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2026 IEEE 16th International Conference "Nanomaterials: Applications & Properties" (IEEE NAP-2026)

NANOmaterials: Applications & Properties - 2026

BOOK OF ABSTRACTS

Budva, Montenegro
2026

Welcome Message

Dear Colleagues,

It is our pleasure to welcome you to the 2026 IEEE 16th International Conference on Nanomaterials: Applications and Properties (IEEE NAP-2026), held from 6 to 11 September 2026 at the Avala Resort in Budva, on the Adriatic coast of Montenegro.

For sixteen years, NAP has brought together the people who move nanoscience forward: physicists, chemists, materials scientists, engineers, and the students who will carry the field into its next decade. The work collected in this book spans twelve tracks and is anchored by four plenary lectures. This year we will host over 200 attendees from 41 countries. Following NAP tradition, every submitted manuscript undergoes rigorous peer review, and accepted papers will be proposed for inclusion in the IEEE Xplore Digital Library and additional indexing databases.

Beyond the talks and posters, we hope you find time for Budva itself: its walled old town, the Adriatic, and the unhurried company of colleagues old and new.

Welcome to Montenegro, and welcome to NAP-2026.

With warm regards,
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Sumy State University (SumDU) holds a special place in the life of this conference: it is where IEEE NAP was born, in 2011, and from which the series has grown into the international meeting we gather for today, now in its 16th edition. One of Ukraine's leading public research universities, based in the city of Sumy, SumDU has developed a strongly international character, welcoming students and scholars from around the world and sustaining academic partnerships across nearly fifty countries. Its teaching reaches across the natural and engineering sciences, medicine, and the humanities, and is matched by a vibrant research culture; the university is recognized in the QS World University Rankings for its research intensity. Through times of real adversity, SumDU has continued to teach, to discover, and to look outward to the global academic community, and it remains a proud co-organizer of the IEEE NAP Conference.

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Best Paper Awards

1. Rajdeep Banerjee, Subhamay Pramanik, Samik Mallik et al., Indian Institute of Technology Kharagpur, India. *"Short-Wave Infrared Black Phosphorus Phototransistor with High Responsivity"*
2. Iryna Sotnyk, Oleksandr Prokopenko, Taras Shevchenko National University of Kyiv, Ukraine. *"Symbol Recognition Using a Multi-Input Programmable Artificial 'Neuron' Based on a Josephson-like Antiferromagnetic Spin Hall Oscillator"*
3. Jiyong Kim, Manuel Gensler, Adam Luczak et al., Fraunhofer IAP, Germany; Lodz University of Technology, Poland; KETI, Republic of Korea. *"Synthesis of ZnO Nanoparticles with Zinc Acrylate and/or Zinc Acetate Ligands for Stable and Bright Quantum-Dot Light-Emitting Diodes"*

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Plenary Lectures

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PL-1 PLENARY

Composition - structure - property relationships in MXenes

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Since their discovery 15 years ago, MXenes, a large family of two-dimensional (2D) transition metal carbides, nitrides, and carbonitrides, have expanded the landscape of nanomaterials science. With over 100 synthesized compositions to date, the rapid growth of the MXene family is driven by designer chemistry control of their composition and structures, including the transition metals, non-metal X sublattice, surface functional groups, and atomic-layer configurations. This large compositional and structural space enables systematic tuning of electronic structure, chemical ordering, defects, surface chemistry, and functional properties. In addition to their chemical and structural diversity, MXenes are known for their high electrical conductivity, hydrophilicity, solution processability, and mechanical robustness, making them attractive for a broad range of applications in nanotechnology.

In this talk, I will discuss how composition and structure govern the properties of MXenes across different length scales. I will present our recent efforts on compositionally complex MXenes, including medium- and high-entropy systems with up to nine transition metals, and discuss how entropy drives transitions from ordered to disordered structures at sub-nanometer thicknesses. I will also discuss how atomic-level defect engineering, including control of vacancies, substitutional defects, and surface chemistry, enables tuning of properties such as electrocatalytic behavior, electrical conductivity, oxidation resistance, and high-temperature stability. Together, these studies demonstrate how compositional and structural control can be used to design MXenes with targeted functionalities.

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PLENARY SPEAKER

Babak Anasori

Dr. Babak Anasori is the Reilly Rising Star Associate Professor at Purdue University, with joint appointments in the Schools of Materials Engineering and Mechanical Engineering. He also serves as the Editor-in-Chief of Graphene and 2D Materials, a Springer-Nature journal. Dr. Anasori received his PhD from Drexel University in 2014 in the Department of Materials Science and Engineering, the birthplace of MXenes. He has authored over 210 refereed publications on MXenes and their precursors and has been a Web of Science Highly Cited Researcher since 2019. His awards include the 2016 MRS Postdoctoral Award, the 2021 Drexel 40-under-40, the 2021 Waterloo Institute for Nanotechnology Rising Star Award, the 2024 ACerS Early Discovery Award, the 2024 Kavli Foundation Early Career Lectureship in Materials Science (MRS), and the 2026 Purdue Faculty Excellence Award for Early Career Research. His lab develops novel 2D carbide and carbonitride MXenes for energy generation, electromagnetic interference shielding, and ultra-high-temperature and extreme environments.

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PL-2 PLENARY

Tuning perovskite nanoparticles through surface modification

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Perovskite solar cells have emerged as promising candidates for next-generation photovoltaics, demonstrating remarkable advances in both efficiency and cost-effectiveness. Surface modification is a valuable materials engineering strategy employed to address structural imperfections, passivate electronic defects, and align energy levels in perovskite solar cells. This approach becomes even more critical when incorporating perovskite zero-dimensional quantum dots into three-dimensional films, as it helps to heal surface imperfections and improve the overall topography.

