., Nanomaterials 12 (2022) 4157.
[5] A. Espinosa et al., Advanced Functional Materials 28(37) (2018) 1803660.

Submission number: 364

ON SINGLE PARTICLES AND COMPLEX AGGREGATES UNDER DIFFERENT MAGNETIC FIELD WAVEFORMS: A FOCUS ON MAGNETIC HYPERTHERMIA

Ortega-Julia, Javier; Ortega, Daniel*; Leliaert, Jonathan

Keywords: Nanomagnetics; Modeling and Simulation; Nanobiomedicine

Our ability to monitor the local heat exchange that occurs during magnetic hyperthermia treatment is still limited. The development of methodologies suitable for clinical settings requires the development of physical models that can predict the heating of complex nanoparticle systems based on their physicochemical characterization. We present here the main findings from three different works revealing significant advancements through three pivotal aspects around magnetic hyperthermia. Firstly, we demonstrate the superiority of square waveforms over sinusoidal in driving more uniform and effective nanoparticle heating, emphasizing waveform choice's critical role in optimizing therapy [1]. Secondly, we introduce an equation that enables precise calculation of individual nanoparticle heat dissipation at nonzero temperatures, would simplify the selection process of optimum nanoparticle distributions, or optimal excitation fields, leading to the most homogeneous tumor heating [2]. Lastly, we discuss the possibility of estimating the expected heating in vivo based on the experimentally determined nanoparticle properties [3]. This approach to nanoparticle heating dynamics underscores the synergy between magnetic field waveform, particle interaction, and temperature management, offering a holistic perspective on enhancing magnetic hyperthermia's efficacy and patient safety.

Submission number: 365

CONTROL OF SKYRMIONS IN VAN DER WAALS FERROMAGNETS

Petford-Long, Amanda*; McCray, Arthur; Li, Yue; Phatak, Charudatta

Keywords: Nanomagnetics; Nanomaterials; Nano-Metrology and Characterization

The properties of materials that display functional (such as magnetic and electronic) behavior change as their dimensions reach the nanoscale. Novel emergent behavior can arise as a result of confinement, and also as a result of the proximity of different materials across interfaces, because of the additional contributions to the energy landscape that these parameters introduce. In order to understand the energy landscape that controls this emergent behavior, it is critical to explore the local behavior of the materials and to correlate this with microstructure and chemistry. In this presentation we will discuss the use of quantitative in-situ cryo-Lorentz transmission electron microscopy for exploring the novel behavior of nanomagnetic materials, since it is possible to image the spatial distribution of the magnetic fields as a function of external stimuli such as applied fields and temperatures. Output from these experiments, combined with modeling and simulation can then be used to elucidate the energy landscape that controls the emergent behavior.-The focus of the presentation will be on 2D van der Waals (vdW) ferromagnets, which display a range of novel properties including supporting chiral magnetic spin structures, such as skyrmions, that can be manipulated by temperature and by applied magnetic field. As one example, we explored the thermal hysteresis of Neel-type skyrmion lattice order in Fe3GeTe2 (FGT) and used an analytical domain energy model to explain this behavior [1]. In the same material we showed that partial surface oxidation leads to a change in domain behavior, which we attribute to an interfacial interaction between the surface antiferromagnetic oxide and the bulk ferromagnetic FGT [2]. Changing the iron content of the vdW ferromagnet to Fe5-xGeTe2 resulted in the observation of the coexistence of topological spin textures of merons, anti-merons, and Neel skyrmions in the same film, and the observation of a topological Hall effect. We will also report our results on other vdW ferromagnetic materials.-[1] A.R.C. McCray et al., Nano Lett. 22, 7804-61485;7810 (2022) [2] Y. Li et al., Applied Nanomaterials 6, 4390-61485;4397 (2023) [3] B.W. Casas et al., Advanced Materials, 2212087 (2023).

Submission number: 366

DIE-TO-WAFER (D2W) HYBRID BONDING – BREAKTHROUGH TECHNOLOGY FOR ADVANCED HETEROGENEOUS INTEGRATION

Abdilla, Jonathan*

Keywords: Hydrophobic, Oleophobic and/or Icephobic nanostructured surfaces

Die-to-Wafer (D2W) Hybrid Bonding – Breakthrough Technology for Advanced Heterogeneous Integration Jonathan Abdilla BE Semiconductor Industries N.V.-With the slowing down of Moore’s law, the semiconductor industry has explored new ways to keep up the pace of technological innovation. Materials play a very important role but in addition to this and more prominent is the adoption of advanced packaging techniques. Chiplets is an emerging concept enabling heterogenous integration. Chiplets have been around for several years but typically all chips came from the same IDM. The industry seems to have now embraced an open source standard called Universal Chiplet Interconnect Express (UCIE). The aim is to make it easier to combine chiplets from different companies thus enabling IP reuse and faster time to market. The prediction is that in the next years there will be an increase in the number of packages employing chiplets and the advancement and emergence of new packaging techniques to assemble them. Die to wafer (D2W) hybrid bonding is a promising new technology for the upcoming top tier advanced packaging regime requiring higher number of interconnects and tighter pitches to control die size. This technology is enabling the continued scaling and improvement of microprocessor performance beyond the limits of Moore's Law. However, D2W hybrid bonding also introduces a new set of challenges that must be addressed in order to successfully implement it in high-volume production. These challenges include the need for new placement technologies and a deeper understanding of the behavior and interactions that impact bonding accuracy. This presentation provides an overview of hybrid bonding process flows and findings from actual D2W bonds performed with a high-accuracy hybrid bonder. We will also highlight some products in the market which make use of this technology and the equipment which enables this.-Acknowledgements-- I would like to extend my sincerest thanks to my colleagues at Besi for their hard work and input, and also to Applied Materials, particularly the Singapore Centre of Excellence team for their collaboration to understand and solve problems as well as for their support in all trials and sample builds

Submission number: 367

NANO-OPTOMECHANICAL DISK SENSORS

Sentre-Arribas, Elena; Aparicio-Millan, Alicia; Ruz, Jose Jaime; Malvar, Oscar; Favero, Ivan; Lemaitre, Aristide; Monteiro, Priscila; Garcia-LOpez, Sergio; Calleja, Montserrat; Tamayo, Javier; Gil-Santos, Eduardo*

Keywords: Nanosensors and Nanoactuators; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

Nano-optomechanical disks are excellent candidates for sensor development in a wide range of applications. These devices simultaneously support very high quality optical and mechanical modes, making them advantageous for sensing. In the last decade, we have proposed their use for liquid characterization [1], pathogen detection [2], and environmental monitoring [3], among others. Here, we review all of these applications, explain their operating principles, and provide insight into their future potential [4]. We particularly focus on their application in pathogen sensing. In this regard, we have recently proved that these devices allow the detection of mechanical modes associated with individual bacteria (Figure 1) [3]. This result paves the way for developing a novel and very promising technique, the mechanical spectrometry of microbiological entities [4]; which promises the detection, mechanical and morphological characterization, and univocal identification of many kind of microbiological entities: human cells, bacteria, virus, proteins, etc.-Acknowledgements This work was supported by the European Union’s Horizon 2020 Research and Innovation Program under grant agreements no. 731868-VIRUSCAN and no 770933-NOMLI. We acknowledge the service from the Micro and Nanofabrication Laboratory and the X-SEM laboratory at IMN-CNM funded by the “Comunidad de Madrid” (project S2018/NMT-4291 TEC2SPACE) and by MINECO (project CSIC13-4 × 10–1794 with support from FEDER, FSE).-

References

[1] E. Gil-Santos, C. Baker, D.T. Nguyen, W. Hease, C. Gomez, A. Lemaitre, S. Ducci, G. Leo, I. Favero, Nat. Nanotech. 10 (2015) 810.
[2] E. Gil-Santos, J.J. Ruz, O. Malvar, I. Favero, A. Lemaitre, P.M. Kosaka, S. Garcia-LOpez, M. Calleja, J. Tamayo, Nat. Nanotech.15 (2020) 469.
[3] E. Sentre-Arribas, A. Aparicio-Millan, A. Lemaitre, I. Favero, J. Tamayo, M Calleja, E. Gil-Santos, ACS sensors 9 (2023) 371.
[4] E. Gil-Santos, Nat. Phot. 17 (2023) 931.

Submission number: 368

TUNING THE MAGNETIC COUPLING OF IRON OXIDE NANOPARTICLES WITH ONION-LIKE ARCHITECTURE

Nunez, Jorge M.; Lima, Enio Jr.; Lohr, Javier; Vasquez Mansilla, Marcelo; Hettler, Simon; Zysler, Roberto D.; Aguirre, Myriam H.; Winkler, Elin*

Keywords: Nanomagnetics; Nanomaterials

In nanostructured systems, the quality and nature of the surfaces and interfaces determine their magnetic behaviour, offering new tools for precise manipulation of desired responses.[1] The onion-like architecture facilitates the integration of proper materials within a single nanoparticle, featuring controlled dimensions and high-quality interfaces, thereby enabling modulation of magnetic inversion dynamics through fine adjustments of magnetic anisotropy and interphase coupling.[2] This study explores various methodologies employed to engineer magnetic nanoparticles (NPs) with onion-like architectures aimed at tailoring magnetization reversion curves. Specifically, we investigate the evolution of structural and magnetic properties in ~20 nm iron oxide NPs from Wüstite to hematite via controlled oxidation through post-annealing thermal treatments. Our focus lies on elucidating the formation of intermediate Wüstite-core/magnetite-shell structures resulting from surface oxidation and the consequent augmentation in shell thickness with annealing. We examine the strain arising from the Wüstite-magnetite phase mismatch and explore the potential for tuning coercive and exchange bias fields, as well as magnetic saturation, through controlled oxidation processes. Furthermore, we delve into the magnetic coupling phenomena within core/shell/shell architectures, wherein a ~22 nm Fe_3O_4 ferrimagnetic core is encapsulated successively by a MgO shell (~1 nm thick) and a $CoFe_2O_4$ ferrimagnetic outer shell (~2.5 nm thick).[3] We observed a single magnetization reversion curve, an enhancement of the coercivity compared to single magnetite nanoparticles, and the presence of exchange bias field. These properties are related with the presence of interphase diffusion and surface disorder, manifesting the complex behaviour exhibited by these nanostructures.

Submission number: 369

DRUG-INTEGRATING AMPHIPHILIC NANO-ASSEMBLIES (DIANAS) FOR TARGETED AND LOCALIZED IMMUNOMODULATION

Tondin, Arthur, Rech; Dal Buono, Teodora; Moffa, Samanta; Fontana, Antonella; Lanzoni, Giacomo; Velluto, Diana*

Keywords: Nanomaterials; Nanofabrication; Nanobiomedicine

see attached file

Submission number: 370

A NOVEL MICROWAVE ASSISTED SOL-GEL SYNTHESIS OF TITANIUM PHOSPHATE CRYSTAL PHASES AND THEIR ANTIBACTERIAL PERFORMANCE

Hubetska, Tetiana*; Khainakova, Olena; Cabal, Belen; Kobylinska, Natalia; Fernandez Valdes, Adolfo

Keywords: Nanomaterials; Nanostructures for extreme environments

This Crystalline titanium phosphates (TiP), inorganic functional materials with a unique structure has recently attracted much attention because it is one of the most prominent materials in the area of chemical and mechanical selective catalysis, electrochemical industry (protonic conductors) and environmental engineering. Three main approaches for the synthesis of crystalline phases of titanium phosphate have been described: (a) the reflux methods; (b) the metal complexing reagent-utilizing methods; and (c) the hydrothermal methods. We are unaware of reports on the preparation of all early published crystalline phases of TiP through this method. Motivated by this observation, we have attempted to synthesize crystalline phases of titanium phosphates through microwave irradiation induced reaction between TiCl4 and H3PO4 of different concentrations. The microwave irradiation with max power 600 W was used. Utilizing a novel MW technique from aqueous solutions, we synthesized crystalline phases of d10–TiP (Ti2O3(H2PO4)2·2H2O), -960;–TiP (Ti2O(PO4)2·H2O), and -945;–TiP (Ti(HPO4)2 H2O) nanostructures with H3PO4 concentration 0.5–1.2 M, 1.5 – 2.0 M and 2.8 – 5.0 M, respectively. The synthesized materials were characterized by XRD, SEM, TEM, FTIR, TG-MAS, and N2 ad/desorption isotherms at 77 K. Their bactericidal capacity was also evaluated by performing susceptibility tests and time-kill kinetic assays. The crystal morphology of the prepared -945;-TiP displays platelet-like structure with a hexagonal shape, which is agreed with the Ti(HPO4)2 H2O produced by traditional methods. The obtained -960;–TiP samples appears smooth and had a dense structure nanofiber. The microwave irradiation with facilitates instantaneous generation of the titanium chloride and phosphoric acid of different concentrations precursor solution, which in consequence makes the process of preparation of crystalline titanium phosphates much faster and less cumbersome compared to other reported chemical hydrothermal routes. The developed process is technically simple and makes use of microwave oven. Practically, the synthesised crystalline phases are potentially useful as a cation exchanger, proton conductor and, especially, biomedical devices.

Submission number: 371

SYNTHETIC MG, FE–LAYERED DOUBLE HYDROXIDE MATERIALS: SYNTHESIS, CRYSTAL STRUCTURE AND ADSORPTION MECHANISM STUDY

Hubetska, Tetiana*; Demchenko, Victor; Kobylinska, Natalia

Keywords: Nanomaterials

Layered structures of the hydrotalcite-supergroup materials consist of positively charged brucite layers with octahedral sites occupied by M2+ and M3+ cations, which usually were found in two polytypic modifications: 3R and 2H. In layered materials, the layer-stacking sequence allows the tuning of ion transport and sorption properties by modulating the host-ion interactions. However, unlike in the case of cations, the relation between the stacking sequence and anion sorption properties is less clearly understood. The present study is concerned the synthesis of synthetic pyroaurite clays with the general formula [Mg2+(1-x)Fe3+x(OH)2][CO32-x/2 mH2O] (where x=Fe3+/(Mg2++Fe3+), 0,15 < x < 0,33) (Fig. 1a). These materials are prepared by co-precipitation method. The obtained sorbents were applied for pharmaceuticals removal using ibuprofen as a model in anionic form. The XRD patterns confirm the formation of pyroaurite-like structure of crystalline phases in the composition range, 0,15 < x < 0,35. Product with x <0,14 and x 0,45 contained brucite or other compounds as an impurity phases. The plate-like morphology of materials is evident by TEM. EDX and AAS analysis showed that the Mg: Fe ratios of the precipitates were equal to those of the starting reaction mixtures. Thus, neither Mg nor Fe precipitated preferentially. The parameter, a, was 3,1120 Å at x = 0,33 and increased to 3,1183 Å at x = 0,20 with a decrease in the amount of Fe. The ionic radii are 0,720 Å for Mg2+ and 0,645 Å for low-spin Fe3+. Thus, the substitution of Mg2+ with smaller Fe3+ decreased the a parameter. The gallery height (7,7707-7,8373 Å and 7,7550-7,88550 Å determined by 3R and 2H, respectively) of sorbents is in all cases lower than the size of the ibuprofen (Fig. 1b) depending on the synthesis route followed and space group of sorbents. Experimental data suggest the analyte molecules in better case form a very thin-lying monolayer, with the carboxylate groups pointing towards the brucite-like layers without stretching interlayer distance according to XRD data. When the samples were immersed into the ibuprofen solution, a part of the Mg2+ ions into the solution (dissolve of hydrotalkite layers).

Submission number: 372

ATOMISTIC SIMULATION OF PLASMA ASSISTED METAL ATOMIC LAYER DEPOSITION

Nolan, Michael*

Keywords: Nanoelectronics; Emerging Plasma Nanotechnologies; Modeling and Simulation

Atomic layer deposition (ALD) is widely used in microelectronics and semiconductor industry to deposit metal and its oxide and nitride thin films as part of device fabrication in nano- or subnano-dimensions. The key advantages of ALD are the conformality and precise thickness control at the atomic scale, which are difficult for physical or traditional chemical vapor deposition methods. The atomic scale understanding of ALD is vital and essential to design and optimize the deposition process, where density functional theory (DFT) calculations play an important role in providing detailed reaction mechanism, theoretical screening of suitable precursors and estimated growth-per-cycle (GPC), while allowing ALD chemistry of new processes to be explored. Cobalt (Co) is a material of high interest in the semiconductor industry due to attractive electrical and physical properties. The replacement of Cu with Co as conductive contacts or interconnects in integrated circuit (IC) devices is an illustrative example. In this contribution, I present our work on plasma enhanced (PE) ALD deposition of Co from first principles simulations of NH_3/H_2 plasma chemistry. For PE-ALD of Co using $CoCp_2$ and N/H-containing-plasma, we determined the state of the Co surface after an ALD cycle establishing preferred surface compositions. We determine reaction mechanism for the metal precursor pulse and the plasma half-cycle on these NH_x-terminated Co surfaces, which corresponds to the steady growth for the PE-ALD. We show the key role of nitrogen in activating the surface and removing Cp ligands, while H is also required to remove unwanted nitrogen, eliminate Cp and activate the surface, so only a plasma with both species will be effective in Co ALD. Finally, the reactions at the initial stages on a range of Si(100) surface terminations are investigated to gain atomic insight on the effect of different substrates on the elimination of Cp ligands.

Submission number: 373

BIOMIMETIC POLYMER ELECTRONICS FOR MULTI-MODAL INTERFACING WITH BIOLOGY

Wang, Sihong*

Keywords: Nanotechnology in Soft Electronics; Nanosensors and Nanoactuators;

Nanomaterials

The human body and other biological systems carry important and complex information that is vital for health monitoring, disease treatment, and human-machine interactions. Electronics stand as unparalleled tools for precisely recording, analyzing, and modulating biological behaviors across all spatial and temporal scales. To achieve intimate and multi-modal interfacing of electronic devices with biological tissues and organs, electronics must mimic various aspects of biophysical and biochemical properties in biological systems. Moreover, biological systems also provide unique operational mechanisms with high energy efficiency. In this talk, I will introduce our recent research in designing polymer-based electronic materials and devices that combine biomimetic properties with advanced electronic and photonic functions. First, I will discuss our research in the development of organic semiconductor- and transistor-based biosensors, with the impartment of several biomimetic properties: (1) skin-like stretchability for mechanical robustness, (2) bioadhesive properties for intimate and stable interface with tissues, and (3) immune-compatible properties for suppressing foreign-body responses. Second, I will introduce our effort in the development of stretchable neuromorphic devices and circuits for implementing AI-based analysis for health data, which paves the way for integrating AI-based computing with wearable and implantable systems. Third, I will discuss our development of stretchable light-emitting polymers and OLEDs for use in skin-like displays and optical bio-stimulations.

Submission number: 375

NANOSCALE MAGNETISM: FROM NEW MATERIALS TO UNCONVENTIONAL COMPUTING ARCHITECTURES

Khalili Amiri, Pedram*

Keywords: Spintronics; Quantum, Neuromorphic, and Unconventional Computing;

Nanomagnetics

The emergence of magnetic random-access memory (MRAM) based on nanoscale magnetic tunnel junctions (MTJs) provides an unprecedented opportunity to develop unconventional computing architectures, with potential impact far beyond replacing existing semiconductor-based memory solutions. This talk will consist of two parts: First, we review the current state of development of ferromagnet-based MRAM, which uses current-induced spin-transfer torque (STT) to switch the magnetic state of nanoscale MTJs. We then discuss how emerging device concepts based on new physics and new materials may enable significant advances beyond today's STT-MRAM. As an example of new physics, we discuss electric-field-controlled MTJs that utilize the voltage-controlled magnetic anisotropy (VCMA) effect for switching, and present recent results on the first VCMA-MTJ devices with sub-1V write voltage. Second, we will discuss how appropriately designed MTJs can be used to fulfill unconventional roles within a computing system, notably as electrically controlled stochastic bitstream generators. We then discuss the application of such devices to artificial neural networks, solvers for difficult computational problems such as combinatorial optimization and integer factorization, as well as physically unclonable functions.

Submission number: 376

GRAPHENE NANORIBBON-BASED ANALOG-TO-DIGITAL CONVERSION

Verton, Pim*; Cotofana, Sorin

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Nanomaterials;

Nanoelectronics

This paper introduces a novel approach towards Analog-to-Digital Converter (ADC) implementation that combines Graphene Nanoribbon (GNR) devices capabilities to provide augmented (more complex than a switch) functionality with the fact that each output bit <i>bi^, <i>i^ -8712; [0,<i>n^-1] of an <i>n^-bit ADC is defined as a periodic symmetric function <i>Fi^(<i>V^in) with period <i>V^max / 2<i>i^, of the ADC input <i>V^in -8712; [0, <i>V^max]. As such, by making use of the Boolean function implementation methodology with two complementary GNRs, the implementation of an <i>n^-bit ADC requires 2<i>n^ GNR devices. To demonstrate our approach we present the implementation of a 4-bit ADC and the evolutionary algorithm that identifies the GNR topologies required for <i>Fi^(<i>V^in), <i>i^ -8712; [0,3] evaluation when <i>V^in -8712; [0, 200 mV]. We demonstrate the correct functionality of our proposal by means of SPICE simulations and compare it with state-of-the-art counterparts. The comparison indicates that our approach exhibits around five orders of magnitude lower power consumption, is operating at four orders of magnitude larger sample frequency, requires nine orders of magnitude lower real estate, and, in terms of Walden's figures of merit, scores three orders of magnitude better in time per conversion step and nine in energy per conversion step. The required GNR device topologies are identified by means of an evolutionary algorithm, allowing a design space of many trillions of possible devices to be searched by evaluating the behaviour of only a few hundred thousand different topologies.