Modifiers with specific dipole moments can create hybrid composites in these nanostructured three-dimensional films, combining the electronic properties of semiconductors with the localized characteristics of the organic modifier. This hybridization can tune the work function and establish a smoother energy pathway for electrons or holes to transition into the transporting layers. Applying self-assembled organic molecule monolayers and quantum dots can significantly reduce charge recombination and enhance both efficiency and long-term device stability. Additionally, hydrophobic molecular layers can protect the highly moisture-sensitive perovskite crystal from degradation in ambient conditions.

In our research, we demonstrate that surface modification of perovskite zero-dimensional quantum dots with perylene modifiers can enhance the electron-transfer properties of high-work-function perovskites ($FAPbI_3$) towards perylene (N,N′-Bis(2,5-di-tert-butylphenyl)-3,4,9,10-perylene dicarboximide, PDC). This enables perylene to effectively function as an electron-transporting layer, potentially replacing fullerenes as electron carriers in perovskite solar cells. Furthermore, perovskite quantum dots with suitable band gap properties and lower work functions and similar structures ($FAPbBr_3$), can undergo energy transfer with the same perylene PDC, making them ideal materials for Perovskite Light-Emitting Diodes (PeLEDs), leading to new technology that has the potential to revolutionize displays and lighting solutions by offering high efficiency, bandwidth, color purity, and low-cost fabrication methods.

PLENARY SPEAKER

Tijana Rajh

Tijana Rajh has extensive experience in the synthesis and study of colloidal semiconductor nanocrystals and their integration into hierarchical assembly. She conducted some of the earliest research on quantum dots, a field that has since grown enormously. Her early studies involved electron-transfer reactions and photoelectrochemistry of colloidal semiconductors and quantum dots, solar energy conversion into chemical fuels, and surface modification of nanocrystalline TiO_2 nanoparticles for light-induced chemistries. She developed methods for seamless electronic integration of chelating ligands and colloidal semiconductors, applied magnetic-resonance techniques to study spin effects in photoinduced electron transfer, and proposed early methods to initiate reactions between semiconductor nanoparticles and biomolecules such as DNA strands and antibodies. Her current work focuses on self-adapting nanostructures for energy transduction, conversion and storage, and hybrid systems for sensing of biomolecules, including quantum qubits.

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PL-3 PLENARY

Structure control of metal clusters and their application in energy and environmental catalysts

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In order to build a sustainable society, it is indispensable to create new innovative materials that can solve the problems of the current society. Strict control of the structure of materials at the nanoscale is expected to lead to the creation of such materials. Ultrafine metal clusters, in which several to several dozen metal atoms are aggregated, have novel electronic/geometric structures and physicochemical properties/functions that are different from those of bulk metals composed of the same elements. In addition, doping (alloying) of different elements to these metal clusters results in a variety of structures, properties, and functions. Thus, metal clusters have high potential as constituent units for innovative materials. However, in order to understand the functions of metal clusters and to apply them as materials, it is essential to establish techniques to strictly control the chemical composition and geometric structure of metal clusters. We have established several techniques to strictly control the chemical composition and geometric structure of metal clusters. We also succeeded in establishing a method to control the supported metal clusters to enhance the functionality of advanced water splitting photocatalysts, fuel cell electrocatalysts, and automotive exhaust gas purifying catalysts. Accordingly, we have achieved the highest water-splitting activity for UV-responsive $BaLa_4Ti_4O_{15}$ water-splitting photocatalysts, created platinum electrocatalysts with higher catalytic activity for oxygen reduction than those currently used in fuel cells, and succeeded in developing highly functional catalysts for automotive exhaust gas purification. These our research is unique in that it consistently achieves the atomic-level control of the metal clusters throughout the entire research, from synthesis to control on the support. This presentation summarizes our recent works concerning these topics[1-5].

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PLENARY SPEAKER

Yuichi Negishi

Yuichi Negishi is a Professor at the Institute of Multidisciplinary Research for Advanced Materials (IMRAM), Tohoku University, in Sendai, Japan. He has studied metal nanoclusters since 1995, beginning with gas-phase clusters and the systematic isolation of glutathionate-protected gold nanoclusters, and developing precise techniques for controlling the size and structure of ligand-protected metal clusters. His current research applies these atomically precise clusters to the design of highly functional catalysts for energy and environmental applications. His honors include the PCCP Prize for Outstanding Achievement of Young Chemists in Physical Chemistry and the Best Young Presenter Award of the Society of Nano Science and Technology.

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PL-4 PLENARY

Physicist in the Kitchen: exploring the gastronomic universe

Andrey Varlamov[1, 2]

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What governs the propagation of heat in food? Why does pizza baked in a traditional wood-fired oven taste different from one cooked in an electric oven? Why are boiled and grilled meats so distinct in flavor and texture? Can we scientifically determine the optimal cooking time for a soft-boiled duck egg or for spaghetti?

This lecture explores these and many other fascinating questions at the intersection of physics and gastronomy. We will discover why spaghetti usually breaks into three pieces rather than two, and how it can be made to snap in two; why a toast with crystal glasses filled with sparkling wine often lacks the expected resonant chime; why vodka typically contains about 40% alcohol; and why professional baristas adjust the grind size of coffee beans according to the weather.

By applying the principles of heat transfer, fluid dynamics, elasticity, acoustics, and thermodynamics to everyday culinary experiences, the lecture reveals the hidden physics behind the food we cook, eat, and enjoy. A journey through the gastronomic universe, viewed through the lens of a physicist.

PLENARY SPEAKER

Andrey Varlamov

Andrey Varlamov is a principal investigator at the Institute of Superconductivity, Innovative Materials and Devices of the Italian National Research Council (CNR-SPIN). Born in Kyiv, he earned his PhD in condensed-matter physics in 1980 under Alex Abrikosov, later held professorships in Moscow and a fellowship at Argonne National Laboratory, and joined CNR in 1999. His research spans superconductivity, the theory of metals and phase transitions, thermoelectricity, and nanophysics; he co-authored the monograph "Theory of Fluctuations in Superconductors" with Anatoly Larkin and has published more than 200 papers. He received the USSR State Prize in Physics (1986) and the Bogolyubov Prize (2018), and his popular-science book "The Wonders of Physics" has appeared in sixteen editions and eight languages.

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Track 1

Nanomaterials Synthesis and Design

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T1-01 INVITED

Cohesive energy model for nanostructure formation on metal surfaces induced by slow highly charged ions

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Slow highly charged ions (HCI) interacting with solid surfaces induce nanoscale modifications producing either hillocks or craters, depending on their potential and kinetic energy, as well as collision geometry [1]. Understanding these mechanisms is essential for advancing next-generation electronic and optoelectronic devices and controlled defect engineering.

In this contribution, I present a two-step cohesive energy model (CEM) predicting the formation of specific nanostructures by linking deposited energy to the resulting surface modification [2]. HCIs carry a substantial amount of potential energy, a portion of which is released as neutralisation energy upon neutralisation at the surface. Beneath the surface, the projectile slows down via interactions with atomic and electronic subsystems. The combined effect of kinetic energy loss and neutralisation energy, controlled by the critical ion velocity, determines the total energy deposited within a near-surface region.

The resulting nanostructure reflects the dominant contribution: hillocks and craters are associated with the neutralisation and kinetic energy dominance, respectively, while their coexistence occurs at the critical ion velocity. Varying the incidence angle reveals the existence of two energy regimes [2]: at low velocities, the process is driven by the critical ion velocity, whereas at higher velocities, the total deposited energy becomes the key parameter. In both regimes, decreasing the incidence angle enhances both energy contributions, resulting in higher total energy deposition, increasing the probability of crater formation. These predictions are consistent with experimental observations for highly charged Xe ions on titanium and gold surfaces, as well as with electron-yield data [3,4]. Using different ions highlights the role of core polarisation in surface modification. Stronger polarisation increases total deposited energy, favouring crater formation [5].

The results show that desired nanostructures can be intentionally created by tuning ion charge state, velocity, and incidence angle, providing a framework for controlled nanostructuring of metal surfaces.

KEYWORDS: Highly charged ions, Metal surface, Collision geometry, Surface nanostructure, Velocity effect

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T1-02 INVITED

New insights into synthesis of inorganic nanotubes - solving the enigma of more than two decades of research

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The breakthrough, enabled the reproducible one-pot synthesis of MoS_2 nanotubes (NTs) from molybdenum oxide via vapor-gas-solid (VGS) reaction, solved a two-decade enigma [1]. However, the reported process left some unresolved issues, such as how to increase the NT yield mixed with platelets beyond 30-40% and how to exclude defect-rich NTs. Here, I will report the successful completion of the first task by synthesizing phase-pure (100% yield) 1D MoS_2 nanotubes [2]. This progress was achieved through the development of a new synthesis for high-aspect-ratio MoO_3 nanowhiskers, the precursor for NTs production, and through careful study of the NTs' growth mechanism and the properties of the intermediate products of this multistep reaction. The synthesis of MoO_3 nanowhiskers was performed separately via a wet-chemistry process. Subsequently, the whiskers were served as a template for the preparation of nanotubes via a high-temperature, reduction/ sulfurization solid-gas reaction. The second task, synthesis of perfectly crystalline NTs was also achieved [2]. Perfectly crystalline NTs are well suited for electro-optical and electromechanical applications [3,4]. In parallel, it was discovered that defect-rich NTs, which have a high surface density of active sites and were initially considered unwanted, demonstrate superior performance as electrocatalysts for the hydrogen evolution reaction (HER) compared to perfectly crystalline NTs [5]. Therefore, our synthesis provides two types of NTs, perfectly crystalline and defect-rich, prepared under different conditions and in a controlled manner. To support advances in NT production and characterization, we sought for a deeper theoretical insight into the structural features of nanotubes, such as hollow core formation and interlayer distance discrepancies. Thus, the formation energy of the nanotubes was calculated from curvature strain, deformation and van der Waals energies, and the mechanism for changes in interlayer spacing was proposed. More specifically, optimizing the van der Waals interactions between incommensurately neighboring layers of the NTs via relaxation requires their expansion or contraction, thereby causing additional deformation within the layers. Thus, the interplay of all three energies influences the layer diameters and, thereby, the interlayer spacing. By integrating experiment and theory, we step forward toward broadening the application-oriented integration of MoS_2 NTs into devices

KEYWORDS: MoS 2, MoO 3, Perfect crystallinity, Defect-rich surface, Hydrogen evolution reaction

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T1-03 INVITED

Hexatic phase in covalent two- dimensional silver iodide

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In three-dimensional crystals, first-order phase transitions are characterized by discontinuous changes in thermodynamic quantities accompanied by the loss of crystal symmetries. In contrast, Kosterlitz- Thouless- Halperin- Nelson- Young (KTHNY) theory predicts that, in two dimensional crystals, the transition from a solid to liquid proceeds through an orientationally ordered "hexatic" phase in a continuous regime. However, some experimental observations suggest alternative, mixed melting scenarios, in which melting proceeds starting through the continuous hexatic phase, followed by discontinuous transitions.

Here we study a phase transition of two dimensional covalently bonded crystal of silver iodide embedded in multilayer graphene using scanning transmission electron microscopy (STEM) with atomic resolution and nanobeam electron diffraction. During heating up to 1200 ^{o}C, our in-situ time and temperature resolved measurements provide evidence for progressive formation of the hexatic phase approximately 25 ^{o}C below a sudden transition to the liquid phase, supporting the mixed melting scenario [1].

KEYWORDS: Two dimensional phase transitions, 2D silver iodide, Graphene, Hexatic phase, Transition scanning electron microscopy

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T1-04 INVITED

First-principles investigation of defects in hexagonal-diamond silicon

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Recent progress in the synthesis and characterization of hexagonal-diamond silicon (2H-Si) in the form of nanowires [1] has highlighted its distinct structural, electronic, and optical properties compared to the conventional cubic-diamond (3C-Si) phase. While the physical properties of 2H-Si have been widely investigated, the role of impurities in this phase remains largely unexplored, particularly in the high-doping regime. In this work, we present results from density functional theory (DFT) simulations examining the effects of substitutional doping in 2H-Si and comparing them with those in the 3C phase.