Submission number: 377

GRAPHENE-BASED COMPLEMENTARY-STYLE LOGIC GATE WITH MEMORY-LOCK

Cucu Laurenciu, Nicoleta*; Timmermans, Charles; de Groot, Nicolo; Cotofana, Sorin

Keywords: Nanoelectronics

As CMOS feature size vertiginously approaches atomic limits, high leakage and power density and exacerbating IC production costs are prompting for development of new materials, devices, beyond von-Neumann architectures and computing paradigms. Within this context, graphene has emerged as a promising post-Si front runner, owing to its remarkable properties. In this paper, we propose a generic graphene-based complementary-style Boolean gate structure with memory-lock, that allows logic and non-volatile memory co-location. The gate with memory-lock is composed of 2 cells - a pull-up cell performing the gate Boolean function and a pull-down cell performing the inverted Boolean function. Each cell in turn, has a graphene logic layer that carries out Boolean gates computation, and a graphene memory layer for storing the logic state of the gate. As simulation vehicle we considered an inverter gate with memory-lock. Simulation results indicate a current ratio of write/read to/from memory of 1.64*10^2 for gate input low, and of 2.55*10^2 for gate input high. Furthermore, the inverter with memory-lock exhibits a 128× smaller area footprint when compared to the traditional physically separate logic (e.g., 7nm inverter gate) and memory (e.g., 7nm 6T SRAM cell), establishing the potential of proposed structure with memory-lock for more compact and energy efficient future beyond CMOS nano-electronic implementations, and making it highly promising for high-density computations.

Submission number: 378

GRAPHENE NANORIBBON BASED MCCULLOCH-PITTS NEURAL NETWORK

Dumitru, Florin-Silviu; Enachescu, Marius*; Antonescu, Alexandru; Cucu Laurenciu, Nicoleta; Cotofana, Sorin

Keywords: Nanoelectronics; Modeling and Simulation; Quantum, Neuromorphic, and Unconventional Computing

In the context of an artificial intelligence and machine learning landscape that is evolving at an unprecedented pace, we propose a low power, high-speed, mixed-signal graphene nanoribbon-based (GNR) McCulloch-Pitts neuron (MCPN) implementation featuring programmable synaptic weights and inhibitory inputs. By definition, a generic MCPN is comprised of two parts, a weighted summation element and a decision element, called a soma. Our summation element implementation uses three distinct non-rectangular GNR devices, biased under specific conditions, to fulfill the roles of current source, low-side and high-side switches. The programmable excitatory and inhibitory synapses were obtained leveraging GNR SRAM cells and logic gates, hence providing the flexibility needed by real-world applications. The decision element's threshold activation function was implemented using a chain of GNR inverter structures which manifest the function's characteristic in the analog domain. Modulation of the decision element's threshold is achieved indirectly by means of a configurable resistive load which is varied depending on the configuration stored in SRAM. Our benchmark results, obtained using a generic 5 by 5 pixel pattern recognition application, reveal that the GNR-based implementation achieves 3.5× less power consumption, 20× higher speed, while occupying 3× less active area when compared to its FinFET analog circuit counterpart.

Submission number: 379

QUATERNARY MIN LOGIC GATE WITH BALLISTIC GRAPHENE DEVICES

Rallis, Konstantinos*; Tsintotas, Konstantinos; Dimitrakis, Panagiotis; Rubio, Antonio; Sirakoulis, Georgios

Keywords: Nanoelectronics; Nanomaterials; Modeling and Simulation

Owing to its remarkable characteristics, Graphene has become a focal point of interest across numerous research domains, particularly electronics. It is being explored as a potential material for creating nanodevices that could form the basis of both traditional and novel computing circuits. In this work, we investigate the ability of Graphene Nanoribbon-based devices to perform basic quaternary logic (QL) operations. After mentioning the common practices in using Graphene for the realization of Multi-Valued-Logic circuits, we examine the possibility of utilizing the quantum mechanical phenomena that drive the functionality of small-sized Graphene Nanoribbons (GNRs) in the form of Graphene Quantum Point Contacts (GQPCs), in order to provide alternative quaternary logic circuit implementations with special characteristics.

Submission number: 380

THREE-DIMENSIONAL LOGIC IN MEMORY DEVICE FOR ULTRA-LOW POWER PARALLEL EVOLUTIONARY COMPUTING

Zhang, Zhizhong; Lin, Kelian; Feng, Xueqiang; Wang, Jinkai; Zhao, Weisheng; Zhang, Yue*

Keywords: Spintronics; Quantum, Neuromorphic, and Unconventional Computing; Modeling and Simulation

In this paper, a three-dimensional all-spin parallel evolutionary computing (ASPEC) device is proposed to realize the evolutionary algorithm in a single device instead of a traditional CMOS circuit. A 3D magnetic tunnel junction (MTJ) array is used to store the genetic information of the whole population. Using the spin transfer torque (STT) effect with spin diffusion mechanism, we realize a parallel computing scheme for chromosome replication, proliferation, crossover, gene mutation, and selection. Getting benefit from the logic-in-memory (LIM) architecture consisting of MTJ arrays, the ASPEC device is not only non- volatile but also avoids memory wall. Our results show that the time complexity of evolutionary algorithms is reduced due to the parallel computing design, and the energy consumption is also significantly cut down owing to non-volatility and its avoidance of Joule heating.

Submission number: 381

SPIN WAVE MAJORITY GATES CASCADING BY GILBERT DAMPING EMBRACEMENT (CAN THE DEVIL BE TURNED INTO AN ANGEL?)

Anagnostou, Pantazis*; Van Zegbroeck, Arne; hamdioui, Said; Adelmann, Christoph; Ciubotaru, Florin; Cotofana, Sorin

Keywords: Spintronics; Quantum, Neuromorphic, and Unconventional Computing; Nanomagnetics

Recent theoretical and experimental spintronics developments clearly indicate that Spin Waves (SW) interference based Majority gates (MAJ3) open an alternative road towards ultra low-power circuit implementations potentially capable to outperform CMOS counterparts. However, hurdles still exist, e.g., gate cascading, as due to the very nature of SW interference MAJ3 gates are not input output coherent, i.e., produce output waves with different amplitudes corresponding to 'weak' and 'strong' majority, which precludes their direct cascading within the SW domain. State of the art designs address this issue by means of hybrid SW-CMOS systems that make use on domain converters, which are energy expensive and diminish if not nullify the ultra-low power promise of the SW-based computing paradigm. In this paper we propose a gate cascading technique that rely on the natural SW amplitude decay while propagating through a magnetic conduit. We demonstrate the concept by constructing the building block MAJ3(MAJ3(In1, In2, In3), In4, In5) and verifying its correct behaviour by means of micromagnetic simulations. We evaluate the proposed design in terms of energy consumption, delay, and area, and our calculations indicate that, when compared with its domain conversion counterpart, our proposal consumes 49.5% less energy, at the expense of 48% area and 76.5% delay overhead, respectively.

Submission number: 382

SPIN WAVE THRESHOLD MAJORITY GATE

Van Zegbroeck, Arne*; Ciubotaru, Florin; Anagnostou, Pantazis; Meng, Fanfan;

Adelmann, Christoph; hamdioui, Said; Cotofana, Sorin

Keywords: Spintronics; Quantum, Neuromorphic, and Unconventional Computing;

Nanomagnetics

Current Spin Wave (SW) state-of-the-art com- puting relies on wave interference for achieving low power circuits. Despite recent progress, many hurdles, e.g., gate cascading, fan-out achievement, still exist. In a previous work, we introduced a novel SW phase shift based computation paradigm and demonstrated that an n-input Threshold Logic Gate (TLG) can be implemented with n + 1 phase shifters operating on the same SW. In this paper we further develop this concept by introducing a phase shift amount reading method by means of parametric amplification. We make use of 3-input Majority Gate (MAJ3) as discussion vehicle and introduce a novel majority function evaluation approach which postpone the threshold related calculations to the gate output readout stage. Subsequently, we verify this principle by means of micromagnetic simulations and discus the results. Finally, we utilize the proposed MAJ3 gate to implement a collection of representative logic circuits from the EPFL Combinational Benchmarking Suite and evaluate and compare their area, energy consumption, and Energy Area Product (EAP) with the ones of 7 nm CMOS technology node based counterpart implementations. Our estimations indicate that EAPCMOS EAPSW average value is 5.25 and 2.2 for a SW transducer feature size of 20 nm and 30 nm, respectively.

Submission number: 383

TRUE ATOMIC FORCE MICROSCOPY IMAGES: REMOVING SCANNING ARTEFACT USING DUAL-TIPS PROBE

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Keywords: Nanorobotics and Nanomanufacturing

Scanner artifacts stem from the nonlinear dynamic behavior of piezoelectric actuators and the interaction conditions between the tip and objects, exhibiting characteristics such as non-linearity, creep, hysteresis, and geometric artifacts. During an AFM scan, the tip-sample convolution effect arises from the geometric interactions between the tip and the surface being imaged. This convolution effect is a primary cause of AFM artifacts, resulting in limited sharpness and distinct geometries of objects, which are influenced by the mechanical interaction characteristics of the AFM. Deconvolution of AFM images can typically be approached from two main perspectives. One approach involves using a known geometric tip with a precalibration process to recover the sample's true shape by accounting for the known geometric effects on the convoluted images. However, these geometric methods have their limitations. For instance, the actual contact point is complex due to the heterogeneity of probe tips and samples, and there may be errors in the shape measurement during the calibration process. Another set of approaches for deconvolution is based on statistical methods that require multiple images for the samples of interest, such as localization atomic force microscopy. While this method can efficiently locate the apex of the targeted protein, it requires a large number of images, and some topographical information may be sacrificed during the apex finding process. Therefore, there is still ample room for more comprehensive approaches to reveal the true shape of nanometer/subnanometer objects. In this research, we have successfully produced high aspect ratio dual-tip probes, resembling "chopsticks," and conducted a wear experiment to enable dual imaging acquisition during measurements. We have managed to maintain the height difference between the tips within a tolerance of less than 5nm and performed a slope wedge device to further decrease the tip height difference. With the fabricated dual-tip probe, we first established the principles of the scanning strategy to elucidate the imaging process. Subsequently, we applied an imaging recovery algorithm that deconvolutes tip effects based on geometry

Submission number: 385

TERAHERTZ GENERATION IN EXCHANGE BIASED CO/IRMN HETEROSTRUCTURE

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Keywords: Spintronics; Nanomagnetics; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

A spintronic emitter has been created, consisting of layers of ferromagnetic film Co (3 nm thick) and antiferromagnetic film IrMn (5 nm thick) on Al_2O_3 substrate. The Co and IrMn layers were deposited using the magnetron sputtering method. A study of the exchange bias field between the ferromagnetic and antiferromagnetic layers was carried out using the THz time-domain spectroscopy method. The possibility of manipulating the direction of the exchange bias under the influence of laser heating and weak magnetic fields has been shown. The mechanism of THz radiation generation in the spintronic emitter has been investigated.

Submission number: 386

PHOTOLUMINISCENT CARBON DOTS AS MODIFIERS TO IMPROVE THE ELECTROCHEMICAL PERFORMANCE OF SCREEN PRINTED ELECTRODES

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Keywords: Nanomaterials; Nano-Energy, Environment, and Safety; Nanobiomedicine

Carbon quantum dots (CQDs) are zero-dimensional nanomaterials with an outstanding performance over conventional semiconductor quantum dots. They can be obtained through different precursors and methods along with several post-processing treatments, such as purification or surface functionalization [1]. This CQDs are used and studied because of their unique optical properties derived from the control of the crystallinity and distribution of functional groups along with their size and morphology. They are also excellent candidates for the modification of screen-printed carbon electrodes (SPCEs) that allow us to detect a large variety of target analytes [2]. SPCEs are widely used since they present many advantages: they are low-cost, portable, and disposable electrochemical sensors that require a small amount of volume. In this work, we have prepared different types of CQDs from citric acid [3] which were used to modify different SPCEs to detect compounds of biological interest, as dopamine (DA). The CQDs sizes were characterized by means of atomic force microscopy (AFM), and the detection of the analyte was performed by different electrochemical techniques using a Micrux potentiostat (ECSens model) [4] which is an ultra-compact device.

Submission number: 387

EXPLORING THE LIMITS OF MAGNETISM IN 2D AND BEYOND

Santos, Elton*

Keywords: Spintronics; Nanomagnetics; Nanomaterials

Long searched but only now discovered two-dimensional (2D) magnets are one of the selected group of materials that retain or impart strongly spin correlated properties at the limit of atomic layer thickness. In this presentation, I will discuss how different layered compounds (e.g., CrX3 (X=F, Cl, Br, I), MnPS3, Fe5-xGeTe2, Cr2Ge2Te6) can provide new playgrounds for applications and fundamental exploration of spin correlations involving quantum-effects, topological spin-excitations and ultrafast laser pulses. In particular, I will show how van der Waals magnets do not require any magnetic anisotropy to stabilize 2D magnetism and demonstrate the null valid of the Mermin-Wagner theorem in practical applications. Moreover, some recent results of ultrafast laser excitations on different vdW heterostructures will be shown towards all-optical control of their magnetic properties with efficient heat management.

Submission number: 388

ASYMMETRIC MAGNETIC RESPONSE INDUCED BY COMPOSITIONAL GRADIENTS IN NI-FE NANOWIRES

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Keywords: Nanomagnetics; Spintronics; Nanomaterials

The control over domain wall motion in cylindrical nanostructures is a key factor for developing the next generation of spintronic and logic devices. Among several strategies, introducing changes in the chemical structure of the wire (chemical barriers) has been proven to be an effective way to pin the domain walls, but determining the direction of domain wall movement still remains as an open challenge. Following the same approach, in this work we introduced gradients of composition in Ni-Fe nanowires to pattern a ratchet profile of domain wall energy along the nanowire axis, in order to create an asymmetry for domain wall movement. Nanowires were synthesized using template-assisted electrodeposition. The composition was gradually changed between Ni90Fe10 and Ni35Fe65 along the nanowire longitudinal axis in periods of a few micrometers). By combining laterally resolved X-ray Absorption Spectro-microscopy (XAS) and X-ray Magnetic Circular Dichroism (XMCD), we correlated the chemical structure of single nanowires with their 3D spin texture. By applying external magnetic fields along the nanowire axis, we studied the evolution of the magnetic state depending on the field direction. In addition, First Order Reversal Curves (FORC) were also measured in arrays of nanowires. The FORC diagrams of nanowires with homogeneous composition and nanowires with axial gradients of composition. While the diagram of homogeneous nanowires is highly symmetric with respect to the interaction field axis (HU), an asymmetry arises in the diagram of nanowires with axial gradients, evidencing the emergence of asymmetrical magnetization processes in the nanowires.

Submission number: 389

INFLUENCE OF CHEMICAL AND GEOMETRICAL MODULATIONS ON MAGNETIC PROPERTIES OF CO-NI BISEGMENTED NANOWIRES

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Keywords: Nanofabrication; Spintronics; Nanomagnetics

The recent and innovative progress in fabrication and characterization techniques has enabled the design of metallic and magnetic multisegmented nanowires (NWs) with tailored physico-chemical properties. Ferromagnetic NWs can exhibit controlled features such as peculiar magnetic anisotropy, enhanced coercivity and well-defined pinning of magnetic domain walls, among others, achieved through precise tuning of the geometry and composition of the NWs modulations. Although such modulations have been studied independently, the achievement of simultaneous modulations in composition and diameter has been challenging [1]. In this study, we developed both at once, compositionally and diameter modulated Co-Ni bi-segmented NWs, whose composition is different for each NW segment and changes at the interface between the wide and narrow segments. Former nanoporous alumina membranes (NAMs) are made by combining electrochemical anodization, pore widening and atomic layer deposition (ALD) processes, obtaining a well-defined pores diameter modulation with a sharp transition between the two diameter segments. Afterwards, NAMs are filled by electrodeposition techniques by carefully controlling the current profile, which allows to fill each of the bi-segmented nanopores with different magnetic materials, thus resulting in compositionally and geometrically modulated NWs. Therefore, four different samples were fabricated with a fixed 3:1 ratio in the diameter modulation of bi-segmented NWs and varying the composition of the thinner and wider segments (Co-Co, Ni-Ni and Co-Ni or Ni-Co, respectively). Morphological and compositional analysis were conducted by SEM and HR-TEM techniques. Temperature dependent magnetic hysteresis loops (HLs) have been measured by VSM to determine the influence of geometrical and chemical modulations on the magnetic behaviour. The intrinsic magnetization reversal of the NW segments and the magnetostatic interactions among NWs are strongly dependent on the different combinations between the composition and diameter modulations of the segments. [1]Pitzschel et al. J.Appl.Phys. 109, 033907 (2011)

Submission number: 390

LOCAL TUNING OF THE ELECTRONIC PROPERTIES OF ULTRATHIN VAN DER WAALS MATERIALS BY ALKALI METALS DOPING

Frisenda, Riccardo*

Keywords: Nanomaterials; Nano-Optics, Nanophotonics, and Nano-Optoelectronics;

Nano-Energy, Environment, and Safety

Mechanical exfoliation of van der Waals (vdW) crystals allows to routinely produce high quality two dimensional (2D) crystals in a laboratory. Thanks to their ultrathin nature, the electronic properties of these materials are highly susceptible to external stimuli and interaction with the environment. In this talk I will present a strategy to tune the structural and electronic properties of 2D materials, by alkali metals adsorption and intercalation in ultra-high vacuum [1]. Due to the presence of a loosely bound s electron, these atoms form ionic bonds and act as strong donors inducing a chemical doping in the host vdW material. Thanks to spatially resolved Raman spectroscopy we can study the changes in the vdW materials induced by the AM atoms. In this talk I will discuss the dynamic of potassium atoms adsorption, diffusion and intercalation in few layer and multilayer graphene, covering the topic of charge donation and local strain in graphene [2]. The detection of intercalation fronts and islands underscores the complex, collective nature of this phenomenon, offering valuable insights for potential applications in energy storage systems.

Submission number: 391

EFFECT OF ELECTRIC FIELD ON THE WEAK INTERACTION OF TWO-DIMENSIONAL BILAYER STACKED MATERIALS

Cao, Shuo*

Keywords: Nanoelectronics; Modeling and Simulation; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

Stacked two-dimensional (2D) materials together to form van der Waals heterojunctions can combine the-advantages of different 2D materials with improving the performance of new low-dimensional materials-optoelectronic devices [1, 2]. The quantitative analysis of the weak interaction of 2D stacked materials is very-few [3]. Constructing the models of stacked bilayer graphene, Graphene/MoS2 and Graphene/WS2 heterostructures shown in Figure 1, by applying a gradually increased electric field in both positive and negative directions on the three 2D stacked bilayer structures, the numbers of interlayer charge transfer reflect-the weak interaction changes between the bilayer materials shown in Figure 2 [3]. It is concluded that the-stronger weak interaction, and the smaller the band gap in the electronic structure of 2D bilayer stacked-materials in Figure 3, and vice versa.

References

[1] Yihang Zeng, Zhengchao Xia, Roei Dery, Kenji Watanabe, Takashi Taniguchi, Jie Shan & Kin Fai Mak, Nat. Mater.
22 (2023) 175.
[2] Yuan Liu, Yu Huang & Xiangfeng Duan, Nature. 567 (2019) 323.
[3] Changcheng Xu, Yong Ding, Shaofeng Wang & Shuo Cao, Spectrochim Acta A. 303 (2023) 123182

Submission number: 392

RAPID AND EFFICIENT REMOVAL OF DICLOFENAC SODIUM FROM AQUEOUS SOLUTION VIA BINARY MGFE-LDH-61655;FE3O4 NANOCOMPOSITES

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Keywords: Nanomagnetics; Nano-Energy, Environment, and Safety; Nanostructures for extreme environments

Diclofenac (2-[2-(2,6-dichloroanilino) phenyl] acetic acid, DCF) and its metabolites (e.g., 4'-hydroxydiclofenac (4'-OH-DCF) or 5-hydroxylated DCF (5-OH-DCF) had been frequently detected in the various water sources usually as emerging compounds, because of its widespread human and veterinary use since the 1970s. Adsorption is simple, cheap, rapid, easy to operate, and an e-64259;cient technology for removing pharmaceuticals, as well as no degradation products will be generated. Many adsorbents were used for diclofenac removal such as activated carbon, natural clay and layered double hydroxides (LDH). LDH adsorbent nanomaterial is nontoxic, resembles synthetic clay minerals in its properties and it is easily prepared. In this work, binary Mg,Fe-LDH-61655;xFe3O4 (x = 0 to 2.0) nanocomposites were prepared via the in-situ growth of Mg,Fe-layered double hydroxides (LDHs) onto magnetite nanoparticles and applied for anionic diclofenac motives removal. These materials are prepared by combination co-precipitation and hydrothermal methods, and systematically characterized by several techniques e.g. XRD, SEM, EDX, TEM, etc. The XRD patterns confirms formation of both LDHs and magnetic phases. The plate-like morphology is evident by TEM confirm Mg,Fe-LDH and Mg,Fe-LDH-61655;xFe3O4 nanocomposite. Higher Fe3O4 loading leads to increase in the hydrodynamic sizes of the nanocomposite structure. Various influence factors like concentration, pH and time were systematically investigated. To assess the safety of materials was also conducted leaching experiments on the materials. The capacity of magnetic nanocomposites to adsorb DCF increased with increasing solution pH The maximum adsorption capacity for Mg,Fe-LDH-61655;0.3Fe3O4 was 158.16 mg/g. Further results indicated that the adsorption isotherm for diclofenac anions retention could be fitted to Freundlich and Langmuir equations. The values obtained indicate that organic groups are adsorbed on Mg,Fe-LDH by an electrostatic process without significant anion-exchange process. Besides, after 3 regeneration cycles, Mg,Fe-LDH-61655;0.3Fe3O4 still retained high ordered morphology with magnetic response.