We analyze both p-type and n-type dopants, exploring their behavior in neutral and charged states [2,3]. Our simulations reveal that impurities in 2H-Si adopt different local symmetries compared to those in 3C-Si, reflecting the influence of the host crystal structure. For acceptors, we find that 2H-Si exhibits lower formation energies and shallower charge transition levels than the cubic phase, making p-type doping more favorable in the hexagonal structure. Conversely, n-type dopants show lower formation energies and transition levels in 3C-Si, suggesting more efficient electron activation in the cubic phase. These trends persist even in the ultra-high doping regime [4].

Building on these insights, we employ a band-offset diagram for the 2H and 3C polytypes to propose a model in which hole doping can energetically stabilize the 2H phase. This provides a potential strategy for phase engineering via carrier injection [3]. These findings also lay the groundwork for understanding dopant interactions with stacking faults in 2H-Si [5].

Overall, this work provides new insight into doping behavior in non-cubic group-IV nanostructures, which is essential for enabling 2H-Si applications in future optoelectronic and quantum devices.

KEYWORDS: Defects, Hexagonal-diamond silicon, Semiconductor, DFT, Ab initio

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T1-05 ORAL

Tuning electrochemical synthesis parameters to create porous oxide layers with complex channel structures

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Anodic oxidation (anodization) is a widely used method for producing nanostructured metal oxides. Anodic Aluminum Oxide (AAO), formed in this process, is broadly applied due to the ability to precisely control its morphology through electrochemical parameters such as voltage and electrolyte type. Process modifications, including lowering the applied voltage or using phosphoric acid-based electrolytes at relatively low voltages, enable the formation of oxide layers with complex channel geometries, such as Y-shaped[1,2] or serrated pores. The choice of electrolyte also significantly influences the optical properties of both the AAO layer and the underlying aluminum surface. Anodization in organic acids (e.g., malic, citric, or etidronic acid) results in oxide layers with rainbow-like coloration, while phosphoric acid produces milky films. Additionally, pore ordering can be tuned by employing mixtures of different acids[3].

This work discusses the selection of anodization conditions for obtaining AAO layers with complex channel geometries, particularly Y-shaped and serrated structures. AAO was fabricated on aluminum foil using various acid solutions and water-alcohol mixtures as electrolytes. Results show that combining different acids, along with adjustments in voltage and hydrodynamic conditions, enables the formation of channels with complex geometries. The development of nanostructured surface topography on aluminum during anodization is also addressed.

KEYWORDS: Anodization, Anodic alumina, Nanoporous layers, Channels with complex geometries

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T1-06 ORAL

High-performance arsenic-free selector-only memory enabled by trap-state engineering in Sb-doped Ge_2Se_3

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Next-generation storage-class memory (SCM) requires high density and low power consumption. Selector-only memory (SOM) is a leading candidate because it integrates both selector and memory functions into a single chalcogenide layer, enabling highly scalable and multi-stackable 3D crossbar arrays. However, most SOM materials rely on toxic arsenic (As), which limits their use in large-scale semiconductor manufacturing. To overcome this, we developed an As-free Sb-doped Ge_2Se_3 SOM device that is both environmentally friendly and CMOS-compatible.

The devices were fabricated using an industry-compatible co-sputtering process. Our core strategy focuses on trap-state engineering rather than simple composition tuning. By systematically varying the Sb concentration (0 to 21 at%), we identified 16 at.% Sb as the optimal doping level. This strategic doping modifies the local Ge-Se bonding network to create optimized shallow trap states. This engineered environment stabilizes hole transport and field-induced threshold switching, resulting in a significantly more reliable switching operation. Structural analyses using TEM, XRD, and XPS confirm that Sb doping enhances the thermal and physical stability of the amorphous phase. Specifically, Sb suppresses structural relaxation at temperatures up to 350°C, which is directly linked to improved endurance and reduced threshold voltage (Vth) drift. We also observed that excessive doping (>21 at.%) leads to the formation of Sb clusters. These nanoclusters cause carrier scattering and degrade transport symmetry, proving that precise nanoscale control of Sb concentration is critical for performance.

The optimized 16 at.% Sb-doped SOM device achieved outstanding electrical characteristics: a wide memory window (MW) of 2.3 V, an ultra-low leakage current of ~20 nA, and superior Vth stability. These results demonstrate a significant improvement over undoped Ge_2Se_3 devices in terms of power efficiency and operational reliability. This study confirms that trap-state engineering in As-free chalcogenides is a highly effective and scalable path for the next generation of high-density 3D data storage solutions.

KEYWORDS: Selector-Only memory (SOM), As-free, Trap-state engineering, Sb-doped Ge2Se3, 3D crossbar array

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T1-07 ORAL REMOTE

First principle study of spontaneous polarization due to Co and V substitution in wurtzite AlN

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Spontaneous polarization is an emerging area in modern electronics owing to its application in various fields especially in high speed transistor operations. Ferroelectric materials exhibit spontaneous polarization due to spatial displacement between centers of positive and negative charges. Often spontaneous polarization is linked to piezoelectricity due to its sensitive dependency on mechanical stress and temperature[1] making these materials useful for acoustics and various actuators as well. While most ferroelectic materials are perovskite oxides, recently wurtzite related materials like YbAlN[2] and ScAlN[3] have been also emerging as viable alternatives. This paper investigates the spontaneous polarization of wurtzite Aluminium Nitride (AlN) structures substituted with transition metals Cobalt and Vanadium using first-principles calculations. Five structures were chosen for each metal at substitution concentrations of 25% and 50%. Peak spontaneous polarization of 0.216 C/m^2 and 0.271 C/m^2 were achieved at 25% substitution of Vanadium and 50% substitution of Cobalt in wurtzite AlN respectively. This depicts a substantial enhancement compared to the calculated value of -0.1229 C/m^2 for pristine AlN[4]. This has been mainly achieved through the distortions of the lattice structure and the changes in the bond length between metal and nitrogen atoms along the c-axis[5]. The negative value of the total energy obtained for all these structures is an indication of their stability. This makes V and Co-substituted Aluminum Nitride a potential substitute for polarization purposes, especially in the production of GaN HEMT, FeFET, and RF filters.

KEYWORDS: CoAlN, VAlN, First-principles calculation, Spontaneous polarization, High-electron-mobility transistors

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T1-08 ORAL

From nanoscale polymer chain dynamics to dielectric response: DMA-tuned pH-responsive hydrogels

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pH-responsive hydrogels have attracted significant interest for implantable sensory systems due to their ability to undergo substantial water uptake and to exhibit tunable swelling responses to environmental stimuli, leading to detectable changes in their physicochemical properties [1]. Acrylamide and acrylic acid (AAm-AAc) based hydrogels exhibit swelling behavior moderated by the ionization of carboxylic groups, enabling tuneable response to environmental pH stimuli [1]. Additionally, swelling, mechanical properties, and transport characteristics of hydrogels can be effectively tuned through monomer composition and network structure [2]. However, for dielectric based sensing applications, the high water content of such systems can limit signal contrast with the surrounding biological environment, as the dielectric response is largely governed by water dipole polarization, thereby suppressing nanoscale contributions arising from polymer chain conformation and network structure, which require molecular-level analysis to be resolved.

In this study, we investigate the effects of incorporating N,N-dimethylacrylamide (DMA) as a non-ionic comonomer on the swelling behavior, dielectric, and mechanical properties of P(AAm-co-AAc-co-PEGDA) matrix. A combined experimental and computational approach is employed, in which molecular-level conformational changes in the polymer network are analyzed using LAMMPS simulations to estimate the radius of gyration (Rg), enabling correlation between nanoscale chain behavior and macroscopic swelling response. Hydrogels were synthesized via free-radical polymerization and characterized by pH-dependent swelling, mechanical testing, and permittivity measurements. Three formulations were prepared: (1) AAm/AAc = 90/10, (2) AAm/AAc/DMA = 89/10/1, and (3) 80/10/10 mol%.

For mechanical tests and permittivity readings, a new synthesis protocol is developed to produce homogeneous thin layers 1.5mm thick, allowing direct rheological characterization. Rheological analysis revealed that the mechanical properties of AAm-AAc based hydrogels decrease with increasing DMA concentration. Formulations (1) and (3) exhibited relatively consistent storage modulus values of approximately 17,000 Pa and 11,000 Pa, respectively, whereas formulation (2) showed more variable values in the range of 13,000-15,000 Pa. This variability is attributed to the insufficient DMA content, which likely led to inhomogeneous dispersion within the polymer network.

Swelling analysis showed that the overall swelling capacity of AAm-AAc-based hydrogels decreases with increasing DMA concentration, without affecting the pH-dependent swelling behavior of the system. These experimental findings are qualitatively supported by LAMMPS-based nanoscale molecular simulations, which indicate reduced polymer chain expansion with increasing DMA content, as reflected by decreased Rg values.

KEYWORDS: PH-responsive hydrogels, Nanoscale chain dynamics, Dielectric properties

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T1-09 ORAL REMOTE

Spark ablation of Cu(x)O nanoparticles: size and phase control

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Copper oxide nanoparticles Cu(x)O have attracted significant interest due to their catalytic, antimicrobial, and electronic functionalities. At the nanoscale, these materials exhibit increased surface activity along with tunable optical and electrical characteristics, which makes them highly suitable for use in environmental, sensing, energy-related applications, and biomedical applications [1]. A key challenge remains the precise regulation of particle size, phase composition, and aggregation state in order to optimize performance while ensuring sustainable synthesis routes.

In this work, a completely dry spark ablation technique is utilized to synthesize Cu(x)O nanoparticles directly from copper electrodes, without chemical precursors or solvents [2]. Each electrical discharge vaporizes a small volume of copper, which is then rapidly cooled in a nitrogen carrier gas, forming a continuous aerosol of nanoparticles typically in the range of 2-20 nm. By adjusting parameters such as carrier gas flow rate and ablation time, the study investigates their impact on particle nucleation, growth mechanisms, spatial distribution of clusters on the substrate, and agglomeration dynamics.

The nanoparticles are systematically characterized using complementary analytical techniques to elucidate their structure and composition. Scanning Electron Microscopy coupled with Energy Dispersive Spectroscopy (SEM-EDS) is employed to examine particle morphology and elemental composition. Raman spectroscopy and transmission electron microscopy (TEM), supported by selected area electron diffraction (SAED), are used to identify copper oxide phases through vibrational signatures and crystallographic analysis, respectively, while enabling the distinction between Cu_xO phases.

The findings highlight that spark ablation represents a fast, controllable, and eco-friendly approach for producing Cu(x)O nanoparticles with adjustable size, aggregation characteristics, and phase composition. The precursor-free nature of the method, together with precise parameter control, establishes this method as a sustainable and efficient route for fabricating copper oxide nanomaterials applicable across diverse technological and biomedical fields.

KEYWORDS: Spark ablation, Copper oxide nanoparticles, Size control, Phase control, Aerosol synthesis

ACKNOWLEDGEMENTS: Spark ablation, Copper oxide nanoparticles, Dry synthesis, Size and phase control

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T1-10 ORAL

Green-synthesized copper nanoparticles for functional latent fingerprint visualization: A nanomaterials approach

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Fingerprints represent one of the most reliable and persuasive sources of forensic investigations. Development of such latent prints has long depended upon the use of powders and chemicals effective as these, but which all too frequently necessitate the consideration of the issue of toxicity, cost, and environmental consequence [1]. Forensic nanotechnology has become a promising solution to address these issues. The unique physicochemical characteristics and high surface area-to-volume ratio of nanoparticles enable improved selectivity and sensitivity for latent fingerprint detection [2]. Plant-based green synthesis methods produce nanoparticles that have gained interest for their lower toxicity levels, cost efficiency, biodegradability and ability to meet sustainable forensic science objectives [3].