Submission number: 393

CYTOTOXICITY OF PARAMAGNETICS NANOPARTICLES FE-CO OBTAINED BY REACTIVE MECHANICAL GRINDING IN MURINE MACROPHAGES

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Keywords: AI for Nanotechnology

Paramagnetic nanoparticles of Fe-Co alloy (NP-FeCo) have gained relevance in nanomedicine due to their numerous biomedical applications. However, the biological effects and health implications of NP-FeCo are controversial, necessitating further research. This study aimed to determine the cytotoxic activity of NP-FeCo obtained by reactive mechanical milling in murine macrophages. NP-FeCo were donated by the Interdisciplinary Professional Unit in Engineering and Advanced Technologies, who synthesized and characterized them. J774A.1 murine macrophages were cultured in supplemented DMEM medium at 37°C. Cytotoxic effects were determined in J774A.1 cells by dose-response viability curves with WST-1 at 24 and 72 hours. Biological effects such as cell morphology changes and cell death induction were evaluated using rapid staining HemacolorTM and annexin V-FITC/propidium iodide with conventional or EPI-fluorescence microscopies. Results showed related to cytotoxic effect of NP-FeCo in J774A.1 cells, to elemental composition, concentration, and exposure time. The alloys that induced the lowest and highest cytotoxicity at 24 and 72 hours were NP-Fe80Co20 (IC50: 144/172 -956;g/mL) and NP-Fe40Co60 (IC50: 19/2 -956;g/mL), respectively (p -8804; 0.05, ANOVA). Morphological analysis revealed spherical cells with eccentric nuclei, pronounced fissures, evident nucleoli, and low-density cytoplasm. The cytoplasm contained nanoparticles, suggesting endocytic process activation, while the extracellular space showed cellular debris, possibly due to cell death. These cellular changes occurred independently of the concentration and elemental composition of both nanoparticles. Cell death analysis revealed that treatments induced phosphatidylserine externalization and changes in cell membrane permeability during treatments with NP-FeCo at 80:20 (1.17/0.31 FC-UFR) and 40:60 (1.63/0.98 FC-UFR), compared to the 1X PBS control. These characteristics were associated with late apoptosis induction. In conclusion, this study demonstrates that the cytotoxic and apoptotic effects of NP-FeCo in J774A.1 macrophages are related to their composition, concentration, and exposure time, with the 80:20 alloy showing promising potential for biomedical

Submission number: 394

AUTOMATED SYSTEM FOR EVALUATING CELL GROWTH AND HYPOXIC REGIONS OF 3D SPHEROIDS VIA A MACHINE LEARNING APPROACH

Heo, Min Beom*

Keywords: Nano-Energy, Environment, and Safety

This study investigated the applicability of the area of spheroids and hypoxic regions for efficient evaluation of drug efficacy using machine learning. We initially developed a high-throughput detection method to obtain the area of spheroids and hypoxic regions that can handle over 10,000 images per hour with an error rate of 2-3%. The machine-learning models were trained using cell growth of 6 cell lines (i.e., HepG2, A549, Hep3B, BEAS-2B, HT-29, and HCT116) and hypoxic region variations of two cell lines (i.e., HepG2 and BEAS-2B); our model can predict the area of spheroids and hypoxic region of certain growth date with high precision. Our method represents a well-trained model that can reduce the efforts for pre-experimentation in various studies by providing cell growth dates corresponding to the preferred size of spheroids and hypoxic regions. Its applicability was demonstrated by treating HepG2 spheroids with sorafenib and evaluating the drug efficacy by comparing the difference in the areas of cell size and hypoxic regions based on the predicted results .

Submission number: 395

2D MOS2: LARGE-SCALE GROWTH, INTEGRATED OPTOELECTRONICS AND BEYOND

Ge, Gaohui; Zhu, Juntong; Zhang, Jiazhen; Cui, Fan; Li, Xiao; Wu, Jiang; Perez de Lara, David; zou, Guifu; Xu, Hao*

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanomaterials; Quantum, Neuromorphic, and Unconventional Computing

Two-dimensional (2D) transition metal dichalcogenides (TMDs), which possess inherently mechanical flexibility and tunable bandgaps, atomic level thickness, as well as unique electronic and optical attributes, are prominent candidates for optoelectronics in the post-Moore period. To date, the growth of high-quality and large-scale monolayer MoS2 has been one of the main challenges for practical applications. We have developed a MoS2-8722;OH bilayer-mediated method that can fabricate inch-sized monolayer MoS2 on arbitrary substrates. The field-effect transistor arrays were fabricated, showing high on/off ratio up to ~107 and large device mobility. Afterwards, a heterosynapse-inspired photodetector is proposed for the intelligent edge visual system to process spatiotemporal information. Meanwhile, a hippocampus-inspired device based on MoS2 for illumination time encoding is fabricated, in which the encryption technology is employed for data security. Moreover, we have demonstrated the potential application of MoS2 devices in artificial neural network. To further adjust the optical absorption range of TMDs, we have engineered the optical properties of MoS2 via alloying with Se to extend its optical absorption to the NIR region, and the phototransistor was fabricated based on monolayer MoS2(1-x)Se2x. When under 780 nm (~1.59 eV) illumination, the device delivered a photoresponsivity of an external quantum efficiency up to 11230%.

Submission number: 396

OPTOELECTRONIC CHARACTERIZATION OF WS2 SINGLE NANOTUBE FIELD EFFECT TRANSISTOR

Pelella, Aniello; Kumar, Arun; Intonti, Kimberly; Durante, Ofelia; De Stefano, Sebastiano; Han, Xinyi; Li, Zhonggui; Guo, Yao; Giubileo, Filippo; Camilli, Luca; Passacantando, Maurizio; Zak, Alla; Di Bartolomeo, Antonio*

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanomaterials; Nanoelectronics

Transition metal dichalcogenides (TMDs), like carbon, can form nanostructures such as tubes and fullerenes. Tungsten disulphide (WS2) nanotubes (NTs) have attracted attention for a variety of uses due to their near-perfect structural properties and semiconducting nature, which leads to superior mechanical and electro-optical performance. WS2 NTs are semiconductors with a well-defined band gap, which can be either indirect or direct depending on the NTs' chirality. This makes them highly suitable for use in semiconductor device applications. Additionally, the rolling of two-dimensional sheets into a cylindrical shape creates quantized conditions along the circumferential direction, leading to unique band structures with sharp peaks in the density of states. Furthermore, the rolling of WS2's tri-atomic layers into nanocylinders results in a polar structure and broken inversion symmetry, which gives rise to unique nanostructure properties such as bulk photovoltaic effect, piezoresistivity, and 0D ferroelectricity. In this study, a high-quality WS2 NT is used as the active channel of a FET. The existence of two slightly different Schottky barriers at the drain and source contacts leads to self-powered photodetection, with rise and fall time constants on the order of milliseconds. Notably, when biased with Vd = 2 V, the phototransistor exhibits a responsivity of a few mA/W at ambient temperature conditions. The device was also tested for data storage applications. We demonstrate a two-state memory, which can be switched by applying different gate pulses (Vg=± 50 V). The device shows good endurance and a memory window of 130%. Moreover, we show that the combination of gate and laser pulses enables a four-state optoelectronic memory. This research presents promising results for data storage, Boolean logic, and neural network applications.

Submission number: 397

FABRICATION AND CHARACTERIZATION OF HIGHLY STABLE ZINC OXIDE-BASED MEMRISTORS

SAKA, KUBRA*; Efkere, Halil -304;brahim; OZCELIK, Suleyman; Gokcen, Dincer

Keywords: Nanoelectronics; Nanofabrication

As solid-state technologies continue to advance, academia, industry, and consumer markets are witnessing remarkable breakthroughs in CPUs, GPUs, power systems, optoelectronics, etc. Memristors are promising devices that attract attention, particularly in memory devices and neuromorphic systems in which they emulate synaptic properties. Since the emergence of the memristor concept in the literature, various studies have been carried out on the fabrication of memristors with different structures using different materials as active layers, including metal oxides, organic materials, and chalcogenides [1]. In this study, we elaborated the fabrication and characterization of zinc oxide (ZnO) based memristors, exhibiting a pinched hysteresis loop. The oxide layer and top metal contact were deposited by sputtering and thermal evaporation methods, respectively. The proposed memristor structure consists of an active metal oxide layer (ZnO) sandwiched between the top (Ag) and bottom (ITO) electrodes. Characteristics of memristive switching were successfully obtained in a voltage sweeping range between - 2V and 2V with 0.1V step voltage for 1000 cycles. When the I-V measurement results (1st and 1000th cycle) are investigated, it is observed that the Ag/ZnO/ITO memristor structure was highly stable (Fig. 1). As a future work, we aim to explore the effects of metal contacts.

Submission number: 399

FUNCTIONALIZATION OF POLYMER SURFACES FOR ORGANIC PHOTORESIST MATERIALS

Longo, Roberto*; Lang, Xiuyao; Sridhar, Shyam; Cho, Kyeongjae; Ventzek, Peter

Keywords: Modeling and Simulation; Nanoelectronics; Nanomaterials

Photoresists are thin film materials designed to transform an optimal image into a mechanical mask. Diverse exposure techniques such as photolithography induce modifications in the exposed areas that result in solubility changes that can then be selectively removed with appropriate agents (developers). Photoresist materials need to keep pace with the increasingly demand for feature size reduction. Typically, photoresist materials are organic polymers that can present small cross-sections to the incoming photons, resulting in poor trade-off between resolution, sensitivity, or line-edge roughness. Photoresists also require a high etch-resistance relative to the substrate material, in order to preserve patterned features after the mechanical mask has been created. The main strategy to improve polymer performance during such processes is functionalization with different elements that can deliver higher efficiencies while keeping the chemical reactivity of the original polymer design. We present here photoresist polymer modeling with general characteristics and investigate the functionalization of the polymer surface using density-functional theory (DFT), with a focus on reactive halogen adsorption. Physical and chemical surface reactions and the corresponding byproducts are identified, obtaining self-limitation thresholds for each specific functionalizing agent. Moreover, spectral signals of the modified polymer surfaces are analyzed in detail, to allow experimental validation of the proposed surface modifications. Finally, using ab initio molecular dynamics (AIMD) and time-dependent DFT (TD-DFT), we study the interaction of energetic ions and electrons with the modified polymer surfaces, to validate the obtained functionalizations as effective improved etch-resistance strategies. The computational results provide valuable insights on the complex physical, chemical, and dynamic ion and electron interactions with functionalized polymer photoresists, with the immediate consequence of allowing the extraction of definite strategies for improved photoresist polymer performance.

Submission number: 402

NANOCOLUMNS AND NANOPARTICLES BASED DUAL SCALE STRUCTURES

Martinez, Lidia*; Garcia-Martin, Jose Miguel; Huttel, Yves

Keywords: Nanomaterials; Nanofabrication

This talk will be focused on the precise fabrication of nanocolumns (NCs) and nanoparticles (NPs) using sputtering based techniques and their combination to create more complex structures. Sputtering techniques are of importance to the industry, so this kind of nanostructuration offers new possibilities from an industrial perspective. First, the fabrication techniques will be presented. Ultra-high vacuum physical methods were used to grow the NCs by Glancing Angle Deposition (GLAD) [1] and NPs fabricated by means of a Multiple Ion Cluster Source (MICS) [2], highlighting the control over chemical composition, shape and dimensions of the fabricated nanostructures. These are environmentally friendly techniques since they are carried out at room temperature with moderate energy consumption, do not involve chemicals (i.e., no generation of toxic byproducts), and allow for the production of nanostructured surfaces of considerable size (several square centimeters in the lab) with high purity, making them quite appealing for industrial applications (scaling-up is feasible). Later, different examples will be presented like antibacterial coatings [3], chemical detection using enhanced surface spectroscopies [4], photo-induced self-cleaning surfaces [5], or controlled wettability among others. In these cases, the combination of NCs and NPs can lead to synergic effects.-Acknowledgements Authors acknowledge funding from PID2021-126524NB-I00 financed by MCIN/ AEI /10.13039/501100011033/ and “ERDF A way of making Europe”, by the “European Union” and CSIC (ref. BILTC22001 and ILINK22048).-

References

[1] J. M. Garcia-Martin et al., Appl. Phys. Lett. 97, (2010) 173103.
[2] D. Llamosa et al., Nanoscale 6, (2014) 13483.
[3]--D. Medina-Cruz et al., Nanomedicine: Nanotechnology, Biology, and Medicine 17, (2019) 36–46.
[4] G. Barbillon et al., submitted.
[5] F. Fresno et al., Adv. Sustainable Syst., (2021) 2100071.

Submission number: 403

THE PREPARATION OF CARBON DOTS-FOR-THE DETECTION OF ASCORBIC ACID VIA TURN-ON FLUORESCENCE SENSING

Kim, Jongsung*

Keywords: Nanosensors and Nanoactuators; Nanomaterials; Nanobiomedicine

Ascorbic acid (AA) is a potent antioxidant and biomarker that can prevent free radical formation in cells and treat Parkinson's disease (PD) patients [1]. In this study, a turn-on fluorescent sensor for the detection of ascorbic-acid (AA) was developed using carnosine modification of carbon dots (CDs) prepared from polyphenolic tannic-acid and ethylene glycol-bis (b-aminoethyl ether)-N,N,N',N'-tetraacetic acid (EGTA) using hydrothermal process [2]. The carnosine modified CDs (TATA-Car CDs) shows fluorescence quenching by addition of Cu+2. But the-fluorescence was recovered by addition of ascorbic acid. The morphological and optical properties of CDs were-studied via TEM, XRD, UV-Vis, and fluorescence spectroscopy. The CDs displayed green fluorescence with-excitation and emission wavelength maxima of 400 and 509 nm, respectively. These novel CDs are responsible for-the selective turn-on fluorescence sensing of AA (0 to 15 nM) when mixed with copper (Cu2+) ions and deliver a-low detection limit of 1.34 nM. The selectivity of the TATA-Car CDs-Cu2+ for AA sensing was examined by-fluorescence measurements of various interferants such as Glu, DA, EP, GSH, 5-HT, Cys, SO4-, Al3+, and Cl-The-practicality and feasibility of TATA-Car CDs were investigated in human serum samples.

References

[1] H. Li, Y. Zhou, J. Du, J. Photochem. Photobiol. A Chem. 429 (2022), 113945.
[2] X. Ma, S. Lin, Y. Dang, Y. Dai, X. Zhang, F. Xia, Anal. Bioanal. Chem. 411 (2019) 6645.

Submission number: 404

IMPROVING SKIN ADHESION IN ELECTRICAL MUSCLE STIMULATION WITH VINYL-DECORATED SILICA NANOPARTICLE INFUSED COMPOSITE PAD

Lee, Chang Kee*; Yun, Jungmin; Lim, Dae Young; Kwon, Miyeon

Keywords: Nanomaterials; Hydrophobic, Oleophobic and/or Icephobic nanostructured surfaces; Nanotechnology in Soft Electronics

Electrical Muscle Stimulation (EMS) is a widely utilized therapeutic technique that involves the application of electrical impulses to induce muscle contractions. Effective EMS application requires proper electrode placement and adherence of the electrode pads to the skin, which is critical for delivering effective treatment and ensuring patient comfort [1]. Proper adhesion of the electrode pads ensures optimal conductivity and prevents movement during muscle stimulation, thus ensuring smooth signal transmission, accurate muscle stimulation, reducing the risk of skin irritation or pad detachment, and enhancing therapeutic safety and comfort [2]. This study presents a novel approach that combines the properties of two distinct materials to enhance the performance of EMS pads. Firstly, a vinyl-decorated silica nanoparticle/polydimethylsiloxane (v-SNP/PDMS) composite was developed to significantly improve the adhesion force. The second material, a carbon nanofiber-carbon nanotube (CNF-CNT) composite, was dispersed in pure water, forming the basis of the EMS pad. The v-SNP/PDMS composite was applied to the surface of the EMS pad through a one-step fabrication process, resulting in a hybrid EMS pad. The experiment conducted on this hybrid EMS pad demonstrated a substantial enhancement in performance compared to conventional EMS electrodes. The utilization of silica nanoparticles in adhesive performance has been proven to be essential for the advancement of dry EMS pads. The integration of the v-SNP/PDMS composite with the CNF-CNT-based EMS pad resulted in superior adhesion to the skin, guaranteeing stable signal transmission during physical activity. Additionally, the thin and flexible nature of the hybrid EMS pad, coupled with its resistance to external deformation, enhances user comfort and usability during exercise. This innovative approach not only overcomes the limitations of existing EMS electrodes but also opens up new possibilities for diverse applications, particularly in fitness clothing and rehabilitation devices. In conclusion, the findings indicate that the hybrid EMS pad holds great potential for improving the effectiveness of EMS in physical therapy and fitness training.

Submission number: 405

VARIABILITY IN THE ELECTRONIC STRUCTURE OF ELONGATED JELLYBEAN DOTS IN SILICON

Feng, MengKe*; Liang, Dylan Haowen; Cifuentes, Jesus; Mai, Philip; Escott, Christopher; Dzurak, Andrew; Laucht, Arne; Saraiva, Andre

Keywords: Quantum, Neuromorphic, and Unconventional Computing; Modeling and Simulation

In quantum computing, silicon quantum dots have emerged as one of the material platforms that have a strong potential of achieving the goal of a fault tolerant quantum computer, due to its high-fidelity gates [1,2], as well as a strong scalability potential with the support from existing semiconductor foundries [3]. One important consideration in scalability is the long-distance coupling between qubits as the size of the quantum devices increase. Sparse arrays of qubits and devices can be used as the quantum architecture expands allowing the accommodation of electronic components and wiring [4] and could also enable the adoption of novel error correction schemes more robust against errors. We focus here on the use of a multi-electron quantum dot as a long-range mediator between neighbouring qubits, also known as a jellybean dot [5]. In this study, we employ a simulation tool built using unrestricted Hartree-Fock as the basis and we investigate how the electronic structure of the jellybean dot changes with both the elongation of the dot gate, as well as the inclusion of surface roughness arising from the Si and SiO2 interface. Surface roughness occurs due to the amorphous nature of SiO2 and can lead to variability in the individual qubits [6] but the impact on a jellybean dot with hundreds of electrons can be different. Figure below shows an example of the rough surface that is representative of the typical interface in silicon quantum dots in (a). In (b), we show the last electron charge density (calculated from the charge differential of the last two electrons), in the absence of surface roughness. In contrast, when we include surface roughness in the simulations, we can observe the impact of surface roughness on the charge densities in (c).

Submission number: 406

ENHANCING CAPABILITIES OF SILICON PHOTONIC INTEGRATED DEVICES USING TRANSPARENT CONDUCTING OXIDES

Sanchis, Pablo*; Navarro-Arenas, Juan; Caso, Jorge; Parra GOmez, Jorge

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Quantum,

Neuromorphic, and Unconventional Computing; Nanomaterials

Transparent conducting oxides (TCO) are typically doped metal oxides that can offer an extremely small real refractive index at telecom wavelengths and large refractive index changes by means of the plasma dispersion effect. Both properties are tremendously attractive for enhancing the capabilities of current silicon photonic integrated devices by providing new functionalities or improved performance in terms of footprint, energy consumption, operational bandwidth, or speed. Moreover, transparent conductive oxides (TCOs) could be seamlessly incorporated into silicon CMOS platforms, offering a straightforward integration path for large-scale manufacturing. Hybrid TCO/Si devices have been developed for implementing a large variety of passive functionalities, photonic memories, or optical modulators. In this work, we will review the potential of TCO/Si technology to enable essential functionalities in photonic neural networks, such as reconfigurable activation functions. Operating close to the epsilon-near-zero condition allows large changes in the real and imaginary parts of the TCO refractive index. Therefore, phase-amplitude modulation can be achieved in a single TCO/Si device, enabling a more expressive form of modulation based on complex numbers that effectively doubles the information capacity of the neural network. Furthermore, we have demonstrated how arrays of TCO/Si modulators with varying lengths can expand the number of states in the complex plane. Finally, we will also show a new approach for selectively tuning the optical constants of TCOs in hybrid photonic devices using a reactive laser annealing technique.

Submission number: 408

MULTILAYER GRAPHENE NANORIBBONS AS A MODEL FOR CHARGE TRANSPORT IN GRAPHENE-BASED THIN FILMS

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Keywords: Modeling and Simulation; Nanomaterials

An understanding of the charge transport mechanisms as well as optical properties of the multilayer graphene and related 2D material thin films is highly important for the graphene- and graphene-like-based composite applications. These films are composed of numerous randomly distributed 2D nanosheets with different edge structures, functionalization of their edges and surfaces, inhomogeneous mutual overlaps, and disordered defects of different origins. Narrow strips of graphene are commonly referred to as graphene nanoribbons (GNRs). The electronic properties of GNRs strongly depend on their edge structures (armchair or zigzag), and, in the case of armchair GNRs, on their width. So, the mentioned features of GNRs, in conjunction with the possibility of their partial overlap, allow one to consider GNRs as simple models of 2D nanosheets composed of not perfectly stacked graphene layers. Such models can be used to predict, for example, the charge transport due to their non-ideal structure. Using plane-wave DFT quantum chemical approach, we considered single-, double-, triple-, and multilayer van der Waals thin films composed of zigzag and armchair GNRs with different widths, taking into account their possible different mutual overlaps. Then, combining the bandstructure and phonon spectra calculations, the Eliashberg transport spectral function, the Boltzmann transport equation, and the phonon-assisted optical absorption spectra, we evaluated the influence of the composition and inner structure of the multilayer GNR films on their electric and optical properties.

Submission number: 409

PHOTOELECTRONIC DEVICES BASED ON SILICON AND GRAPHENE

Xu, Yang*; Li, Zongwen; Zhang, Zhi-Xiang

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Nanoelectronics; Nanofabrication

Si-based photodetectors and image sensors have played a crucial role in driving the rapid development of the information age. Among them, broadband spectrum detection is paramount for the future development of the information society. Spanning from X-rays to infrared, broadband spectrum detection not only provides valuable visual and imaging information about objects but also aids in the analysis of internal structure and composition. It finds applications across various fields including machine vision, unmanned driving, environmental monitoring, space remote sensing, and cultural relic protection. However, traditional Si photodetectors are constrained by the inherent bandgap of Si, limiting their spectral response range and hindering their ability to meet the urgent demand for broadband spectrum detection in future Si-based intelligent cognitive chips. Integrating new two-dimensional (2D) materials, mechanisms, and structures with Si technology is crucial to achieve broadband spectrum detection. Leveraging the advantages of relatively straightforward mass production and preparation of Si-based chip-scale heterogeneous integration technology, the development of Si-based intelligent broadband spectrum cognitive chips emerges as a key focus in future semiconductor technology development. The integration of large-area graphene with Si, prepared through chemical vapor deposition and macro self-assembly, aids in overcoming the detection bottleneck of traditional Si-based devices and holds significant research significance. Our research focuses on the foundational units of two types of imaging chips: Si/2D materials photodetectors and Si/2D materials charge-coupled devices. Using graphene as an example, we explore the working mechanisms of Si/2D materials heterojunction imaging chips to surpass the performance limits of traditional semiconductor optoelectronic imaging technology. By leveraging mature Si CMOS technology, we aim to develop high-performance dedicated readout circuits and advance the technology of integrated chips utilizing novel micro-nano optoelectronic functional materials.