The aim of our present research is to develop a sustainable solution to biosynthesize copper nanoparticles (CuNPs) with the use of the natural, ubiquitous waste material, mandarin peel. Mandarin peels abound with phytochemicals such as flavonoids, polyphenols, essential oils, as well as organic acids. Such phytochemicals fulfil two functions in our biosynthesis, they act as natural reducing agents to synthesize the copper ions into the nanoparticle form, as well as stabilizing agents to inhibit agglomerations in the particles. We used copper (II) chloride dehydrate as a metal precursor and mixed it with mandarin peel powder in controlled environment conditions to successfully produce viable copper-based nanoparticles (CuNPs). The process is not only chemically non-toxic, but it also recycles organic waste, consistent with the green chemistry principles. CuNPs synthesized were then primarily characterized through Dynamic Light Scattering (DLS) and UV-Vis spectroscopy, confirming the production of nano-scaled particles with good dispersibility. The average particle size determined by DLS is around 35-40 nm.

The use of CuNPs showed high affinity with the fingerprint residue-made primarily from sweat, amino acids, as well as naturally excreted human skin oil in the development of latent prints in both porous (paper) and non-porous surfaces (metal knife). The results of the present research demonstrate notable visualization of latent fingerprint development as compared to traditional black powder. This process enhanced the contrast of the details in the ridges to yield high-contrast prints. The green method reduces chemical waste and health hazards found in standard approaches by providing an affordable, sustainable solution for nanomaterial production. Further studies will evaluate the function of biosynthesized CuNPs across different surfaces in terms of sensitivity and stability.

KEYWORDS: Advanced nanomaterials, Green synthesis, Forensic nanotechnology application, Latent fingerprint detection, Nanotechnology in life sciences

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T1-11 ORAL

Plasma-assisted synthesis of PLA-derived nanoparticles with tunable structure

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This work introduces a dry physical approach for the synthesis of polymer-derived nanoparticles from a poly(lactic acid) (PLA) precursor using a gas aggregation source (GAS) combined with plasma-assisted vacuum thermal deposition (PAVTD). In this filament-fed system, a polymeric filament is continuously supplied and thermally evaporated into the aggregation chamber. Unlike magnetron sputtering or plasma-enhanced chemical vapor deposition (PECVD), this approach enables nanoparticle formation from polymer-like fragments, allowing partial preservation of the original polymer structure. Vaporized species undergo fragmentation and repolymerization under plasma conditions, forming nanoparticles that are subsequently transported through an orifice for deposition.

The structure of the nanoparticles is strongly influenced by deposition parameters. Preliminary results indicate that increasing plasma power leads to a progressive loss of the original PLA backbone and promotes the formation of more cross-linked plasma-polymer nanostructures. These structural and chemical changes are characterized using SEM, XPS, FTIR, NMR, and GPC.

The integration of continuous filament feeding, together with feedback control of the evaporation rate, improves process stability and reproducibility compared to conventional PAVTD approaches. The presented method offers a promising route for the controlled synthesis of polymer-based nanoparticles with tunable chemical structure.

KEYWORDS: Plasma-Assisted deposition, Plasma-polymers, Gas aggregation source

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T1-12 ORAL

Carbon dots from torrefied wheat bran obtained by NaOH exfoliation - properties, calcium modification and fluorescence detection

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Carbon dots (CDs) are versatile 0D carbon nanostructures whose optical properties strongly depends on the core structure and surface chemistry. They are promising fluorescent nanomaterials; however, sustainable synthesis routes are still needed. Here, we present a modified top-down method to produce CDs from wheat bran by combining mild pyrolysis (220-400°C, 10-60 min) with aqueous NaOH exfoliation, followed by neutralization and multistage purification (filtration and dialysis). The influence of thermal treatment on structure and optical properties was assessed using FT-IR, XRD, and HR-TEM, together with UV-Vis and fluorescence spectroscopy. We investigated correlations between processing conditions, nanostructure, and photoluminescence. CDs obtained at 400°C for 60 min (WB-400-60) were highly crystalline and showed a narrow size distribution (~2.7 nm). They exhibited a fluorescence quantum yield of 17.1% at an excitation wavelength of 290 nm. The UV emission was stable, with an emission maximum at ~334 nm upon excitation in the 250-300 nm range. Calcium acetate modification (WB-400-60-Ca) changed the fluorescence characteristics: the excitation maximum shifted (from 290 to 310 nm) and the excitation-independent emission range broadened (to ~250-350 nm), with an emission maximum at ~410 nm. The CDs were evaluated as fluorescent probes, and optical detection was based on fluorescence quenching. The WB-400-60 CDs were used for the determination of Fe^{2+} (0.5-50 µM; LOD 74.1 nM), chloridazon (0.01-10 mg/L; LOD 0.35 µM), and paracetamol (1-40 mg/L; LOD 0.5 µM). These results confirm that waste biomass such as wheat bran is a viable precursor for functional CDs and that metal-ion modification can be used to alter their optical response; future work will focus on more controlled modification with metal cations to further tune emission and selectivity.