Submission number: 410

INVESTIGATION OF THE EFFECT OF AGNPS-BASED NANOCOMPOSITES ON PSEUDOMONAS AERUGINOSA BIOFILM FORMATION UNDER DYNAMIC CONDITIONS AT LOW WALL SHEAR STRESS

Rima, Maya; Villeneuve-Faure, Christina; Ferracci, Mathieu; Fatima, El Garah; Ludovic, Pilloux; Boudou, Laurent; Roques, Christine; Makasheva, Kremena*

Keywords: Nanobiomedicine

Although medical devices, whether implanted or not, are intended to ensure well-being, they may turn into a reservoir for the colonization and growth of microorganisms, thus supporting the onset of a resilient biofilm and ultimately contributing to serious infections. To address this challenge, advancing the development of medical devices with anti-biofilm proprieties is considered a promising approach. Here, we explore nanocomposite materials based on silver nanoparticles (AgNPs) deposited on the surface of a thin silica (SiO2) layers for their potential effect on the adhesion, detachment, viability and biofilm formation of Pseudomonas aeruginosa. Findings revealed a rapid bactericidal effect of AgNPs, noticeable within 30 minutes of exposure. Moreover, the presence of some residual viable cells leads to delayed surface colonization for this nanocomposite with no structured biofilm, even after 3 days of dynamic culture, in comparison to SiO2. Interestingly, the reinoculation of the potentially persistent P. aeruginosa population exhibited flexibility, allowing it to proliferate more rapidly on fresh AgNPs-based nanocomposites than in the first round, although the biofilm structure was different compared to SiO2 biofilm. The significant reduction in biomass and biofilm alteration upon AgNPs contact needs more exploration to determine whether these effects are correlated with an increase in bacterial sensitivity. This study underlines the promising potential of AgNPs coating in the conception of novel antimicrobial/antibiofilm surfaces. Simultaneously, it spotlights the possible adaptation of P. aeruginosa PAO1-Tn7-gfp, emphasizing the necessity for future research to address this phenomenon.

Submission number: 411

2D MATERIAL TRANSFER ON MEMS/NEMS STRUCTURES

Zahradni-269;ek, Radim*; Fecko, Peter

Keywords: Nanofabrication; Nanomaterials; Nanosensors and Nanoactuators

In the field of 2d material transfer, several methods exist to put a 2D sheet (continual layer on the layer in the range of cm) or flake (from the 2D crystal in the range of µm) on the desired position on MEMS or NEMS devices. These devices are standardly made of silicon on an insulator (SOI). For sheet materials, the most common transfer method to any substrate is wet-based [1], which uses specific solutions to etch the catalyst on which the sheet was grown and remove the support layer after the transfer on MEMS, usually made from PMMA. When using the sheet of material, it is sometimes necessary to use additional shaping by the lithography to achieve the desired shape. At the end of this process, residual polymer contamination is possible. This contamination could be lowered by low-energy hydrogen plasma or a combination of different solvents [2, 3]. For 2d crystal flakes, the transfer method differs. It uses primarily the dry method [1]. In this method, the first exfoliation with the scotch tape is done on the PDMS sheet before transferring it to the desired substrate. With this approach, you need extra equipment: a transfer station equipped with a microscope with a long working distance and the PDMS holder that can move precisely (one of the microns) in x,y, and z. This method is material and time-consuming compared to wet transfer used for 2d sheets. Sometimes, to mitigate the use of lithography done on the flake, which is necessary in the case of 2d sheets, the flakes are standardly transferred on prepattern electrodes, such as Wan der Paw structures or finger electrodes. The preparation of the MEMS structure after the transfer is necessary to remove the buried oxide layer, which mechanically prohibits the device from moving. The oxide layer is typically etched by HF acid. However, this method can not be used on materials sensitive to HF acid. A different approach for the transfer is needed. First, the HF etching of buried oxide is done. Then, the transfer itself is carried out using PMMA membranes with support windows. In the case of sheet transfer, there is no problem. However, in the case of flakes, the process needs to be modified with any sacrificial layer added from different materials and extra PMMA

Submission number: 412

STRUCTURAL DETAILS AND MAGNETIC DISORDER OF BIMAGNETIC CORE/SHELL FERRITE NANOPARTICLES

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Keywords: Nanomaterials; Nanomagnetics; Nanofabrication

Among the nanomaterials, magnetic liquids have gained a considerable attention, being developed for current worldwide issues, in technological and environmental advances, production of energy in a sustainable manner, diagnosis and treatment of diseases [1, 2]. They consist of dispersions of nanosized (typically 2 -15 nm) spinel ferrite particles in non-magnetic liquid media. Using heterogeneous nanostructures as bimagnetic core/shell nanoparticles, different characteristics can be combined in a unique object, which may contribute to the fine tuning of their physical and chemical properties. As both magnetic anisotropy and magnetization are structure-dependent for both the core and the shell, a detailed study of the nanocrystal structure is a key point for developing high performances NPs systems [3]. Nevertheless, the spatial confinement at nanoscale also induces a symmetry breaking at the particle boundary of ultra-small particles and it produces a structure with a magnetically ordered core and a shell of disordered spins. Then, it provides the appearance of unique surface effects such as the existence of an exchange coupling field, originating from magnetic interaction between spins lying on the interface between the ordered core and the disordered shell [4]. Here, we will focuss on these effects observed in bimagnetic nanoparticles synthesized in our laboratory. It will enlighten the role of structural details and magnetic disorder for a better understanding of their magnetic behaviour.-Acknowledgements The authors are greatly indebted to Brazilian agencies, CNPq, CAPES and FAPDF and to the Brazilian-French Program of Colaboration CAPES/COFECUB.

References

[1]--V. Pilati, G. Gomide, R. Cabreira Gomes, G. F. Goya, J. Depeyrot, Langmuir, 37, 1129 (2021).
[2]--J. C. Riedl, M. Sarkar, T. Fiuza, F. Cousin, J. Depeyrot, E. Dubois, G. Meriguet, R. Perzynski, V. Peyre, J. Colloid Interface Sci., 607, 584 (2021).
[3]--F. G. Silva, J. Depeyrot, A. F. C. Campos, R. Aquino, D. Fiorani, D. Peddis, J. Nanosci. Nanotechnol.,19, 4888 (2019).
[4]--R. Cabreira Gomes, F. G. Silva, T. Q Silva, G. Gomide, V. Pilati, R. Aquino, J.

Geshev, R. Perzynski, J. Depeyrot, J. All. Compounds, 824, 153646 (2020).

Submission number: 413

DESIGN RULES FOR LASER-TREATED ICEPHOBIC METALLIC SURFACES FOR AERONAUTIC APPLICATIONS

Bonaccurso, Elmar*

Keywords: Hydrophobic, Oleophobic and/or Icephobic nanostructured surfaces;

Nanostructures for extreme environments; Nanofabrication

Abstract Ice accretion on external aerodynamic surfaces impacts safety and performance of aircraft. Non-environmental-friendly methods have been used to remove ice formations on-ground (e.g. de-icing fluids) and in-flight (e.g. bleed air used as active ice protection system). Surface microstructuring is a promising strategy for manufacturing icephobic surfaces that can delay ice accretion or reduce ice adhesion to aircraft surfaces. Among those means to make icephobic surfaces, replicating and optimizing [2] superhydrophobic surfaces from nature [1] appears a promising route. In this talk we demonstrate that short and ultra-short pulsed laser treatments are a viable technology to decorate alloys used in aviation with various functions. Among those, icephobicity is at the center of our interest. We will show that with such surface treatments ice adhesion can be effectively reduced and the performance of active ice protection systems can be increased [3,4].-

References

[1] W. Barthlott and C. Neinhuis, Planta 202, 1, 1–8 (1997).
[2] A.I. Aguilar-Morales, S. Alamri, and A.F. Lasagni, J. Mater. Process. Tech. 252, 313–321 (2018).
[3] V. Vercillo, S. Tonnicchia, J.-M. Romano, A. Garcia-8208;GirOn, A.I. Aguilar-8208;Morales, S. Alamri, S.S. Dimov, T. Kunze, A.F. Lasagni, E. Bonaccurso, Adv. Funct. Mater. 30, 1910268 (2020).
[4] S. Alamri, V. Vercillo, A.I. Aguilar-Morales, F. Schell, M. Wetterwald, A.F. Lasagni, T. Kunze., E. Bonaccurso, Adv. Mater. Interfaces 7, 2001231 (2020).

Submission number: 414

DESIGN OF INTEGRATED MR SENSOR FOR MAGNETIC MEMS MICROMIRROR MOTION DETECTION

Malago, Perla*; Piot, Adrien; Lumetti, Stefano; Enger, Luiz; Palma Guerreiro, Sara;

Fleury, Clement; Lagosh, Anton

Keywords: Nanomagnetics; Nanosensors and Nanoactuators; Spintronics

Magnetoresistive (MR) sensors feature high sensitivity, improved signal-to-noise ratio and enhanced thermal stability compared to state-of-the-art solid state magnetic field sensors. Among the MR technologies, anisotropic magnetoresistive (AMR) sensors are attractive owing to their relatively simple and cheap CMOS-compatible fabrication process, which makes them easily prone to miniaturization and integration into MEMS thereby offering the possibility to achieve high sensitivity at low cost in a relatively compact footprint [1]. Here, we present a theoretical study on the design of an AMR sensor to be integrated on a magnetic MEMS micromirror for closedloop system control. The system includes an array of permanent magnets as well as copper micro coils and an array of AMR sensors located on the mobile suspended mirror substrate (see Figure 1). The MEMS device exploits the Lorentz force due to the interaction of the electrical current with the external field generated by the magnets to actuate and control the micromirror motion. The AMR sensor – placed between the micro-coils and the reflector – is designed to measure in real-time the magnetic field variation associated to the angular movement of the MEMS micromirror. The latter is designed via finite-element (FE) simulations [2, 3] while the AMR sensor geometry is optimized via micromagnetic simulations [4] combined with FE calculations. The AMR sensor response can be tailored to a specific magnetic field range of interest by varying the dimensions of the sensor and the material parameters. To this aim, the AMR response of high aspect-ratio Permalloy (Py) (Ni80Fe20) stripes with thickness (t) ranging from 5 to 50nm, width (w) from 200nm to 5um and length (L) from 25um to 250um has been computed. Additionally, to ensure a linear sensor response in the field range of interest, barber-pole structures consisting of 5 nm of Chromium and 50 nm of Gold have been designed by calculating the electrical current distribution via FE simulations. A systematic study was performed to determine the optimal AMR sensor configuration capable of tracking the motion of the magnetic MEMS micromirror.

Submission number: 415

EXTRACTION AND CHARACTERIZATION OF TIO2 PIGMENTS FROM COMMERCIAL PAINTS

Philippe, Allan*

Keywords: Nano-Energy, Environment, and Safety; Nano-Metrology and Characterization

TiO_2-nanoparticles are widely employed as pigments in coatings and paints due to their superior optical properties. However, a portion of these particles inevitably enters the environment through runoff resulting from weathering or physicochemical degradation of painted surfaces. To assess the potential environmental impacts of these nanoparticles, comprehensive fate and ecotoxicity studies are imperative, necessitating the use of particles closely resembling those released into the environment. In response, we developed an extraction method designed to isolate TiO_2-particles from commercial paints. Employing a diverse range of six contrasting paints alongside a pure TiO_2-pigment, we compared the efficacy of two extraction methods based on dispersion in a solvent and centrifugation, in terms of recovery, purification rate, and preservation of both inorganic and organic particle coatings. Characterization of paints and their corresponding extracts was conducted using cryogenic transmission electron microscopy, inductively coupled plasma optical emission spectroscopy, thermogravimetric analysis coupled with mass spectrometry, and infrared spectroscopy. Our findings revealed that the alkaline-based extraction method resulted in significant damage to the particle coatings even at ambient temperature. Conversely, extraction with acetic acid as a solvent facilitated the retention of both inorganic and organic coatings. Recovery rates exceeding 70% were achieved for all paints and extraction methods, yet complete removal of SiO_2 proved challenging, even under alkaline conditions. Notably, polymers present in the paints exhibited improved removal efficiency with acetic acid compared to alkaline treatment, albeit with variations among paint formulations. $CaCO_3$ removal was effective with both extraction methods. In conclusion, our developed extraction method enables the isolation of TiO_2-particles with structural and coating similarities to those aged within paints. However, we recommend using silicates-free paints when SiO_2 interference is of concern for the study design. Furthermore, this method could be interesting for pigment recycling, offering a gentler alternative to existing techniques that compromise particle

Submission number: 416

ADVANCED ELECTRODES OF BIOCHAR@NB2O5-NANONEEDLES FOR ENERGY STORAGE

Lustosa, Glauco; de Souza, Isabela; Bizzo, Waldir*; Mazon, Talita

Keywords: Nanomaterials

Recently, increased interest in efficient and sustainable energy storage solutions has driven research into innovative materials applied to the development of supercapacitors (SCs), which have gained enhanced attention due to their promising properties, such as high power density, long cycle life, good stability and a fast and reversible charge-discharge process. The use carbon-based materials in SC have stood out due to their characteristics, such as a high electrical conductivity, high surface area and chemical stability, in addition to its abundance from many sources. The production of biochar from the pyrolysis of biomass shows a renewable alternative to face environmental and energy challenges. Biochar is characterized by a porous structure and a substantial surface area, making itself as a potential candidate for energy storage applications [1-3]. Here, we investigate a one-step synthesis of biochar composite with Nb2O5 nanostructures anchored on carbon surface to improve the electrical properties. For this, a sugarcane bagasse biomass was pre-treated in an aqueous acid solution followed by filtering and washing until neutral pH (~ 6-7). After drying (80 °C/12 h) the biomass was added in different aqueous solution of urea (1:2 w/w) and niobium ammonium oxalate (1:1, 1:2 and 1:3 w/w), then submitted to a thermochemical treatment at 750 °C/4 hours and N2 atmosphere. The powder was macerated and sieved in a 200-mesh sieve. XRD characterization shows peaks attributed to Nb2O5–orthorhombic phase (JCPDS card n° 2710-03) and the broad region observed between ~22–33° was indexed as C<002> diffraction peak related to an amorphous carbon structure with randomly oriented aromatic sheets. The SEM reveals the morphology as nanoneedles (with width of ~30–80 nm) well-distributed on the biochar surface. To obtain the electrodes, a paste composed of biochar, carbon black and PVDF (8:1:1 w/w) was prepared with addition of ~4 drops of N-methyl-2-pyrrolidone (NMP), then deposited on nickel foam (1x1 cm) and dried at 65 °C/12 h. The energy storage properties of electrodes were electrically characterized in a 3-electrode system using 3 M KOH electrolyte. The Cyclic Voltammetry, performed in a range of -8722;0.5 to 0.3 V (scan

Submission number: 417

TOLUENE GAS SENSORS BASED ON PRINTED ZINC OXIDE (ZNO) NANOPOROUS LAYERS (NPL) GENERATED BY SPARK ABLATION TECHNIQUE

Mazzola, Vincent; Mazzola, Vincent*; Park, Minsoo; Ricciardella, Filiberto; Schouten, Niels; Roels, Pauline

Keywords: Nanosensors and Nanoactuators; Nanofabrication; Nanoelectronics

Metal oxide semiconductor (MOS)-based gas sensors dominate sensing technology due to their high sensitivity, relatively low production cost and simple fabrication. To improve the sensing performance and fulfil the new requirements from diverse growing applications sectors, different strategies have been implemented from a material perspective to--precisely engineering MOS surface morphology at the nanoscale.Spark ablation is an attractive technique to generate metal and MOS materials that allows excellent control on the nanoparticle size distribution and composition. Spark ablation, a dry gas-phase nanoparticle production method, enables highly reproducible and pure material deposition. Furthermore, spark ablation offers the versatility to--control other morphological features such as porosity and the layer dimension.Herein, zinc oxide (ZnO) nanoporous layers (NPL) were used as sensing layer to detect toluene gas molecules in the part-per-million concentration range (ppm). The NPL were printed on a four-electrode chip using an impaction printer coupled with the spark ablation generator. The influence of the sparking and printing conditions, such as sparking power, flow and printing speed, on the NPL were analysed. Prior to the gas sensing tests, the samples were annealed at 600 °C for 10 minutes, to stabilize the sensing layer. The sensing performance were evaluated conducting resistivity measurements on 2 sensing devices. The ZnO-based devices were exposed to toluene for 5 minutes, followed by a 20 minutes-long recovery step. The gas sensing measurement protocol enables to extract key figure of merits of the sensors like sensitivity, calibration curve, and limit of detection (LOD) .The presented work gives insights about the simple implementation of printed NPL based on spark ablation technique for gas sensing applications. Considering the simplicity of the device fabrication, the performance show interesting results, especially in terms of sensitivity. Further studies will be executed to optimize the sensing performance varying the NPL structure and investigate potential cross-selectivity towards others volatile organic compounds.

Submission number: 418

NANOPARTICLES BASED ON CO, ZN AND CU MIXED FERRITES: STRUCTURE AND MAGNETISM

Pereira, Barbara*; Coppola, Priscilla; Kern Barreto, Cynara; Gomes da Silva, Franciscarlos; Gomide, Guilherme; de Oliveira Paula, Fabio Luis; Aquino, Renata; Depeyrot, Jerôme

Keywords: Nanomagnetics; Nanomaterials; AI for Nanotechnology

Spinel ferrite nanoparticles exhibit versatility across a broad spectrum of applications. In the context of magnetohyperthermia applications, our focus lies in exploring ferrofluids derived from a blend of cobalt, zinc, and copper ferrite nanoparticles. These particles are meticulously crafted to finely adjust the magnetization and magnetic anisotropy of ferrite magnetic nanoparticles through variations in chemical composition. The intention is to enhance the magnetic properties specifically for magnetohyperthermia purposes [1]. The synthesis of these nanoparticles involves hydrothermal coprecipitation in an alkaline medium, followed by a surface treatment that establishes an iron-rich surface layer, facilitating their dispersion in acidic medium [2]. The chemical composition of the nanoparticles is accurately determined through chemical analysis using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) and Energy Dispersive X-ray Fluorescence Spectroscopy (EDX). This dual analysis enables the precise identification of core and shell volumes and the stoichiometry of core materials in all examined samples. To delve into the structural aspects, X-ray Diffraction (XRD) is employed to study crystalline structure and nanoparticle sizes. The distribution of cations within the crystalline structure was studied using X-ray excited photoelectron spectroscopy (XPS) technique using synchrotron radiation. Transmission Electron Microscopy (TEM) images depict their morphology and aid in determining mean sizes, aligning well with deductions from XRD analysis. A comprehensive magnetic characterization is conducted using a SQUID magnetometer. Both low and high field (7 T) DC magnetization experiments, coupled with hysteresis loop measurements, offer insights into the magnetic behavior of the samples. Exploring Specific Absorption Rate (SAR) measurements in a few samples reveal notably high values compared to existing literature, with the SAR increasing with the addition of Zn and Co in the core composition.

Submission number: 419

INTERFACIAL REACTIONS AND MICROSTRUCTURAL EVOLUTION OF SN-BASED SOLDER JOINTS PREPARED WITH REACTIVE FE NANOPARTICLES

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Keywords: Nanopackaging

The aim of this study was to gain a better understanding of the strengthening mechanisms in reactive metal-nanocomposite solder joints. To achieve this, Sn-3.5Ag/Cu solder joints were produced using Fe nanoparticle (NP)-doped flux with up to 2 wt.% NP additions. The concentration of the NPs between the solder and the substrate prevents the excessive growth of intermetallic phases (IMC) at the interface without impairing the properties of the solder joint such as toughness. Furthermore, this method can be used in surface mounting technology without an additional step in the production line. Advanced high-resolution electron microscopic investigations in conjunction with elemental analysis by energy dispersive X-ray spectroscopy allowed for detailed observations and analysis of the changes in the chemistry and microstructure of the substrate/IMC layer/solder joint region, prior and after long-term aging. Atomic-scale characterization of the IMC layer was performed using atom probe tomography analysis. The microstructural evolution of the interfacial region and the bulk of the solder during the reflow process and the subsequent long-term aging at elevated temperatures of up to 180°C through interaction with the Fe nanoparticles can be described as follows: It is assumed that the diffusion of iron into the Cu6Sn5 IMC phase during the liquid-solid reactions can lead to changes in the crystal lattice stoichiometry to form (Cu, Fe)6Sn5, whereby the Cu3Sn structure seems to remain unchanged. In addition, the dissolution of iron nanoparticles in the Sn-Ag solder, followed by the solid-state interfacial diffusion during long-term aging, can result in the formation of a FeSn2 phase and partial iron segregation near the interface. Analysis of the growth kinetics of the interfacial layers after high-temperature storage revealed an increase in the activation energy of the formation of IMCs and suppression of their growth with the addition of Fe-NPs to the solder alloy. The results of isothermal shear tests and nanoindentation mapping of the joint area confirmed that incorporation of optimized amounts of reactive Fe-nanoparticles to the flux can significantly improve the mechanical performance of the Sn-based solder joints.

Submission number: 420

INTRODUCING A NEW PARAMETER FOR BENCHMARKING THE GAS SENSITIVITY OF LSPR SENSORS

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Keywords: Nanosensors and Nanoactuators; Nanomaterials; Modeling and Simulation

The interpretation of the gas sensing performance of localized surface plasmon resonance (LSPR) based sensors is not trivial. The most widely used approach in the literature is using the bulk refractive index sensitivity (RIS), calculated by dividing the measured plasmon resonance peak shift (-8710;-955;-p) with the refractive index difference of the exchanged gases (-8710;n-b) [1]. In this approach, the gases are characterized by their bulk refractive index (n-b) only, without considering gas layers adsorbed on the surface of the used nanoparticles or the effect of the plasmon field's decay. The problem with this approach is that the resulting RIS values calculated by exchanging gases are usually an order of magnitude higher than those calculated by calibrating the LSPR sensor with liquids of known refractive index. In order to resolve these apparent discrepancies between LSPR sensitivity calibrations in liquids and gases, and for the proper evaluation of the gas sensing performance of these sensors a new model was introduced that takes into account both the surface sensitivity and the plasmon decay of the nanoparticles to evaluate the measured LSPR response considering adsorbed gas layers with a -8710;n-l (t) function, where t is the thickness of the adsorbed gas layer. Based on this model, a new benchmarking function, termed as gas sensitivity GS(t) is introduced. GS(t) characterizes the gas sensing performance of a plasmonic sensor and is independent of the type and pressure of the tested gases. To demonstrate the applicability of this parameter, a novel plasmonic sensor based on ellipsoidal gold nanoparticles arranged in tightly packed hexagonal lattices [2] was tested by switching the gas atmosphere between inorganic gases, namely He/Ar and Ar/CO2, at constant pressure and room temperature. It was demonstrated that the proposed sensitivity model provides a unified explanation for the sensors' response, consistent with their behaviour both in the tested liquids and gases and that the derivative of the gas sensitivity function, dGS(t)/dt, can be conveniently used as a single parameter for benchmarking purposes.

Submission number: 421

INFLUENCE OF FUNCTIONALIZED MWCNTS ON OXIDATIVE STRESS IN BEAS-2B CELLS

Dola, Sundeep*; Kovuri, Umadevi; Eswaramoorthy K, Varadharaj; Chebbiyam, Chandrasekhara Sastry

Keywords: Nanobiomedicine; Nanofabrication; Nanomaterials

In this work, we employed a comprehensive approach to examine the duration of exposure to multi-walled carbon nanotubes (MWCNTs) affects the biochemical and biomechanical responses in human lung epithelial cells (BEAS-2B). The study aimed to explore the physicochemical characteristics of functionalized MWCNTs and their potential to cause molecular or cellular damage. Utilizing Fourier Transform Infrared (FT-IR) spectroscopy and Field Emission Scanning Electron Microscopy (FE-SEM), we confirmed the addition of functional groups to the MWCNTs and observed modifications in their interlayer distances. The findings indicate a temporal pattern in the cellular uptake of MWCNTs and the production of reactive oxygen species (ROS), which are accompanied by progressive alterations in the cells' biomechanical properties. Notably, the internalization of MWCNTs exhibited a sigmoidal trend, predominantly occurring within the first 6 hours of exposure. This pattern of uptake was paralleled by variations in oxidative stress levels and changes in cellular mechanics. The outcomes of this investigation shed light on the dynamic nature of toxicity induced by MWCNTs over time, suggesting its significance for the preliminary risk evaluation of the toxicological characteristics of similar nanomaterials.

Submission number: 422

INVESTIGATION OF MECHANICAL MILLING INFLUENCE ON LATTICE VIBRATIONAL BEHAVIOUR OF MOO3/AL2O3 FOR HIGH TEMPERATURE SOLID LUBRICANTS

Dola, Sundeep*; Eswaramoorthy K, Varadharaj; Chebbiyam, Chandrasekhara Sastry

Keywords: Nanofabrication; Nanomaterials

This study focused on the synthesis of ultrafine MoO3/Al2O3 nanocomposite powders featuring enhanced thermal properties, synthesized through mechanical milling over various durations. The properties of the nanocomposites were investigated using a suite of spectroscopic techniques including Powder X-ray Diffraction (PXRD), Scanning Electron Microscopy, Electron Dispersive X-ray Spectroscopy, Fourier Transform Infrared (FTIR) Spectroscopy, Raman Spectroscopy, optical absorption, as well as Thermogravimetric and Differential Thermal Analysis. The PXRD results highlighted orthorhombic structures of MoO3 and Al2O3. Analysis of XRD data and Williamson-Hall plots indicated that the crystallite sizes and lattice strains were approximately equivalent. Raman spectroscopy provided qualitative insights and confirmed the orthorhombic structures within the nanocomposite. SEM imaging showed vanadium deposits on molybdenum surfaces. FTIR analysis identified the primary bonds in the nanocomposite, including Mo=O and Al=O. Thermal stability assessments showed that the MoO3/Al2O3 nanocomposite remains stable up to 670 °C with minimal weight loss, suggesting its potential use as a high-temperature solid lubricant.

Submission number: 423

CELLULOSE NANOCRYSTAL HYDROGEL MICROSPHERES FOR TARGETED DELIVERY OF PROBIOTICS IN THE GASTROINTESTINAL TRACT

Jati, Akrip; Batta-Mpouma, Joseph; Turner, Amiya; Kotagiri, Nalinikanth; Kim, Jin-Woo*

Keywords: Nanobiomedicine; Nanomaterials; Nanofabrication

Microencapsulation has emerged as a promising strategy for delivering oral probiotics, playing a crucial role in restoring gut microbiome health. This method holds vast potential to protect and release specific microbial strains to the desired target site within the gastrointestinal tract (GIT). Despite advancements, current encapsulation carriers still face numerous limitations such as suboptimal encapsulation efficiency and insufficient control over probiotic release, attributed to factors like carrier shape, porosity, and composition. Here, we introduce hydrogel microspheres (HMs) composed of cellulose nanocrystal (CNC) and alginate (ALG) composites as advanced controlled release systems (CRSs) for effectively encapsulating and releasing probiotic cells. CNCs offer favorable filler and mechanical attributes, enabling the formation of matrices with controllable porosity and structural stability, critical for probiotic encapsulation. However, CNC alone lacks the molecular morphology necessary to form HMs. ALG, with its reversible gelation and microsphere-forming capabilities, addresses the structural limitations of CNCs by synergistically forming HMs that can dynamically respond to the fluctuating acidity levels within the GIT, ranging from from acidic (i.e., ~ pH 2-3) to alkaline (i.e., ~pH 6-8) environments. Collaboratively, CNC and ALG form a composite that safeguards the integrity of the hydrogel microcapsules (HMs) throughout the GIT while efficiently releasing probiotic cells in response to pH variations. This composite is hypothesized to function as a pH-controlled release system, enabling precise delivery of encapsulated probiotics to the targeted location (e.g., colon) within the GIT. To test this hypothesis, the encapsulation efficiency and the kinetic release profile of probiotics are studied using in-vitro simulations of GI conditions (Fig. 1). The outcomes of this study aim to yield a more effective encapsulation technique and a sustainable probiotic delivery system, offering significant potential benefits for GI health.

Submission number: 424

ACCURATE DETERMINATION OF NUMBER CONCENTRATION IN SPHERICAL GOLD NANOPARTICLES USING MULTIPLE ANALYTICAL TECHNIQUES

Minjeong, Kwak*

Keywords: Nano-Metrology and Characterization; Nanomaterials; Nano-Energy, Environment, and Safety

The quantification of number concentration in nanoparticle suspensions is essential but challenging due to the lack of standardized reference materials. This study aims to accurately measure the number concentration of gold nanoparticles (AuNPs) in aqueous suspension, employing five distinct analytical methods—Transmission Electron Microscopy (TEM), Scanning Mobility Particle Sizer (SMPS), Inductively Coupled Plasma Mass Spectrometry (ICP-MS), Nanoparticle Tracking Analysis (NTA), and Flow Cytometry (FCM). Accurate number concentration data are crucial for applications in areas such as drug delivery, diagnostics, and environmental monitoring, where precise dosing and particle behavior are critical. Each analytical technique offers unique benefits: TEM confirms particle size and morphology with high-resolution imaging; SMPS not only evaluates size and concentration via electrical mobility but also counts particles; ICP-MS provides elemental analysis for total gold content; NTA enables real-time concentration measurements through Brownian motion analysis; FCM measures individual particles to assess distribution and aggregation. The integration of these methods on synthesized monodispersed AuNPs explores the strengths and limitations of each technique, enhancing the understanding of particle characteristics. For instance, TEM provides structural validation, SMPS excels in detailed size distribution and counting, ICP-MS achieves precise quantification, NTA offers real-time tracking, and FCM effectively differentiates particle populations. This comprehensive approach not only enhances the accuracy of measuring number concentration but also contributes to the standardization of nanoparticle measurements in research and industry, ensuring data reliability and reproducibility.

Submission number: 425

DIRECT ORGANIC-INORGANIC CO-ASSEMBLY OF ORDERED MESOPOROUS TRANSITION METAL DICHALCOGENIDES FOR ADVANCED SENSORS

Tao, Li*

Keywords: Nanofabrication; Nanomaterials; Nanosensors and Nanoactuators

Endowing transition metal dichalcogenides (TMDs) with mesoporous structure can greatly enhance their porosity, accessible specific surface area and exposed active sites, leading to better performances in many fields. Current top-down processes suffer from lattice damage due to invasive process like etching, while bottom-up processes like hard-template nanocasting or thermal assisted conversion having drawbacks in quality or environmental control. Herein, we report a facile synthesis of ordered mesoporous TMDs by direct organic-inorganic co-assembly in dual solvent (DMF/H2O). The amphiphilic block copolymer polyethylene oxide-b-polystyrene (PEO-b-PS) is used as the organic template, and (NH4)2MoS4 or (NH4)2WS4 as the inorganic precursor. After solvent evaporation induced self-assembly and thermal treatments, highly ordered mesoporous MoS2, WS2 and MoS2/WS2 with highly crystalline framework, high specific surface area (44-91 m2/g) and large pore sizes (15-21 nm) are obtained. Semiconductor gas sensors based on mesoporous TMDs exhibit extraordinary sensing performances including high sensitivity, fast response (6 s), low limit of detection (12 ppb), and ultrahigh selectivity towards NO2 among 13 kinds of gases at room temperature, benefiting from its highly porous and crystalline framework, as well as rich active edge sites. This work paves a non-invasive way to develop novel ordered mesoporous TMDs-based semiconductor materials for various applications.

Submission number: 426

INVESTIGATING THE SURFACE COATING COMPOSITION OF TITANIUM DIOXIDE NANOPARTICLES AFTER IN SITU EXPOSURE TO NATURAL AQUATIC ENVIRONMENTS

Tayyebi, Narjes*; Philippe, Allan

Keywords: Nano-Energy, Environment, and Safety

The increased release of titanium dioxide nanoparticles into surface waters, along with their interactions with natural organic matter (NOM), has raised environmental concerns regarding the behaviour, fate and risk assessments of these particles under natural aquatic conditions. However, the available data about this topic are restricted to highly simplified controlled laboratory conditions and systems. Recently, we successfully developed a method providing a realistic exposure of nanoparticles to surface waters using dialysis bags as passive reactors (Figure 1). Inside this reactor, the complexity and the temporal variability of a large number of environmental parameters, e.g., dissolved organic carbon, are reproducible [1]. Making use of this method, we have been investigating the composition and structure of NOM-coating formed under field conditions onto five different TiO2-nanoparticle types, encompassing both hydrophobic and hydrophilic variants as long as extracted TiO2 nanoparticles from sunscreens and paints. These particles were exposed to 40 different natural waters, each analysed by FT-ICR MS (Fourier-transform ion cyclotron resonance mass spectrometry), and EEM fluorescence (excitation-emission matrix fluorescence spectroscopy). After collection of the nanoparticles exposed to surface waters using dialysis bags, the formed natural coatings have been analysed using ATR-FTIR (Attenuated total reflectance-Fourier transform infrared) , XPS (X-ray photoelectron spectroscopy), ToF-SIMS (Time-of-Flight Secondary Ion Mass Spectrometry), and the state-of-the-art method of laser desorption ionization FT-ICR MS for directly measuring the sorbed molecules on the particle surface [2]. The obtained data depicts the significance of initial coating of TiO2 nanoparticles, on NOM-sorption, rather than water parameters. On the other hand, the data obtained from analogous nanoparticle types, can be used to develop a model for predicting the characteristics of the NOM-coating based on water parameters.

Submission number: 427

THE INVESTIGATION OF POLARIZATION AND LIGHT INCIDENT ANGLE ON THE REFRACTIVE INDEX SENSITIVITY OF AN LSPR BIOSENSOR

Rebeka, Kovacs*; Bonyar, Attila

Keywords: Modeling and Simulation; Nanosensors and Nanoactuators; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

Localized surface plasmon resonance (LSPR) sensing is a label-free method that can be utilized for biosensing [1] and various applications due to their sensitivity to the change in their surrounding medium's refractive index. The performance of the sensor strongly depends on the geometry of the nanoparticles, the refractive index of the media around them, and the incident electromagnetic field. The interaction between light and metal nanoparticles causes a collective electron oscillation at the surface of the nanoparticles (such as gold or silver), which produces an increase in absorption and scattering of the electromagnetic wave and it can be utilized in LSPR biosensing [2]. In this research, the aim was to investigate how different linear and circular polarizations affect the sensitivity of a sensor based on hexagonally arranged ellipsoidal gold nanoparticles. The study was carried out using the finite element method (FEM), with Comsol Multiphysics' Wave Optics Module.

Submission number: 428

NANOPRECISION INTERFACES FOR PFAS-FREE FOULING AND POLLUTION CONTROL

Tiwari, Manish K.*

Keywords: Hydrophobic, Oleophobic and/or Icephobic nanostructured surfaces;

Nano-Energy, Environment, and Safety; Nanofabrication

Nanoengineering of non-wetting surfaces offers a promise to widen their application, which nearly always have multiple competing functional requirements. However, the challenges around sustainability, energy-efficiency, robustness, etc. continue to remain major bottlenecks to progress. In this presentation, we will discuss the need for precision and scalability in surface manufacture, with an emphasis on surfaces for controlling (bio)fouling which impairs a large number of energy and propulsion systems. The biofouling issue is also linked with antimicrobial resistance (AMR), a major healthcare challenge. The role of substrate mechanical properties will also be discussed by drawing from recent advances in flexible non-wetting surface designs which enhance the liquid impact resistance property of such surfaces. An extension of this strategy will then be discussed, specifically focussing on pollution control applications. Next, I will share some perspective on how interfacial nanoengineering may need to evolve to meet future human healthcare and net zero aspirations in infrastructure resilience, built environment and transport applications. To this end, we will discuss recent progress around replacing poly- and perfluoroalkyl substances (PFAS) – ingredients in wide-spread use in non-wetting surfaces synthesis but with major ecological and human health harm potential – using metal and covalent organic frameworks, and introducing sustainably sourced materials.

Submission number: 430

MULTIPLEX ELECTROCHEMISTRY BIOSENSOR FOR SIMULTANEOUS DETECTION OF CUTANEOUS LEISHMANIA AND PARACOCCIDIOIDOMYCOSIS

Roza, Noemi; Simões, Agnes; Faria, Aline; Bach-Toledo, Larissa; Mazon, Talita*

Keywords: Nanosensors and Nanoactuators; Nanobiomedicine

Neglected tropical diseases (NTDs) are ancient illnesses afflicting the most vulnerable populations, frequently lacking primary healthcare facilities[1]. Some NTDs present similar symptoms, complicating diagnosis based solely on clinical history [1]. Rapid and accurate point-of-care (POC) diagnosis could speed both precise diagnosis and the initiation of treatment. This work aimed to develop a multiplex electrochemical immunosensor to assist in simultaneously diagnosing cutaneous leishmania and paracoccidioidomycosis. The construction of the immunosensor board, a crucial component of the diagnostic tool, involved the integration of a counter electrode (CE) and two working electrodes (WE), both gold and an Ag/AgCl reference electrode (RE), into a Printed Circuit Board (PCB) [2]. The working electrodes (WE), interconnected by tracks, were designed with different sizes. This strategic choice allowed us to distinguish the current ranges for each WE and could reduce production costs by using only potentiostat. The antigen-antibody interaction analysis, an essential step in the process, was performed for L. braziliensis and P. brasiliensis antigens using the Dot Blot molecular technique. This analysis demonstrated a strong interaction between the antigen intended for immobilization on the sensor and the antibody used to characterize the immunosensor in the laboratory. The immunosensor was then constructed using the cystamine-glutaraldehyde system to immobilize the antigens on WEs. The immobilized L. braziliensis and P. brasiliensis antigens were characterized by Fourier Transform Infrared Spectroscopy (FTIR), confirming the successful immobilization of the antigens. Evaluation by confocal microscopy further validated the efficiency of antigen immobilization, a critical aspect of the sensor's functionality. The sensor's performance was evaluated using differential pulse voltammetry (DPV) and cyclic voltammetry (CV), two electrochemical techniques. The results of these analyses demonstrated good reproducibility and stability, indicating the immunosensor's robustness and underscoring our biosensor's reliability for the simultaneous detection of cutaneous leishmania and paracoccidioidomycosis.

Submission number: 431

DEVELOPMENT OF SYNTHETIC MAGNETOSOMES FOR SYNERGISTIC CHEMOTHERAPY AND MAGNETIC HYPERTHERMIA DUAL THERAPY

Moreno Maldonado, Ana Carolina*; Jimenez, Maria Carmen; Molina, Ignacio; Ibarra, Ricardo; Goya, Gerardo

Keywords: Nanobiomedicine; Nanofabrication; Nanomagnetics

Magnetosomes are intracellular structures in magnetotactic bacteria, where the magnetic nanoparticles (MNPs) are individually enveloped by a magnetosome membrane. These structures, characterized by magnetic dipolar interactions, exhibit unique magnetic properties, such as enhanced power absorption when compared to individual MNPs. In this study we present synthetic magnetosomes (SM) as a novel system for active release via remote and non-invasive magnetic stimuli. SMs containing the chemotherapeutic cis-Pt drug were designed for localized and "on-demand" chemotherapy and magnetic hyperthermia dual therapy. Transmission electron microscopy images showed that SMs arrange into curved chains of magnetic nanoparticles (MNPs) covered by a lipid bilayer, governed by the magnetic dipolar interactions between particles. Through in vitro assays on the pancreatic adenocarcinoma cell line PAN02, we confirmed the synergistic effects of dual and simultaneous therapy using SM. These results indicate that lower doses produce greater effects compared to chemotherapy and magnetic hyperthermia treatments administered separately.

Submission number: 432

DEFENDING AGAINST DECAY: NANOMETRIC SILICA LAYERS FOR STEEL CORROSION PROTECTION

Wala-Kapica, Marta*; Borak, Beata; Simka, Wojciech; Krzak, Justyna

Keywords: Nano-Energy, Environment, and Safety; Hydrophobic, Oleophobic and/or Icephobic nanostructured surfaces; Nanomaterials

Steel is one of the most popular construction materials, due to its relatively low cost and durability. Unfortunately, it is also prone to corrosion, despite many attempts to eradicate this phenomenon. Simply substituting it with other materials proves futile, as corrosion is an inherent trait of metals, driven by the thermodynamic preference for their oxide forms over metallic states. The global economy suffers substantial losses to a few percent of the GDP, due to corrosion-related damages [1]. Various corrosion protection methods have been proposed, ranging from paints and protective coatings to corrosion inhibitors [2]. With an elimination of the protective coatings based on hexavalent chromium, once considered among the most effective anticorrosive treatments but concurrently posing health hazards to factory workers, a demand for new corrosion protection techniques has emerged [3]. Among them the thin silica-based layers have been a very interesting alternative due to their unique properties, such as nanometric thickness, high homogenous structure, and strong substrate adhesion [4]. Moreover, SiO_2 is chemically neutral, inert and does not affect the living organisms and the environment [3], [5]. Their preparation using the sol-gel method is an easy and environmentally friendly process, which also gives a huge field for the layers modification by adjusting sol compositions and thus product customisation. This study investigates the corrosion resistance of steel elements protected with silica-based coatings, doped with cerium oxide nanoparticles with self-healing properties. Both the coating and the powders was prepared via the sol-gel technique. Electrochemical impedance spectroscopy serves as the primary tool for corrosion assessment, offering insights into the efficacy of these coatings in investigating steel corrosion.- Acknowledgements This research has been funded with the Polish National Science Centre OPUS 20 (LAP) grant no: 2020/39/I/ST5/03493

Submission number: 433

MICRO AND NANO-TEXTURED GOLD ELECTRODE FABRICATION AND CHARACTERIZATION TOWARDS ELECTROCHEMICAL IMMUNOSENSOR FOR POINT-OF-CARE DETECTION

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Keywords: Nanosensors and Nanoactuators; Nanofabrication; Nanoelectronics

Electrochemical immunosensors are powerful tools for developing point-of-care tests, i.e. biosensors executed at the site of patient care, owing to their possibility of miniaturization. The use of antibodies as receptors to capture target analytes allows high detection specificity, while the electrochemical detection allows to convert the biological recognition event into a measurable electrical signal. One of the limitations of such transduction system is that the sensitivity may not be sufficient for specific biomarkers (e.g., D-dimer) and should be improved. Among the existing amplification strategies, the use of microtextured gold surfaces was proven efficient for the detection of two proteins thanks to larger active surface area. However, the current fabrication process of the enhanced surfaces involves the use of vertical deposition of silica nanoparticles as sacrificial layer for further electrodeposition process, which hinders reproducibility and scalability. To tackle this challenge and continue improving the detection limit and sensibility, this work investigates the fabrication and characterization of gold electrodes textured at both the micro- and nanoscale based on anisotropic wet etching of silicon and electrophoresis deposition of gold nanoparticles. For the microtextured patterns, the use of anisotropic wet etching of silicon is studied as a simpler and highly reproductible surface patterning method. In addition, it eases scalability. For the nanotextured patterns, electrophoresis deposition of gold nanoparticles was chosen due to its simplicity and ease of implementation. Moreover, the conjugation of gold nanoparticles with antibodies allows to consider the electrodeposition of biofunctionalized nanoparticles, providing perspectives for new usage methods with longer stability through time, since the electrodes can be biofunctionalized directly at the patient location. Overall, four configurations are considered and electrochemically characterized, as well as tested against the detection of Human IgG as biological model.