KEYWORDS: Carbon dots, Chemical exfoliation, Biomass-derived nanomaterials, Calcium modification, Optical detection

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T1-13 ORAL REMOTE

Squid cartilage-derived carbon quantum dots for selective fluorescence sensing of hexavalent chromium in water

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The detection of hexavalent chromium in water remains a significant analytical challenge due to its high toxicity, widespread industrial origin and high solubility, which facilitates rapid dispersion in aquatic systems. In the present study, carbon quantum dots (CQDs) were synthesized through a hydrothermal process using squid cartilage derived from Uroteuthis duvaucelii. This marine biowaste material has not been previously explored for such applications. The resulting squid cartilage-derived CQDs (SC-CQDs) exhibit an average particle size of 4.28 nm and are readily dispersible in aqueous media. Microscopic and spectroscopic characterisations reveal the formation of nanoscale carbon frameworks enriched with oxygenated surface functionalities, which play a crucial role in the observed optical behaviour. The SC-CQDs exhibit excitation-dependent photoluminescence, along with a measurable dependence on solution pH, indicating the contribution of surface states to their emission. Their sensing performance of SC-CQDs was systematically evaluated against various metal ions, among which Cr(VI) induced a pronounced selective quenching of fluorescence intensity. A concentration-dependent response was obtained, yielding a limit of detection of 5.4 µM. Although the sensing performance does not surpass that of highly sophisticated analytical platforms, the simplicity of synthesis, low material cost, and operational ease render the SC-CQDs particularly suitable for preliminary monitoring of chromium contamination in resource-limited and minimally equipped settings. Overall, this study demonstrates the viability of SC-CQDs as sustainable and efficient fluorometric probes for chromium detection in aqueous environments.

KEYWORDS: Carbon quantum dots, Squid cartilage (Uroteuthis duvaucelii), Hydrothermal synthesis, Photoluminescence quenching, Hexavalent chromium (Cr(VI)) sensing

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Posters

T1-14 E-POSTER

Synthesis and characterization of $EuFeO_3$ nanopowders with a perovskite-type structure

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Orthoferrites of rare-earth elements $RFeO_3$ (R = rare-earth ion) have been the subject of intensive research due to their electrical and magnetic properties, which are determined by the interaction between spin, orbital, and crystal-chemical degrees of freedom. $RFeO_3$ also exhibits high thermal stability and electrical conductivity, low dielectric losses, high dielectric permittivity, ferroelectricity, polarizability, etc. [1-2].

The nanocomposites were obtained by the Pechini method and the heterogeneous precipitation method. Solutions of $Eu3^+$ nitrates, obtained by dissolving europium oxides with a main-component content of 99.99% in nitric acid, were used as starting materials. Mixtures with different $Fe3^+$ contents were prepared from nitrate solutions. The obtained precursor was dried at 120 °C for 24 hours and then subjected to heat treatment at 800 °C. The characteristics of the samples were determined using physicochemical methods: X-ray diffraction (XRD), thermogravimetric (TG) and differential thermal (DTA) analysis, and electron microscopy. The nanocomposites were identified as having a perovskite-type structure. The XRD patterns do not show any other peaks corresponding to Eu, Fe, Eu_2O_3, Fe_2O_3, or any other additional impurity-related phases. According to SEM, the synthesized powders have a conglomerate structure. $EuFeO_3$ exhibits a granular nanocrystalline microstructure composed of nearly isometric, rounded particles with typical sizes of 60-125 nm.

The $EuFeO_3$ samples, characterized by a predominantly isometric granular microstructure and dense nanoparticle agglomeration, exhibit relatively low specific surface areas of 2.49 and 7.61 mZ/g. This morphology results in a compact structure, which is reflected in lower densities of 6.46 and 6.87 g/cm3. The negative ζ-potential value of −14 mV indicates limited electrostatic stability of the particles in the dispersed medium and their tendency toward agglomeration, which is consistent with the observed compact microstructure.

KEYWORDS: $EuFeO_3$ nanopowders, Orthoferrites, Perovskite structure, Pechini method, Rare-earth ferrites

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T1-15 POSTER

Photocatalytic activity of the heterostructures based on CeO_2-La_2O_3-Dy_2O_3 fluorite and anatase

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Today, progress in the development of photocatalytic materials for 'green' technologies and environmental protection is focused on improving the optical properties of semiconductor oxides and creating composite structures based on them. One effective strategy for improving the optical characteristics of titanium dioxide is to create heterostructures based on it by introducing cerium dioxide and other rare-earth elements into its composition, which can contribute both to improving the photocatalytic activity of the photocatalyst and to increasing its stability in aggressive environments and extending its service life. In our study, a new heterostructure based on cerium, lanthanum, and dysprosium was created, with an anatase component (CSR = 11.5 nm). The heterostructures were formed by mechanosynthesis, followed by thermal treatment of the powder to ensure heterojunctions between the components of the nanocomposite system.

The photocatalytic activity of the samples was tested using solutions of methylene blue (MB), rhodamine B (RhB), methyl orange (MO), and orange G (OG) with initial dye concentrations of 20 mg/dm3. The experiments and calculations of the parameters were carried out according to standard methods. The data obtained show that the presence of dysprosium in the structure of the samples inhibits the photocatalytic decomposition of cationic dyes, whereas in the presence of CeO_2 (95 mol.%)-La_2O_3 (5 mol.%)-TiO_2 particles, photodegradation of MB and RhB occurs. At the same time, the molecules of the anionic dyes OG and MO interact intensively with the surface of the heterostructures and decompose over time. The reaction rate constants are in the range of $10^{-}3$ to 10^{-4}. Thus, the introduction of a titanium-containing component allows the activity of the rare-earth fluorite to be shifted from the visible light region to the UV region.

KEYWORDS: Photocatalysis, TiO_2 heterostructures, Cerium dioxide, Rare-earth oxides, Semiconductor oxides

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T1-16 E-POSTER

Quinoline derivatives as fluorescent probes for zinc determination in living cells

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Ca^{2+}, Mg^{2+}, and Zn^{2+} are the most abundant divalent cations in the body. 8-Hydroxyquinoline (8HQ) are known for its wide range of optical, chemical properties and biological effects. Cation chelation is an important feature of these compounds in the creation of biologically active substances. Metal complexes of 8HQ exhibit antibacterial and antiproliferative activity. 8HQ derivatives possess favorable photophysical and coordination properties for developing fluorescent metal sensors. N-(6-methoxy-8-quinolinyl)-4methylenebenzenesulfona mide (TSQ) is well known as a fluorescent indicator of intracellular zinc. The aim was to determine the possibilities of chelation of calcium, magnesium and zinc by (8HQ) derivatives 2-(4-methoxystyryl)quinolin-8-ol (STQ-Me), 2-(4-ethoxyphenylethenyl) quinolin-8-ol (STQ-Et) and 2-(4-(trifluoromethyl)styryl)quinolin-8-ol (STQ-CF_3) based on physiological solution. The potential of this substance for studying dynamic changes in intracellular zinc was tested in comparison with the TSQ. The cytotoxicity and fluorescence of test molecules in living cells in the presence of cations was investigated.