Submission number: 434

PREPARATION OF MAGNETIC MXENES BY FE INTERCALATION

Wiedwald, Ulf*

Keywords: Nanomagnetics; Nanomaterials; Nanobiomedicine

Yet, the success of generating magnetic MXenes remain very limited since Fe, Co or Ni are incompatible with MAX phases precursors. We present an alternative approach to master magnetic properties of 2D MXenes by intercalating Fe into Ti3C2Tx MXene thin films on Si/SiO2 substrates in ultrahigh vacuum (UHV) conditions. Annealing of bare MXenes at T = 1023 K removes -8722;F, -8722;Cl and -8722;OH as confirmed by in situ mass spectrometry and Auger electron spectroscopy. The intercalation of Fe is studied by deposition of a 6 nm Fe film on top of the MXenes and subsequent annealing at T = 300-1000 K. X-ray diffraction shows an increase of the interplanar spacing between MXene sheets (dMX+Fe - dMX = 0.16 ± 0.02 nm). X-ray photoelectron spectroscopy and X-ray absorption near edge spectroscopy reveal that Fe remains metallic. Depth profiling detects Fe down to 30 nm deep into MXene multilayers while MXenes keep intact. We study the magnetic properties by vibrating sample magnetometry (VSM) and ferromagnetic resonance (FMR). VSM suggests a new magnetic Fe-MXene phase with MS = 660 ± 80 kA/m and a Curie temperature of 485 K while FMR at 9 GHz and 300 K shows two ferromagnetic and one paramagnetic signal, which we address to the remaining Fe of the initial film and the intercalated Fe in form of quasi 2D disks and Fe ions dissolved deep in the MXene thin film. Funded by DFG-Project-ID 530103526. Support by CRC/TRR 270 (Project ID 405553726) is gratefully acknowledged.

Submission number: 435

ASSOCIATING BIOCHAR: ZNO NANORODS-BASED ELECTROCHEMICAL BIOSENSOR TO ARTIFICIAL INTELLIGENCE TO DETECT S AUREUS IN HUMAN HAND SKIN

Bach-Toledo, Larissa; Faria, Aline; Ana Carolina, Padilha; Padilha, Reinaldo; Bonacin, Rodrigo; Mazon, Talita*

Keywords: Nanosensors and Nanoactuators; Nanomaterials; AI for Nanotechnology

Nosocomial infections are caused by Staphylococcus aureus (S. Aureus) and are one of the causes of mortality in hospitals and Intensive Care Units. Controlling the presence of these bacteria in health professionals' hands is essential to controlling nosocomial infections [1]. This work aimed to build and validate an electrochemical immunosensor to detect S. aureus in human hand skin, using biochar: ZnO nanorods composite (biochar: ZnO NRs). During the validation step, artificial intelligence (AI) was employed to enhance the test's assertiveness. The immunosensor was built in a Printed Circuit Board (PCB) with all electrodes integrated. The biochar was synthesized through the pyrolysis of the cassava and characterized by FTIR and Raman. ZnO NRs were synthesized by chemical bath deposition onto the biochar surface. The biochar:ZnO NRs were deposited on the working electrode to aid in immobilizing the antibodies and improve the path of the electrons [2]. The immunosensor was characterized by Scanning Electron Microscopy (SEM) and Differential Pulse Voltammetry (DPV). The results demonstrate good reproducibility, repeatability, selectivity, and specificity. The validation stage was carried out using samples collected from 400 volunteers. The results obtained from the immunosensor was compared with those obtained by the Mannitol Salt Agar test. During validation stage, parameters such as current (µA), electrical potential (V), relation between current/electric potential, hand hygiene status (sanitized or unsanitized), temperature, ambient humidity, and result of the cultivation of samples collected from the hands were compiled and analyzed using artificial intelligence techniques. Collected data was used to develop 11 models employing both: Machine Learning (ML) and (2) Deep Learning approaches. All the models were validated using 5-fold cross-validation. The SHAP (SHapley Additive exPlanations) technique was used to analyze the influence of the variables (features) in the model. Biosensor results reached 67.5% accuracy. The accuracy of the test was increased to 98% by combining biosensor data with external variables using ML and DL techniques.

Submission number: 436

INDUCTIVE SUPERPARAMAGNETIC NANOPARTICLE DETECTION CONSIDERING MATERIAL PROPERTIES IN KHZ AND MHZ RANGE

Margo Hauwaert*; Montserrat Rivas ; Jean-Pierre Raskin

Keywords: Modeling and Simulation; Nanosensors and Nanoactuators; Nanomagnetics

The use of magnetic nanoparticles (MNP) is considered promising in the design of biosensors and immunosensors thanks to two major advantages. First, MNP allow a pre-treatment and pre-concentration of the targeted analyte, enabling a significant reduction of the detection limit by a factor 2 to 1000 [1] . Second, the reduced magnetic background in biological samples compared to its electrical or electrochemical equivalent makes MNP suitable nanomaterials as labels (or ‘tags’) for detection with improved sensitivity and lower noise levels. [2] The use of inductive sensors for nanoparticle detection has several assets, including good linearity of the sensor transfer function and a wide dynamic range. [3] Understanding and optimising the sensing process requires to merge different scales of physics : nanophysics and nanomagnetism of nano-scale particles are interacting with the magnetic field of a micro/macro-scale coils to detect nano/micro-scale biomolecules. Physical phenomena ranging from nano to macro scale complicate multiphysics simulations, often resulting in simplifying hypothesises for practical purposes.- In this work, we study the interactions between SPIONS (superparamagnetic ferrous oxide nanoparticles) and an inductive sensing coil which would be used to detect the presence of nanoparticle. The inductance could for example be included in a resonant circuit. However, this focus does not focus on the sensing system, rather on the tranduction phenomena. We analyse how positionning SPIONS within the coil affects the global permeability surrounding the coil, how this varies with frequency and how this interferes with the AC properties of the coil. Using a multifphysics modelling tool, we study how attributing AC-varying susceptibility [4] to the SPIONS compares with considering a constant DC permeability of the magnetite/maghemite nanoparticles. The points of comparison are (1) the shift in coil self impedance, stray capacitance and resonance frequency due to presence of nanoparticles, (2) the shift in coil AC properties (skin effect, quality factor,…) and (3) the overall limit of detection and sensitivity of the coil.

Submission number: 437

3D MAGNET MOTION RECONSTRUCTION VIA A HYBRID GRAPHENE-BASED HALL/AMR SENSOR ARRAY PLATFORM FOR TACTILE SENSING APPLICATIONS

Lumetti, Stefano*; Malago, Perla

Keywords: Nanosensors and Nanoactuators; Nanofabrication; Modeling and Simulation

State-of-the-art tactile sensor systems that rely on magnetic principles detect the flux density change due to the applied force and are usually based on conventional Hall-effect sensors. In comparison with the latter, magnetoresistive (MR) sensors exhibit higher sensitivity and signal-to-noise ratio, and anisotropic MR (AMR) sensors are especially appealing as they are cheap, easy-to-fabricate and readily prone to miniaturization. On the other hand, graphene has emerged as an attractive material for the realization of highly sensitive, CMOS-compatible and cost-effective Hall sensors. In this work, we present the design of a new magnetic sensor structure capable of tracking the 3D motion of a permanent magnet via the combination of a graphene-based Hall sensor with AMR sensor arrays in a single compact platform, suitable to be integrated into novel miniaturized 3D magnetic tactile sensors. The proposed tactile sensor architecture encompasses a permanent magnet embedded in a flexible membrane that moves above the fixed hybrid Hall-AMR sensor platform. The Hall sensors are realized by patterning of a monolayer graphene film grown by CVD and transferred onto a Si/SiO2 substrate, followed by polymeric encapsulation. AMR sensor arrays made of thin Permalloy (Py, Ni80Fe20) stripes are fabricated on top of the dielectric layer and their MR response is linearized via barber-pole biasing. For system design, finite-difference-based micromagnetic simulations (MuMax3) are performed to simulate the AMR sensor response and find their optimal geometry, whereas finite-element simulations (Ansys Maxwell) of the electric current distribution in the Py stripes enable the optimization of the barber pole geometry. The magnetic field generated by the permanent magnet is computed via analytical expressions implemented in the Magpylib Python package and used as external field input in the micromagnetic simulations. Using this novel magnetic sensor platform, the 3D movement of a sub-mm NdFeB magnet can be reconstructed by solving a magnetic inverse problem: planar AMR sensor arrays are exploited to derive the magnet motion in the x-y plane, whereas the graphene-based Hall sensor allows to infer the displacements in the z direction.

Submission number: 438

ROBUST PHOTOACTUATION OF HUMIDITY-SENSITIVE PDAP/SILICON NANOCANTILEVERS

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Majewski, Pawel; Graczykowski, Bartlomiej

Keywords: Nanosensors and Nanoactuators

We demonstrate the fabrication of poly(diaminepropane)-coated Si cantilevers through a plasma polymerization technique and their use as photothermal, humidity-driven actuators. The developed pDAP films exhibit high elasticity with Young's modulus ranging between 6.5 and 8 GPa, and remarkable mechanical durability across temperatures from 20 to 80 °C. Notably, the pDAP layer of merely 50 nm thickness can be freely suspended over a millimeter-sized opening, showcasing an impressive length-to-thickness ratio of approximately 40,000. Such freestanding polymeric membrane can even endure the temperature of 420°C for 10 min. The pDAP layers respond to multiple stimuli including atmospheric moisture, temperature, and laser light which we employ for tunable deflection of cantilevers.-Our study shows robust dynamic characteristics of pDAP/silicon beams when stimulated via photothermal heating. The determined relaxation times owing to water sorption remain below 10 ms, and relaxation times owing to thermal expansion are of the order of 40 -956;s enabling the actuation at frequencies from 10 Hz to 1 kHz. After a million of actuation cycles such actuator exhibit no changes in the performance, i.e., deflection amplitude and relaxation times have not deteriorated. The demonstrated light-to-motion conversion opens exciting possibilities for future applications based on biocompatible and standard technologies.-

ReferencesA. Krysztofik, P. Pula, M. Pochylski, K. Zaleski, J. Gapinski, P. Majewski, B. Graczykowski, Fast Photoactuation and Environmental Response of Humidity-sensitive pDAP-silicon Nanocantilevers. Adv. Mater. 2024, 2403114. https://doi.org/10.1002/adma.202403114

Submission number: 439

TAILORING EXCHANGE COUPLING AND COERCIVITY: SIZE AND SHELL FRACTION DEPENDENCY IN HARD/SOFT CORE/SHELL FERRITE NANOPARTICLES

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Keywords: Nanomaterials; Nanobiomedicine; Nanomagnetics

In recent decades, magnetic ferrite nanoparticles have been extensively studied for applications like magnetohyperthermia, which uses their ability to convert magnetic field energy into heat for treating certain cancers [1,2]. At nanoscale, their magnetic properties are governed by the collective magnetic ordering of the core and by size and surface effects, in particular surface disorder. Then, at low temperatures, the magnetic structure of these nanoparticles can be seen as an ordered core surrounded by a shell of disordered spins with resemble to a spin glass like (SGL) structure. Thus, at this interface the coupling between the ordered spins of the core and disordered spins of the shell leads to an exchange bias (EB) field that can be measured by the shift of hysteresis loops after field cooling procedure [3,4]. In this work, we investigate the size and shell fraction dependency of the exchange anisotropy field on hard/soft core/shell ferrite nanoparticles. For this purpose, we synthesized three samples of ultrasmall core/shell nanoparticles (~ 3-4 nm) based on CoFe2O4@-947;-Fe2O3.--Two of them are made of 4 nm sized nanoparticles with different maghemite volume fractions, and two of them present different sizes and the same shell volume fraction. Magnetic hysteresis loops are collected at low temperature and varying the cooling field intensity. It allows obtaining both, variations of the exchange anisotropy and coercivity fields. Both, EB and coercive fields are larger for nanoparticles of smaller sizes and larger shell volume fractions. A mesoscopic scale approach and the Monte Carlo (MC) method [5] are used in diluted assemblies, considering inter-particle and intraparticle interactions together with particle size polydispersity. The experimental results are given together with numerical results and allow us to interpret the observed behavior.-

References-

[1] Beji et al, S, Chem. Mater. 22, 5420–5429. (2010)
[2] Pilati et al J. Phys. Chem. C, 122 (5), 3028–3038. (2018)
[3] R. Cabreira-Gomes,et al J. Magn. Magn. Mater. 368, 409 (2014)
[4] F. G. Silva et al J. Phys. D: Appl. Phys, 46, 285003 (2013)
[5] Silva, F. G et al Nanoscale Adv.,4, 3777-3785 (2022)

Submission number: 440

SOFT MAGNETIC COMPOSITE CORE FOR ELECTRIC MOTORS: DESIGN AND PROCESSES

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Keywords: Nanomagnetics; Nanomaterials; Nanofabrication

The project aims, firstly, to explore an original pathway to design an iron-based ferromagnetic material using soft chemistry (polyol process). Secondly, the objective is to consolidate the obtained magnetic powder using Spark Plasma Sintering (SPS) or Metal Injection Molding (MIM) and determine the magnetic properties of the resulting consolidates. Finally, it aims to manufacture a small magnetic rotor for a lab-scale magnetic motor. Powders and consolidates will be characterized by XRD and SEM for the structural and microstructural properties, by dc-magnetometry and FMR for the magnetic properties and by Vickers hardness measurements for the mechanical properties. Multiphysics modelling (COMSOL) will be then carried out to investigate the magneto-mechanical behavior of a well-sized rotor including the engineered consolidates.

Submission number: 441

MAGNETIZATION DAMPING IN SINGLE CRYSTALLINE AND POLYCRYSTALLINE Y3FE5O12 FILMS

Krysztofik, Adam*; Coy, Emerson; Dubowik, Janusz

Keywords: Nanomaterials; Nanomagnetics; Nanofabrication

Yttrium iron garnet ($Y_3Fe_5O_{12}$, YIG) is one of the compounds intensively investigated in terms of microwave and magnonic applications. This material is distinguished by its low damping of the magnetization precession, enabling the long-range propagation of spin waves. At the moment, it is predicted that information processing devices based on spin waves will have significantly lower energy consumption compared to those based solely on electronic transport. Potential applications are therefore the main motivation for the undertaken research.-During the presentation, the results of studies on the structural and magnetic properties of thin yttrium iron garnet films will be discussed. Particular attention will be paid to the magnetization dynamics and its mutual relationship with the structural properties of the developed layers. More importantly, we will focus on the interpretation of the FMR linewidth in various systems. This includes the epitaxial YIG layers grown on lattice-matched and lattice-mismatched garnet substrates, films grown on naturally oxidized silicon, and YIG/metal bilayers, where the metallic films serve as a spacer separating YIG from the GGG substrate

Submission number: 443

HETEROGENEOUS FENTON-LIKE CATALYTIC ACTIVITY IN CORE-SHELL WUSTITE-MAGNETITE NANOPARTICLES

Morales Ovalle, Marco Antonio*; Winkler, Elin L.; Lima, Enio Jr.; Vasquez Mansilla, Marcelo; Goya, Gerardo

Keywords: Nanobiomedicine; Nanomagnetics; Nanomaterials

It is well established that iron oxide nanoparticles (NPs) are capable of decomposing hydrogen peroxide (H2O2) through heterogeneous Fenton (HEF)-like reactions mediated by Fe2+ cations on the surface.[1-4] The resulting free radicals are traceable with electron paramagnetic resonance (EPR) with high specificity.[2,3] However, recent studies suggest that not only the surface ions participate in the decomposition of H2O2, but the ions inside the nanoparticle also participate in the reaction by facilitating the electron transfer from the interior to the surface through Fe2+-O-Fe3+ chains.[5] This mechanism enables the regeneration of surface Fe2+ concentration, allowing the reaction to sustain over time. In this work we study the catalytic activity of core-shell wustite-magnetite NPs (CS-NPs), with the aim to evaluate the wustite core as a reservoir of Fe2+ cations to extend the decomposition of H2O2 for a longer period compared to magnetite as a single phase. To study the HEF-like catalytic activity of this two-phase system, CS-NPs of 14.2(1.5) nm were synthesised by thermal decomposition of organometallic metals. As-made CS-NPs were oxidised by thermal treatment at 100 °C for 1.5, 4 and 73 hours in air atmosphere. The nanoparticles oxidation was followed by XRD and magnetic characterization. The magnetic properties confirm the exchange coupling at the wustite-magnetite interphase, until up to 73 h oxidation time where the absence of exchange bias suggests the complete oxidation of the wustite phase. The free radical production in the Fenton reaction was measured for each NPs oxidation state by EPR using DMPO as a spin trap. The results show an increased formation of free radicals with the time for all the oxidation states. It was also observed that the reaction was sustained for a longer time as compared with the single phase magnetite nanoparticles.

Submission number: 444

ENHANCED SUPERCONDUCTIVITY IN GA NANOWIRES ACHIEVED BY COST-EFFECTIVE METHOD: PRESS-BASED NANO INFILTRATION

Mendonca, Alberto*; Tomiatti, Leonardo; Soares, Carlos; Ribeiro, Pablo; Pirota, Kleber; Beron, Fanny

Keywords: Nanomaterials; Nanofabrication; Nanomagnetics

In 2017, K. O. Moura et al. [1] reported type-II-like superconductivity in a nanostructured array of -946;-Ga nanowires prepared in nanoporous alumina templates by the metallic-flux nanonucleation (MFNN) method [2]. However, since the MFNN technique is designed for preparing single crystalline nanowires, it can be both time-consuming and energy-intensive. The sample must be placed in a furnace at high temperatures, followed by a slow cooling process lasting several days. In this work, we introduce a novel procedure for preparing Ga nanowires developed as a simpler and faster process, named press-based nano-infiltration (PBNI). A solid Ga pellet is heated just above its melting temperature, approximately 30°C, before forcing the liquid metal to infiltrate into the alumina template nanopores, using a hydraulic press under vacuum. The novel process requires significantly less heat consumption, while the pressing lasts only about half an hour. The Ga nanowires prepared by the PBNI method present a clear superconducting behavior below TC = 7.5 K, as shown in Fig. (a), unexpectedly higher than the samples obtained by MFNN (6.2 K) [1]. Furthermore, the superconductivity of the infiltrated Ga nanowires is more persistent under the influence of a magnetic field, requiring twice the magnetic field intensity to destroy the superconducting phase. Another advantage of the PBNI is the high Ga nanowire filling factor achieved, easily exceeding 70%, as shown in Fig. (b). Therefore, this cheaper and faster sample preparation method yield fabricating a large quantity of parallel Ga nanowires exhibiting interesting and unexpected superconductivity properties.-Acknowledgements We acknowledge the Brazilian funding agencies FAPESP (#2017/10581-1, #2020/07397-7, and #2022/16839-9) and CNPq (#31276/2021-6, #140766/2022-7, #443930/2023-6, #421070/2023-4, and #122401/2023-9).-

References

[1]--K. O. Moura et al. Scientific Reports 7, p. 1 (2017).
[2]--K. R. Pirota et al., Magnetic Nano- and Microwires: Design, Synthesis, Properties and Applications, Woodhead Publishing, p. 61 (2020).

Submission number: 445

ADDRESSING UNIQUE THERMAL CHALLENGES OF MONOLITHIC 3D ICS WITH 2D MATERIALS

Chrzanowska-Jeske, Malgorzata*; Jeske, Marcin

Keywords: AI for Nanotechnology

The next generation of computing is focused on neuromorphic systems emulating the human brain and using non-von Neumann architectures that perform calculations "within memory". These new system architectures require performance well beyond current circuits. For more advanced technology nodes, the gate-all-around (GAA) nano-wire/nano-sheet transistors will evolved into CFETs (Complementary Field Effect Transistors) with transistors stacked vertically, placing n-channel and p-channel on top of each other by creatively integrating both nFET and pFET nano-wires in a single stacked structure. Monolithic 3D (M3D) systems based on CFETs deliver lower leakage, increased performance, and significant area reduction at constant gate dimensions. Unfortunately power density increases by the same factor and along with the very dense and specific integration scheme of M3Ds presents unique challenges to dissipating heat. Without the thick bonding layers and bulk substrate present in 3D systems using TSVs (Through-Silicon-Vias), the different tiers are instead separated by very thin inter-layer dielectrics (ILD), which poorly facilitate lateral heat spread. To improve heat dissipation, various 2D materials are considered as thermal interface materials (TIMs), additional intermediate layers (ILs), and interlayer dielectrics (ILD). Thermal simulators are used to investigate their influence on temperature maps and temperature range distributions in 3D ICs.

Submission number: 446

DEVELOPMENT OF E-PAT FOR HIGH-THROUGHPUT SCREENING OF PENETRATION AND TOXICITY (EFFICACY) USING CULTURED DISHES FOR HIGH-RESOLUTION IMAGING WITH 3D CELLS

Baek, Ahruem; Choi, JaeWon; Heo, Min Beom*

Keywords: Nanomaterials; Nano-Optics, Nanophotonics, and Nano-Optoelectronics;

Nanobiomedicine

This thesis presents ground breaking advancements in 3D bio sample research, focusing on addressing cultivation and imaging challenges while simulating physiological conditions for cellular studies. Figure.1 introduces an innovative U-shaped glass dish designed to preserve the integrity of 3D bio samples, particularly fluorescence, during critical processes. Investigating the fabrication, characteristics, and the impact of high-resolution optical imaging on 3D biological sample research, the U-shaped glass dish minimizes mechanical stress, fostering an environment conducive to cell growth. Its significance lies in accurately studying biological research related to complex 3D structures and facilitating high-resolution imaging beyond a 60-fold magnification. Additionally, a 3D cell culture methodology is explored to simulate physiological conditions within the human body, utilizing liver organoids. Figure 2 utilizes the designed and fabricated E-PAT (Extracellular Matrix Permeability and Efficacy Analysis Tip), [1] facilitating fluid flow through the organoid/ECM layer and enabling simultaneous assessment of nanoparticle permeability and cytotoxicity. Consequently, these innovations contribute to the advancement of 3D bio sample research, providing valuable insights and robust tools for improved experimental outcomes.

Submission number: 447

RECONFIGURABLE LOGIC INSPIRED BY DENDRITIC COMPUTATION

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Keywords: Quantum, Neuromorphic, and Unconventional Computing; Nanoelectronics; Nanomaterials

Reconfigurable logic plays a pivotal role in modern electronics and computing due to its unique blend of flexibility, performance, and efficiency. Within this framework, biological neurons that learn complex non-linear input output mappings can serve as a template for designing reconfigurable low-power and area-efficient circuitry. Existing implementations of biomimetic logical circuitry focus largely on computations that occur between neurons, but often lack an emphasis on essential computations that occur in dendritic branches. Recent studies have shown that while dendritic branches and the soma both integrate incoming signals, they apply complementary activation functions. Typically, the soma applies a monotonically increasing activation whereas dendritic activation is non-monotonic in nature. A single neuron with sigmoid activation can be reconfigured to perform most logical functions but fails to perform those that are not linearly separable (such as XOR). In contrast, dendritic activation can execute all Boolean logic due to its non-monotonicity and characteristic thresholding. This behavior is essential for creating a compact and adaptable circuit capable of executing logic operations. We demonstrate a hardware implementation of dendritic computation using a circuit comprising programmable CMOS transistors with two-dimensional transition metal dichalcogenides as the channel material.- Next, we investigate the utilization of a non-monotonic dendritic activation function in models that approach MNIST digit classification with a two-layer fully connected network, CIFAR-10 image classification with a convolutional network, and CORA node classification with a graph convolutional network. In comparison to ReLU and sigmoid activation functions, we found that a dendritic activation function reaches 99% accuracy in fewer training epochs on the MNIST dataset, achieves higher final accuracy at several depths on a two-class subset of the CIFAR-10 dataset, and retains accuracy at larger depths on the CORA dataset. These results establish the potential benefits of utilizing a hardware-based dendritic activation function for the acceleration of both reconfigurable logic and fundamental neural network operations.

Submission number: 448

NANOFABRICATION OF AU-CAPPED SI-NANOPILLARS FOR SINGLE-MOLECULE DETECTION

Dobroiu, Serban; van Delft, Falco C.M.J.M.; Wilson, Robert; Sudalaiyadum Perumal, Ayyappasamy; Nicolau, Dan V.*

Keywords: Nanofabrication; Nanomaterials; Nanosensors and Nanoactuators

Planar surfaces with gold nanoparticles are central to biosensing and diagnostics due to their inertness to most chemical reactions, excellent optical properties, and high signal-to-noise ratio. Despite their advantages, challenges persist in controlling biomolecule density and achieving spatial distribution of nanoparticles. Previous work utilized a kelp root system-inspired 7-ARM PEG-holdfast for precise mounting and efficient fluorescence detection on 20 nm Au-nanoparticles. However, a significant limitation was the tendency of gold nanoparticles to self-assemble into islands, impeding spatial separation of the nanoparticles and thereby resolving single molecule level readout information. To address this, a nanolithography-derived substrate was fabricated, and the biorecognition functionality of a nanopillar with gold caps capable of mounting single biomolecules were demonstrated Relevance: This nano-fabrication approach can be used for future biosensing and diagnostic devices and platforms that require single molecule level resolution using fluorescence and/or surface plasmon resonance-based readouts.

Submission number: 449

PREDICTING THE DYNAMICS OF DNA UNFOLDING: A DATA-DRIVEN APPROACH

Vissol-Gaudin, Eleonore*; Chen, Xiaoli; Soh, Beatrice W.; Ooi, Zi En; Novoselov, Kostya; Yu, Haijun; Hippalgaonkar, Kedar; Li, Qianxiao

Keywords: Modeling and Simulation; AI for Nanotechnology; Nano-Metrology and Characterization

We present a data-driven approach for the study of dynamical systems away from equilibrium. Using DNA unfolding as a case study, we show that the approach is capable of predicting the unfolding statistics of this flexible nanomaterial under an elongational flow. Furthermore, it enables the construction of a set of reduced coordinates which are found to be interpretable, i.e. they are related to measurable physical variables. For a fixed temperature and flow strength, it is possible to construct an energy landscape on the reduced coordinates, and find the stable and metastable states of the system. We demonstrate that the approach can be extended to predict the statistics of DNA unfolding under different flow rates with minimal loss of prediction accuracy and an evolving energy landscape.

Submission number: 450

APPLICATION OF RAPID QPCR MICROFLUIDIC SYSTEM FOR TUBERCULOSIS DETECTION

Hung, Chia-Tse*; Chang, Wei; Chiou, Chiuan-Chian; Lin, Yen-Heng

Keywords: Nanosensors and Nanoactuators; Nanofabrication; Nano-Optics, Nanophotonics, and Nano-Optoelectronics

This study presents a rapid nucleic acid detection technology capable of completing a 40-cycle qPCR reaction in 13 minutes (with optimization, reduced to 8 minutes). Integrated with LabVIEW software, it adjusts temperature, cycle numbers, and reaction time automatically, achieving rapid qPCR for tuberculosis diagnosis.

Submission number: 451

ON-CHIP NI-NANOWIRE BASED ORGANIC SPIN VALVE DEVICE FABRICATION AND MAGNETOELECTRONIC CHARACTERIZATION

KIZIL, Ramazan*

Keywords: Spintronics; Nanomagnetics

Organic semiconductors were thought to be a good candidate for spintronic applications as they may exhibit long spin diffusion time due to their relatively weak spin-orbit and hyperfine coupling [1]. Although conceivable magnetoresistance up to 40 percent was obtained from organic spin valves at cryogenic condition, no or very small magnetoresistance was recorded at near room temperature [2]. The most formidable challenge in organic semiconductor is interface bottleneck to electron transport [3,4] in the organic layer intercalated between two ferromagnet contacts due to the interface resistance. We used an innovative approach to fabricate on-chip organic spin valve using self-assembled polymer of benzene dithiol or biphenyl dithiol in a ferromagnetic (Ni) nanowire. Using porous alumina as the template, we electrodeposited 3-4 um Ni layer and developed a thin polymer layer on top of this metal layer. Putting another 3 um Ni layer on top of this hybrid structure, we synthesized organic polymer built-in ferromagnetic nanowires. These organic layer stripped ferromagnetic nanowires were aligned between the fingers of photolithographically defined microelectrode pairs through well-known electrofluidic assembly technique [5], applying AC field of 45 V and 10 kHz to ethanol dispersed nanowires poured on the chip. We investigated the magnetoelectronic behaviour of this first on-chip nanowire based archetypical spin-valve device (Fig.1) at cryogenic conditions and near room temperature (200 K) using a supermagnet coupled cryogenic probe station through 2-terminal IV measurements. High intrinsic conductivity of the self-assembled polymer of organic molecules helped obtain reproducible IV measurement with almost no interface effect. We obtained magnetoresistance as high as 25% at 200 K for the first time for an organic spin valve owing to well chemisorption of the organic molecule through covalent Ni-S bonding and high intrinsic conductivity. We measured the magnetoresistance (MR) from 0 to 2 Tesla at 1 uA by recoding the change in voltage with the onset of negative MR at 150 mTesla.

Submission number: 452

STUDY OF THE VARIABILITY IMPACT ON CFET CIRCUITS BASED ON VERTICAL NANOWIRES

Amat, Esteve*; del Moral, Alberto; Bausells, Joan; Perez-Murano, Francesc

Keywords: Modeling and Simulation; Nanoelectronics; Nanofabrication

Beyond 3-nm technology nodes complementary Field Effect Transistors (CFET) is regarded as a promising option to implement integrated circuits (IC) and by significantly reduce the IC area foot-print. Because then- and p-devices are stacked one over the other. Nevertheless, in this contribution we want to present an improved configuration with our proposal, where we stack n- and p-type transistors along a single silicon vNW to implement a Circuit-in-Pillar (CiP) strategy (Fig. 1.a). It use allows us to forecast a relevant reduction on SRAM area foot-print (Fig. 1.b). To achieve this vertical structure there are two ways: by combining EBL and RIE processes (expensive procedure) and by using Metal Assisted Chemical Etching (MACE) process, which is cheaper and less complex. The silicon NW is surrounded by an electrically isolated with a GAA structure that acts to gate the flow of electrons through the wire. On the other hand, it is important to remark that as technology node is aggressively scaled down, the device variability has become a relevant limitation factor for the device performance that it should be regarded in this so aggressively scaled down structures. The suitability of our CiP circuit implementation was presented in a previous contribution in IEEE NANO 2022. Then, in this new contribution we have analyzed the variability impact on the performance of our CiP proposal. To do so, we have regarded three source of device variability: Random Dopant Fluctuation (RDF), Line Edge Roughness (LER) and Metal Grain Granularity (MGG). Fig. 2.a shows the influence of the variability on a CMOS inverter (reference circuit) when the different sources are regarded individually or all at the same time (FULL). Fig. 2.b shows the LER as the main variability source. Afterwards, Fig. 2.c presents a variability level below the 10% for all the analyzed sources, even when all sources act at the same time (FULL).

Submission number: 453

DEVELOPMENT OF NEW EMERGING MEMORIES AND THEIR APPLICATIONS

Choi, Shinhyun Choi*

Keywords: Quantum, Neuromorphic, and Unconventional Computing; AI for Nanotechnology

Artificial intelligence (AI) will enable machines to think and solve complex tasks like human beings. In recent years, artificial neural networks have improved recognition and classification accuracy. However, state-of-the-art deep learning algorithms require large network models with multiple layers, which pose significant challenges for complementary metal-oxide-semiconductor (CMOS) implementation due to limitations in conjoining computation, memory, and communication requirements in large networks. As an alternative hardware platform, emerging memories have been proposed for weight storage and fast parallel neural computing with low power consumption. The parallelism property of the crossbar arrays for matrix-vector multiplication enables significant acceleration of core neural computations. In this talk, Prof. Choi will present a systematic study on the fundamental understanding of emerging memory devices (RRAM and PRAM). He will talk about the approach how to achieve highly reliable artificial neurons and synapses for neuromorphic computing which can be a key step paving the way towards post von Neumann computing. In addition, he will also introduce the application of developed crossbar network, which suggests potential applications of emerging memory/computing device-based network to effective data processing for solving real-world problems. He will also talk about his recent work on phase change memory that shows low power consumption with cheap fabrication process. Finally, he will discuss the projections and future directions.

Submission number: 454

SYMMETRY AND TOPOLOGY IN PHOTONIC NANOSTRUCTURES

Abdoulaye, Ndao*

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics

The quest for smaller, lighter, and more efficient optical components usually comes-at the price of reduced functionalities. In this talk, I will provide an overview of how topological-approaches to control light-matter interaction enable novel photonic devices with unique-features and enhanced performance. I will discuss our recent breakthrough in demonstrating-the first topological light source that unidirectionally outcouples to a waveguide from magnetic-biased photonic crystal cavities of arbitrary shape. I will also discuss singularities of non - Hermitian systems and their application in biology and healthcare by detecting attomolar-concentrations of anti-immunoglobulin G. In the last part of the talk, I will present a premier-achromatic broadband metalens that is strategically engineered to span an octave bandwidth-with high efficiency. Such devices will be suitable for free space and integrated optics and pave-the way towards more complex and versatile systems with applications in high-capacity-classical and quantum communications, as well as sensing.

Submission number: 455

SILICON PHOTONICS DEVICES: FROM ADVANCED METAMATERIALS TO BIOSENSING APPLICATIONS

Molina-Fernandez, Inigo*

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Modeling and Simulation; Nanomaterials

Since their first demonstration in the early 2000s, sub-wavelength grating structures have grown in importance within silicon photonics and have demonstrated that they can be useful in commercial applications. Much of the success achieved by these technologies is based on having models that allow deep understanding of their operation as well as simplifying their design through sophisticated homogenization techniques that allow engineering via the metamaterial concept. Recent advances in this field of research have been very fruitful in diverse areas such as the achievement of 220 nm thick SoI devices that are insensitive to polarization [1]; bragg filters with advanced spectral responses [2], or photonic biosensors with improved sensitivities [3]. Photonic biosensors, based on silicon photonics, have shown sensitivity values that are the state of the art. This, together with miniaturization, and compatibility with the CMOS manufacturing infrastructure, makes them excellent candidates for the development of low-cost systems for the in vitro diagnosis. Interferomerter based biosensing devices with coherent readout have shown state of the art performance achieving bulk LODs in the order of 10-8 RIU which places them at the level of well-established techniques such as SPR, which is currently the Golden Standard on the market for the characterization of biorecognition reactions. In this paper we will review some of the fundamentals of SWG structures as well as their use in different applications: polarization agnostic devices, high performance filters, or ultrasensitive sensors. We will also review the advances in photonic biosensors, which have allowed the development of highly sensitive platforms for in vitro diagnosis of diseases and we will see the different challenges that exist to achieve the high degree of accuracy of such solutions.-We acknowledge funding from the Ministerio de Economia y Competitividad, PID2019- 106747RB-I00, PRE2020-096438, PID2020-115204RB-I00, TED2021-130400B-I00, Ministerio de Ciencia, InnovaciOn y Universidades, FPU19/02408, FPU21/04914, Junta de Andalucia P18-RT-1453, P18-RT-793, UMA-FEDERJA- 158, National Research Council Canada (CSTIP, HTSN210, STR2-0102); and Universidad de Malaga

Submission number: 456

QUANTUM INFORMATION AND ARTIFICIAL NEURAL NETWORKS-BASED SIGNAL PROCESSING USING INTEGRATED PHOTONICS

Morandotti, Roberto*

Keywords: Nano-Optics, Nanophotonics, and Nano-Optoelectronics; Modeling and Simulation; Nanomaterials

Integrated photonics advances emerging machine learning and quantum information processing technologies. This work employs on-chip, reconfigurable devices for highly efficient, intelligent, and secure classical and quantum signal processing. We demonstrate simultaneous operations with high speed, low power consumption, and small footprints, paving the way for next generation telecommunication solutions.

Submission number: 457

CONTROLLING LIGHT AT THE NANOSCALE WITH 2D MATERIALS

Alonso Gonzalez, Pablo*

Keywords: Nanomaterials

2D materials have recently attracted considerable attention due to their ability to support light at the nanoscale (polaritons) with extraordinary properties, such as strongly anisotropic propagation (hyperbolic) and extreme field confinement. Among them, the -945;-phase molybdenum trioxide (-945;-MoO3) [1] excels because of its low optical losses, offering an unprecedented material platform for controlling the flow of energy at the nanoscale. In this talk, I will show experimental demonstrations of the unique behavior of nanolight in these crystals, including the visualization of anomalous cases of the most fundamental optical phenomena such as refraction [2] or reflection [3]. Moreover, I will introduce the exotic phenomenon of canalization [4,5], in which PhPs propagate along a single direction with ultralow losses when two biaxial slabs are rotated at a critical/magic angle (Twistoptics).-

References-

[1] W. Ma et al., Nature, 562, 557 (2018).-
[2] J. Duan et al., Nature Communications, 12, 1, 1-8 (2021).-
[3] G. alvarez-Perez et al., Science Advances 8, 29, (2022).-
[4] J. Duan et al., Nano Letters, 20, 7, 5323-5329 (2020).-
[5] J. Duan et al., Nature Materials, 22, 867–872 (2023).

Submission number: 458

QUANTUM TRANSPORT AND NOISE MODELLING CHALLENGES FOR SUB 1-NM NODE CHIPS

Iannaccone, Giuseppe*

Keywords: Modeling and Simulation; Nanoelectronics; Nanomaterials

The semiconductor Industry roadmaps towards sub-1-nm technology nodes anticipate the adoption of new-device architectures and the introduction of advanced materials, which imply increased complexity of geometry and-broader spectrum of materials and of materials interfaces [1,2,3]. Modelling and computational software must-address these challenges both to provide insights of the main physical mechanisms at play and of their effect on-chip manufacturing, performance, and reliability, and therefore to support the development of new technology [3,4]. In this talk, we will discuss the main impact of the introduction of new materials, including transition-metal-dichalcogenides and advanced dielectrics, and of next non-planar device architectures, on co-modelling of materials-and device properties and on multi-physics modelling capable to seamlessly integrate quantum transport and-semiclassical transport modelling. [5,6] We will also discuss the effects of technology advances on noise modelling-both in terms of physical insights and in terms of circuit design. Some semiconductor roadmaps indicate the future adoption of vertically integrated nanosheet transistors based-on two-dimensional semiconductors. The assessment of the impact of access resistance to the channel requires-quantum transport simulations capable to provide insights on the intrinsic limiting factors and on the technology-options available to reduce the access resistance, which is a key factor for device performance. Sub 1-nm chips typically require transistor with very small contact area, posing an additional constraint in the challenge to obtain a-low access resistance. In addition, the adoption of channels with low density of states such as, for example, two_x0002_dimensional semiconducting materials, can limit the achievable device transconductance, which has a strong impact-on device performance. A thorough analysis and optimization of this issue requires coupled simulations of quantum-transport and electrostatics, often including the impact of electron-phonon interaction. Finally, noise is an important source of information on electron-electron correlations. In nanoscale devices,-for example, channel noise is better described by shot noise, which can be enhanced or suppressed with respect to-a Poissonian process depending on the relative importance of competing mechanisms of electron-electron-correlation. We shall show conditions for the enhancement and the suppression of shot noise that have increasing-relevance as transistor size is reduced, and that are too often neglected both in device analysis and in circuit design.

Submission number: 459

BIOMATERIALS BASED HTL FOR ORGANIC LIGHT EMITTING DIODE

Mbarki, G.; Buso, David*; El-Housseiny, H.; Renaud, Cedric; Khalfaoui, Mohamed; Ternisien, Marc

Keywords: Nanotechnology in Soft Electronics

There is an increasing demand for compact, efficient and biocompatible Organic Light Emitting Diode (OLED). More particularly biophotonic applications like imaging, investigating, treating living matter by the use of light require a high level of integration with high efficiency. OLED technology is mature enough to fulfill these requirements, but some applications like optogenetics, therapy, lab on chip require also the use of biocompatible materials (bioresorbable materials may be desirable in some cases). Moreover, biomolecules integration within OLEDs contributes to diminish component embedded energy and therefore its carbon footprint. Nevertheless, biomaterials-based OLED is a challenge--in order to achieve performance requirements, to find suitable fabrication process compatible with their properties and to overcome limitations due to their stability and durability. In this context, this paper is focused on the integration of biomolecules-based Hole Transport Layer within OLED. More particularly we focused on carotenoid materials which exhibit suitable electrical properties to be used as HTL for OLED. This work is part of a collaboration between ISIMM in Tunisia and the LAPLACE laboratory in Toulouse. This study includes DFT (density functional Theory) quantum modeling in order determine structural properties of carotenoids used in this work. Then ATLAS SILVACO TCAD was used to perform numerical modeling of the elaborated structure, and the resulting I-V characteristic was compared to experimental results. Finally, the structure has been optimized in order to achieve the best possible performances.

Submission number: 460

VNWFET-BASED SYSTOLIC ARRAY ACCELERATOR FOR DEEP NEURAL NETWORKS

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Keywords: Quantum, Neuromorphic, and Unconventional Computing; Nanoelectronics

Vertical Nanowire Field Effect Transistor (VNWFET) is an emerging technology that allows 3D integration thus reducing footprint while maintaining energy-efficient design. In this work, we present a complete toolchain from device to complex logic block synthesis. We developed a VNWFET standard cell library which is based on a real device compact model. This allowed us to successfully synthesize our Neural Network Compute Cube (N2C2); the basic computational unit of the targeted Systolic Array as well as evaluating the design, performance and cost of the N2C2 based on vertical technology.

Submission number: 461

NEW FINDINGS IN 2-DIMENSIONAL MATERIALS TOWARDS SPIN-VALLEY QUBITS: MAGNETIC DOPANTS IN GRAPHENE AND MOS2

Kim, Tae Hee*; Do, Nga T.; Mahdi, Muntasir Mahdi; Zhang, Wei; kim, soo min; Hamilton, Michael

Keywords: Nanoelectronics; Nanomaterials

2D heterostructures are promising materials for topological quantum computing, where quantum states are topologically protected against disorder compared to standard quantum computing. Based on fabrication techniques improved, these heterostructures are made up of the layering of different 2D materials in a precisely selected order, which opens the possibility of confining single electrons to few-atom-thick layers, significantly increasing the operating temperature and the coherence of electron spin qubits.[1,2] These progresses make 2DMs and their heterostructures in many ways a promising platform for future quantum technologies. Recently, spin-valley qubits have emerged as a particularly exciting and promising platform due to their unique properties: two key degrees of freedom, i.e. spin and valley. Here, we present a way to control spin and valley properties of electrons in graphene (Gr) and MoS2 via coupling to impurities. The interplay between 2D materials and Pt layer was explored by introducing an ultrathin magnetic or non-magnetic metal interlayer such as Co, Fe, Mn and Ir. Using UHV-MBE technique, we prepared planar films Pt on the wafer-scale CVD-grown Gr and MoS2 layers transferred onto SiO2 substrates, for the characterization of electronic and optical, and structural properties of the 2D-materials-based heterostructures. To investigate the spin transport phenomena, Pt-Hall bar devices were also prepared using the in-situ shadow mask system in the same UHV-MBE chamber. The quantum interference effect was observed even at 77 K for the samples with the metal (M = Co, Fe, Mn and Ir) interlayer thickness less than 2 -8491;. In particular, for the sample of 0.5--8491;-thick M, the WL-WAL crossover was clearly shown in the perpendicular magnetoresistance measured at the temperature lower than 77 K. Strong doping dependent effects were seen in the Gr (MoS2)-based heterostructures. The theoretical analysis of magnetotransport was also performed using modified the Hikami-Larkin-Nagaoka (HLN) equation[3] which is widely used to describe quantum corrections to the conductivity in quasi-2D systems.

Submission number: 462

SPIN DYNAMICS OF VAN DER WAALS MAGNETS PROBED BY SUPERCONDUCTING RESONATORS AND SPIN-ORBIT TORQUES IN ELECTROSTATICALLY GATED CR2GE2TE6

Kurebayashi, Hidekazu*

Keywords: Spintronics; Nanomaterials

Two dimensional (2D) layered van der Waals (vdW) materials can offer their unique physical properties due to their chemical bonding as well as low crystalline symmetry. The weak vdW bonding allows to mechanically exfoliate individual layers, down to one monolayer in many cases while maintaining thermodynamically stable layers [1]. When it comes to magnetism, this is a perfect material class to study the two dimensionality of magnetic ground states [2-3] and their dynamics. So far, the ground states of 2D magnets have been studied by theory of thermodynamics but these are very simplified cases (e.g. the Mermin Wagner theorem for isotropic magnets [4]) and the microscopic nature of them has been largely unexplored due to the inaccessibility of real experiments at such a limit.-To study spin dynamics and magnetic fluctuations in the monolayer limit for vdW magnets, we are developing a microwave technique to efficiently couple magnons and photons down to that limit. To this end, we use on-chip superconducting resonators with a high quality-factor and small mode-volume to match nano-meter thick vdW flakes. By transferring Cr2Ge2Te6 flakes on superconducting lumped element NbN resonators, we achieve the collective coupling strength (rate) of 13 MHz to 18 nm thick Cr2Ge2Te6 [5]. The linewidth of the photon-magnon hybrid mode is used to analyse the magnetic properties of Cr2Ge2Te6. I will discuss more technical details as well as our strategy of how to achieve sensitive measurements of monolayer vdW magnets.-When time permits, I will also show our experiments of spin-orbit torques in electrostatically gated Cr2Ge2Te6 [6].-[1] K. S. Novoselov et al., Science 353, aac9439 (2016). [2] C. Gong et al., Nature 546, 265 (2017). [3] B. Huang et al., Nature 546, 270 (2017). [4] N. D. Mermin and H. Wagner, Phys. Rev. Lett. 17, 1133 (1966). [5] C. W. Zollitsch et al., Nat. Commun. 14, 2619 (2023). [6] I. A. Verzhbitskiy et al., Nat. Electron. 3, 460 (2020).

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DEVELOPMENT OF A HIGH-THROUGHPUT SCREENING PLATFORM FOR NANOMATERIAL TOXICITY ASSESSMENT USING LIVER ORGANOIDS

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Keywords: Nanomaterials

Nanomaterials have become prevalent in various industrial and consumer products, necessitating comprehensive toxicity assessments to ensure human and environmental safety. However, traditional toxicity testing methods often lack the scalability and physiological relevance required for efficient evaluation. In response, this study proposes the development of an innovative high-throughput screening platform tailored for nanomaterial toxicity assessment, leveraging advanced liver organoid models. Central to this platform is the utilization of liver organoids cultured in a floating system, mimicking the physiological microenvironment of the liver. These organoids, derived from hiPSCs, exhibit enhanced functionality and longevity compared to traditional cell culture systems. Leveraging the liver organoid-based floating culture system, previously established for organoid maintenance, we aim to create a robust platform capable of high-throughput screening. The primary objective of this platform is to enable simultaneous assessment of organ functionality preservation and cellular toxicity in liver organoids upon exposure to nanomaterials. By subjecting liver organoids to a diverse range of nanomaterials, we aim to elucidate their potential adverse effects on liver function and cellular integrity. Through real-time imaging and high-content analysis, we seek to capture dynamic changes in organoid functionality and cellular stress, providing comprehensive insights into nanomaterial toxicity. Furthermore, to enhance the physiological relevance of our toxicity assessments, we propose the incorporation of functional assays to evaluate key liver functions such as bile acid transport and mitochondrial stress, to assess organoid functionality and cellular toxicity, respectively. Ultimately, this study aims to provide a transformative approach to nanomaterial toxicity assessment, offering a scalable, physiologically relevant, and cost-effective alternative to traditional animal testing methods. By advancing our understanding of nanomaterial toxicity mechanisms and enhancing human relevance, this platform has the potential to accelerate the development of safer nanomaterials and facilitate regulatory decision-making processes.

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SILICENE AND XENES APPLICATIONS IN NANOTECHNOLOGY

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Keywords: Nanomaterials

Xenes, the monoelemental family of two-dimensional materials, exhibit a variety of interesting properties with high-potential exploitation in nanotechnology [1]. Silicene, the first Xene ever synthesized, represents an opportunity to face the challenging scaling issues of electronic devices, being compatible with ubiquitous silicon semiconductor technology. Despite silicene instability in air, the configuration where silicene is sandwiched in between an alumina encapsulation layer on the top and thin Ag(111) crystal at the bottom turns out to be a versatile platform for multiple applications. An originally developed integration path for the fabrication of room temperature operating mono and multilayer silicene field-effect transistors will be discussed in light of recent improvements in their fabrication [2,3]. Moreover, the encapsulated silicene configuration can also host Xene heterostructures, like silicene-stanene [4], and, most importantly, can be transferred onto a flexible substrate. The application of macroscopic mechanical deformations to the bendable Xenes-based membranes induces a strain-responsive behaviour in the Raman spectrum of silicene that shows high-stability up to one thousand bending cycles, thus holding high-potential for flexible electronics and edge sensing [5].-
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References

[1]--C. Grazianetti et al., IEEE Transactions on Materials for Electron Devices 1 (2024), 1.

[2]--L. Tao, CG, et al., Nature Nanotech. 10 (2015), 227 and C. Grazianetti et al., ACS Nano 11 (2017), 3376.
[3]--C. Massetti, CG, et al., in preparation.
[4]--D. S. Dhungana, CG, et al., Adv. Funct. Mater. 31 (2021), 2102797.
[5]--C. Martella, CG, et al., Adv. Mater. 35 (2023), 2211419.

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MAGNETIC FIELD RESILIENT SUPERCONDUCTING NANOWIRE DEVICES

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Keywords: Nanomagnetics

In this work, we address the challenge of operating , superconducting nanowire single photon detectors (SNSPDs) in high magnetic fields, where conventional semiconductor detectors fail. We used a novel approach of growing niobium nitride (NbN) thin films by ion beam assisted sputtering (IBAS) [1]. Structural and transport characterization revealed that IBAS-grown NbN films retain good superconducting properties down to a critical thickness of approximately 2 nm, consistent with predictions from quantum size effects and weak localization models. Our fabricated NbN SNSPDs demonstrate exceptional performance at 3 K and can operate reliably in magnetic fields as high as 5 T parallel to the pixel plane and 0.5 T perpendicular, effectively doubling the commonly reported field strength limits [2]. The same films were used to fabricate superconducting nanowire cryotron (nTron) devices. We modified the conventional design of these devices by including parallel current-carrying channels. We found show that the adaptation of parallel channel configurations leads to an enhanced gate signal sensitivity, an increase in operational gain, and a reduction in the impact of superconducting vortices on nTron operation within magnetic fields up to 1 Tesla [3]. The parallel nanowire channels permit larger nTron cross sections, further bolstering the device's magnetic field resilience while improving electro-thermal recovery times due to reduced local inductance.- The work was supported by the U. S. Department of Energy (DOE), Office of Science, Office of Nuclear Physics, Microelectronics Initiative, under Contract No. DE-AC02- 06CH11357. Work performed at the Center for Nanoscale Materials, a U.S. Department of Energy Office of Science User Facility, was supported by the U.S. DOE, Office of Basic Energy Sciences, under Contract No. DE-AC02-06CH11357.-[1] T. Polakovic & V. Novosad, "Method of making thin films", US Patent 11,885,009 (2024) [2] T. Polakovic, et al., "Superconducting nanowires as high-rate photon detectors in strong magnetic fields", Nuclear Inst. & Methods, 959, 163543 (2020). [3] T. Draher, et al., "Design and performance of parallel-channel nanocryotrons in magnetic fields", Appl.Phys. Lett., 123, 252601 (2024).

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SYNAPTIC FIELD EFFECT TRANSISTORS FOR NEUROMORPHIC COMPUTING

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Keywords: Quantum, Neuromorphic, and Unconventional Computing

Neuromorphic computing (NC), which emulates neural activities of the human brain, is considered for the low-power implementation of artificial intelligence. Towards realizing NC, fabrication, and investigations of hardware elements - such as synaptic devices and neurons - are crucial. Electrolyte gating has been widely used for conductance modulation by massive carrier injections and has proven to be an effective way of emulating biological synapses. Synaptic devices, in the form of synaptic field-effect-transistors (Syn-FET), have been studied using various materials. Despite remarkable progress, the study of metallic channel-based synaptic transistors remains massively unexplored. Earlier, we demonstrated a three-terminal electrolyte gating modulated synaptic transistor based on metallic cobalt thin film to emulate biological synapses [1]. We realized gating-controlled, non-volatile, and distinct multilevel conductance states in the device, emulating the essential synaptic functions such as short-term and long-term plasticity. Crucial cognitive behaviors, including learning, forgetting, and re-learning, were emulated, showing a resemblance to the human brain. In a recent study on Syn-FET, we have investigated materials with a perpendicular magnetic anisotropy and have demonstrated an electric field control of magnetic anisotropy via grain dimensionality. The reduction in the grain dimensionality is associated with a transition from ferromagnetic to superparamagnetic behaviour. We achieved a reliable, non-volatile, and reversible modulation of the coercive field in both the ferromagnetic and superparamagnetic regimes. The electrical and elemental analysis further confirmed the grain refinement after gating, revealing a transition from a multi-domain to a single domain state with a reduction in grain size. Furthermore, we exploit the electric field-controlled magnetic anisotropy to demonstrate a current-driven deterministic domain wall motion, which is extendable to multilevel magnetic memory and synaptic devices. These results provide an unprecedented insight into the electrical control of grain dimensionality for high-performance spintronics [2]. The results on Syn-FETs with magnetization in-plane and out-of

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ENGINEERING ADVANCED BIO/NANO-HYBRID MATERIALS FOR NANOBIOTECHNOLOGY INNOVATIONS

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Keywords: Nanomaterials

Recent strides in nanotechnology have ushered in a plethora of nanomaterials, both hard and soft bio/nanomaterials, boasting diverse shapes, sizes, and compositions. Their distinctive physicochemical properties, arising from their size, shape, and composition, hold immense promise for propelling diverse fields forward, ranging from molecular/nano sensing, biosecurity, and bio/nano medicine to optoelectronics and nanophotonics. A recent surge of interest has honed in on their unique potential for crafting multifunctional hybrid bio/nanomaterials, tailormade to specific needs. These hybrid nanomaterials promise advanced properties with applications spanning various nanobiotechnology fields, providing a versatile platform for customizing nanoagents to specific applications. Despite notable progress, there remains ample room for enhancement and numerous untapped opportunities for innovative strategies. In this lecture, our recent advancements in designing and fabricating advanced bio-hybrid nanocomposites, particularly tailored for nanobiotechnology applications, will be explored. The fundamental challenges in orchestrating the controlled assembly of nanoparticles into structures with predefined shapes and functions will be addressed, and strategies to achieve the requisite control and functionality will be presented.

Submission number: 468

THERMALLY GENERATED SPIN TRANSPORT AND SPIN SEEBECK EFFECT IN THIN FILM HETEROSTRUCTURES

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Keywords: Nanomagnetics

Spin-heat coupling and thermo-spin transport are emerging areas of interest in the fields of spintronics and nanomagnetism. Central to this research are the longitudinal Spin Seebeck effect (LSSE) and its intricate relationships with magnetic anisotropy and magnon propagation across magnetic insulator/heavy metal interfaces. LSSE generates incoherent magnon excitations when a temperature gradient is applied across a magnetic material's thickness. While the ferrimagnetic insulator Y3Fe5O12 (YIG) serves as the benchmark system for LSSE studies, other insulating rare earth iron garnets like the compensated ferrimagnet Gd3Fe5O12 (GdIG) and the ferrimagnetic insulator Tm3Fe5O12 (TmIG) are also of significant interest but have been less explored in spin-caloritronics. Our group has pioneered the use of RF transverse susceptibility to probe the effective magnetic anisotropy in magnetic materials and heterostructures. By integrating RF transverse susceptibility with LSSE measurements, we have demonstrated the correlation between bulk and surface anisotropy with the field and temperature dependence of LSSE in YIG/Pt heterostructures and other compensated ferrimagnets. Additionally, we have identified a universal scaling of LSSE in GdIG/Pt bilayers with varying thicknesses and substrates, particularly around the compensation temperature. Our recent studies on TmIG/Pt heterostructures with varying film thicknesses highlight the significant roles of anisotropy and Gilbert damping in LSSE . Through a combination of RF susceptibility, LSSE, and broadband ferromagnetic resonance (FMR) experiments, we provide a quantitative analysis of magnon propagation length and its correlation with magnetic anisotropy and Gilbert damping.

Submission number: 469

HIGH ENTROPY MATERIALS: CURRENT FRONTIERS AND FUTURE OPPORTUNITIES

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Keywords: Nanomagnetics

High entropy materials (HEMs) are a class of materials which leverage the chemical entropy of mixing to realize complex alloys which manifest novel properties. These materials were initially proposed as metal alloys in 2004 for structural applications, and indeed have shown superior strength and hardness at high temperatures. The underlying mechanics for these behaviours stems from the entropy of mixing, which increases with the number of chemical species, and encourages homogeneous alloying, even in systems which are typically immiscible. This inherently results in extreme environments, with potentially large distributions in atomic size, mass, or electronegativity. Furthermore, the entropy can also stabilize alloys and structural phases which otherwise could not exist. In 2015 the concept of high-entropy effects was advanced to include simple oxides, and subsequently has grown again, with examples now including a wide range of metals (refractory and non-), ceramics (oxides, borides, carbides etc.), and intermetallic. Some of the more recent efforts have focused on the functional properties of the material, their magnetic, optical, thermal, electronic, and chemical properties, including mixed behaviour such as thermoelectric and superconducting. While this research is still in its infancy, but has proven to be a fantastic playground for functional materials. This talk will provide a high-level view of the functional high entropy materials landscape and current and ongoing research into magnetic HEMs, including hard materials[1, 2], soft materials[3, 4], and frustrated materials[5, 6]. Several themes will be emphasized including the role of these extreme environments and ordering (or lack-thereof) in these materials. The talk will also highlight some of the novel opportunities presented by HEMs in other nanotechnologies including superconductivity[7], catalytic applications[8], and thermoelectric properties[9].

Submission number: 470

USING SMALL-ANGLE SCATTERING TO RESOLVE THE MAGNETIZATION DISTRIBUTION IN NANOSTRUCTURES

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Keywords: Nanomagnetics

Small-angle neutron scattering (SANS) is a technique to investigate the structural and magnetic properties of condensed matter and quantum materials. It probes inhomogeneities in the bulk of materials on a mesoscopic real-space length scale, ranging from approx. 1nm to a micrometer [1]. The spin of the neutron provides SANS with a unique sensitivity to study magnetism and magnetic materials at the nanoscale, like nanoparticles, long-range magnetic domain structures, skyrmion or superconducting vortex lattices.- By integrating SANS with complementary methods, we can obtain a detailed multiscale characterization of the chemical composition, the intraparticle magnetization and magnetic coupling between different phases, e.g. in nanoparticles. Such a characterisation can inform the design of magnetic nanoparticles (MNPs) for various technological, biomedical, or environmental applications by choosing a suitable combination of size, shape, and material for optimal performance. For example, disorder effects -ubiquitous in nanomaterials- crucially determine the magnetic heating performance of MNPs used for hyperthermia, magnetic particle imaging, and catalysis [2].- Surface spin canting or disorder in MNPs is accessible only indirectly using traditional macroscopic characterization. Magnetic SANS offers spatial resolution of the local magnetization response and allows discriminating bulk and surface contributions to magnetic disorder. For example, we could resolve a field-dependent magnetization process near the structurally defective surface of MNPs, that results in a considerable field-related change of the integral particle moment [3]. The results show that surface spins might be susceptible to intermediate fields, analogous to the spin-flop phase observed in bulk antiferromagnetic oxides. Such details are overlooked in the classical model, that views MNPs as a static two-phase system with a collinear magnetized core and a structurally disordered, magnetically dead surface.-[1] D. Honecker et al., Nanoscale Adv. 4, 1026 (2022). [2] A. Lak, S. Disch, P. Bender., Adv. Science 8, 2002682 (2021). [3] D. Zakutna, D. Honecker, S. Disch et al., Phys. Rev. X 10, 031019 (2020).

Submission number: 471

SENSING OF MAGNETIC NANOPARTICLES ON RIGID SURFACES

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Keywords: Sensors, magnetic nanoparticles

Magnetic nanoparticles are excellent candidates for labeling and detecting biomarkers. Studying magnetic nanoparticles deposited on solid substrates could open the door for using rigid samples. One possible bioapplication could be the measurement of magnetic nanoparticles inside cells attached to a rigid surface. Rigid samples, such as antidots and other examples, are promising for biological applications and present technical challenges that warrant further study. In summary, it is interesting to study magnetic nanoparticles on rigid supports both for their applications and their fundamental aspects.

In this work, we designed and optimized a new measurement system using a refractometry radio frequency sensor. We synthesized magnetic biofunctional nanoparticles based on manganese ferrites using the hydrothermal coprecipitation method. Afterward, we deposited the synthesized magnetic nanoparticles in a solid substrate and quantified their signals, obtaining calibrations with a R^2 of 0.9963, and with a very big signal-to-noise ratio for this type of measurement. Finally, we cultured HeLa cells with the magnetic nanoparticles previously synthesized, attached to a rigid substrate, and measured their signal, with positive results. Therefore, our results support the promising use of this new measurement system for biosensing applications.

Submission number: 472

TOWARDS ORIENTED PROLIFERATION OF CELLS BY HIGH ASPECT MAGNETIC NANOPARTICLES

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Keywords: Magnetic nanoparticles, high aspect ratio, regenerative medicine, magnetic field

The application of nanotechnology in medicine entails the development of nanomaterials capable of effective functioning across various biological settings. Iron oxide nanoparticles (IONPs) find extensive use in biomedical research and clinical applications, owing to their high biocompatibility and biodegradability. In this sense, elongated nanoparticles with a high-aspect ratio have demonstrated a superior particle internalization by cells, which is favored by their increased surface area [1]. Nonetheless, gaining a deeper understanding of the characteristics of these materials and their interactions with cells and tissues remains crucial, particularly in scenarios where their magnetic properties are harnessed for specific applications.

In this work, we have explored two iron oxide nanorods with two different sizes and capping agents (silica and PMAO), focusing on their impact on cell behavior. With that purpose, we have investigated the interaction between the IONPs and a well-established fibroblast cell line (L929 cells). Viability experiments were conducted to assess the biocompatibility of the samples, revealing their safe potential application at concentrations up to 0.1 mg Fe/mL for the PMAO samples and faintly below this threshold for the silica ones. Subsequently, we have explored the influence of a static magnetic field during cell culture. By subjecting the system to specific and controlled magnetic environments, we aim to observe any direct effects on cell behavior including proliferation, cell cycle and orientation. The results of these experiments suggest that the presence and orientation of the magnetic particles under the magnetic field induces a modulation of cell behavior including a preferential cell alignment under certain conditions. These findings contribute to comprehending the cellular interactions and mechanisms occurring between cells and magnetic nanoparticles, holding promise for future advancements in innovative strategies within regenerative medicine, tissue engineering, and targeted drug delivery.

Submission number: 473

INDUCTIVE DETECTION OF MAGNETIC NANOPARTICLES

Margo Hauwaert, Vanessa Pilati, Nordin Trifiro, Montserrat Rivas, Jose-Carlos Martinez-Garcia, Jean-Pierre Raskin

Keywords: Inductive Sensing, Superparamagnetic Nanoparticles, Biosensing, Lateral Flow Assay

The use of magnetic nanoparticles (MNP) is considered promising in the design of biosensors and immunosensors thanks to two major advantages. First, MNP allow a pre-treatment and pre-concentration of the targeted analyte, enabling a significant reduction of the detection limit by a factor 2 to 1000 [1] . Second, the reduced magnetic background in biological samples compared to its electrical or electrochemical equivalent makes MNP suitable nanomaterials as labels (or ‘tags’) for detection with improved sensitivity and lower noise levels. [2] The use of inductive sensors for nanoparticle detection has several assets, including good linearity of the sensor transfer function and a wide dynamic range. [3] Understanding and optimising the sensing process requires to merge different scales of physics : nanophysics and nanomagnetism of nano-scale particles are interacting with the magnetic field of a micro/macro-scale coils to detect nano/micro-scale biomolecules. Physical phenomena ranging from nano to macro scale complicate multiphysics simulations, often resulting in simplifying hypothesises for practical purposes.- In this work, we study the interactions between SPIONS (superparamagnetic ferrous oxide nanoparticles) and an inductive sensing coil which would be used to detect the presence of nanoparticle. The inductance could for example be included in a resonant circuit. However, this focus does not focus on the sensing system, rather on the tranduction phenomena. We analyse how positionning SPIONS within the coil affects the global permeability surrounding the coil, how this varies with frequency and how this interferes with the AC properties of the coil. Using a multifphysics modelling tool, we study how attributing AC-varying susceptibility [4] to the SPIONS compares with considering a constant DC permeability of the magnetite/maghemite nanoparticles. The points of comparison are (1) the shift in coil self impedance, stray capacitance and resonance frequency due to presence of nanoparticles, (2) the shift in coil AC properties (skin effect, quality factor,…) and (3) the overall limit of detection and sensitivity of the coil.