To assess the potential use of 8HQ derivatives as fluorescent indicators for zinc detection, a model involving loading KB cells with ZnO nanoparticles (NPs) was selected. When using TSQ, a statistically significant increase in intracellular zinc levels was observed after 30 minutes of incubation with ZnO NPs. The maximum values of the indicator were reached after 45 min and remained stable at this level for up to 2 h. The baseline integrated density of KB cells after staining with TSQ was 25 200 a.u. (median). The baseline integral density of KB cells after staining with STQ-Me was 9 800 a.u., which was 2.5 times less than similar indicators for TSQ. The maximum level of cell fluorescence was recorded after 30 min of incubation. No significant changes in baseline fluorescence of KB cells were observed after STQ-Et staining. Fluorescence increased after 15 min of incubation and began to be restored after 30 min. No changes in cell fluorescence were identified after STQ-CF_3 using. Fluorescent aggregates of STQ-CF_3 were identified between cells. No significant cytotoxicity of the investigated compounds was found.

Based on the results, the 8HQ derivatives STQ-Et and STQ-CF_3 were found unsuitable for assessing zinc levels in living cells. STQ-Me shows potential for measuring zinc levels in living cells. However, STQ-Me was most likely not able to chelate protein-bound zinc, as evidenced by the dynamic fluorescence parameters of KB cells. Thus, STQ-Me has the potential for use in measuring zinc in living cells, but the molecular design requires modification to enhance fluorescence and expand its ability to chelate protein-bound zinc.

KEYWORDS: 8-Hydroxyquinolines, Zinc sensing, ZnO nanoparticles, Fluorescent probe

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T1-17 E-POSTER

Synthesis of titanium matrix composites reinforced with TiB nanosized particles

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Titanium alloys are widely recognized as advanced structural materials due to their unique combination of high specific strength, excellent corrosion resistance, and relatively low density. These properties enable their extensive application in aerospace, marine, biomedical, and defense industries, where weight reduction and high mechanical performance are critical requirements. In particular, titanium alloys retain high strength over a wide temperature range and demonstrate superior resistance to aggressive environments, making them suitable for demanding operating conditions. Consequently, further enhancement of their mechanical properties, especially hardness and strength, remains an important scientific and technological challenge.

In this work, titanium matrix composites reinforced with nanosized titanium monoboride (TiB) particles were synthesized using a TiH_2-TiB_2 powder system. The formation of TiB occurs in situ due to boron diffusion from TiB_2 into the titanium matrix, which ensures strong interfacial bonding and the absence of macrodefects at phase boundaries. The synthesis process leads to the formation of TiB particles with a characteristic needle-like morphology.

It was established that the growth of TiB needles is anisotropic and controlled by preferential boron diffusion along the [010] crystallographic direction. As a result, high aspect ratio nanosized reinforcements are formed. The size and distribution of TiB needles can be effectively controlled by adjusting the synthesis temperature and holding time.

The introduction of nanosized TiB needles significantly improves mechanical properties of the composites, including tensile strength, hardness, and elastic modulus. An increase in the reinforcing phase content above 3 wt.% results in further strengthening; however, a reduction in plasticity is observed. Despite a slight increase in residual porosity, the overall mechanical performance is enhanced due to effective load transfer and reinforcement mechanisms.

The proposed approach can also be applied to the fabrication of irregularly shaped titanium powders reinforced with nanosized TiB, which are promising for additive manufacturing applications.

KEYWORDS: Titanium matrix composites, TiB reinforcement, Nanosized particles, In situ synthesis, Titanium diboride

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T1-18 POSTER

Optimization of the composition and content of composite carbon filler in rubber compositions using different formulations

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Today, there are many optimized multi-component (up to 12-18) rubber compositions, the characteristics of which can be improved by using modern achievements of nanotechnology - nanosized carbon fillers. The biggest problem of using hybrid (composite) fillers, traditional carbon black (CB) in a composition with nanosized carbon materials, for example, carbon nanotubes (CNTs), is achieving a homogeneous distribution of fillers, as a result of the sequential mixing of several components in the matrix. The probability of homogeneous distribution decreases with increasing number of fillers, as does the probability of simultaneous occurrence of interdependent processes, i.e. it is equal to the product of individual probabilities.

The solution to this problem involves the creation of uniformly distributed CB@CNT fillers during CB synthesis (by introducing CNTs into hydrocarbon (CH) raw materials (HCRM), in-situ), which are then added into the rubber matrix, and the ratio of the amounts of CNTs and HCRM, as well as the CB@CNT content in the rubber composition, are pre-calculated.

We assume that to create a solid non-porous rubber composition (we consider the content of CB to be already optimized by the method of sorting out the options), the rubber must wet the entire filler system, creating a layer with a thickness equal to two average diameters of CNTs (d_{CNT}). And the content of CB in the rubber composition according to the initial recipe is reduced by the mass of CNTs in proportion to the ratio of the specific surfaces of CB and CNTs.

That is: $V_{RUB}/(S_{CB}\times m_{CB}+S_{CNT}\times m_{CNT}) = 2d_{CNT}$ (1),

where: V_{RUB} - volume of rubber; S_{CB} - specific surface area of CB; m_{CB} - mass fraction of carbon nanotubes; S_{CNT} - specific surface area of CNT; m_{CNT} - mass fraction of CNTs; and $m_{CB}=m_{CB}^{0}-(S_{CB}/S_{CNT})\times m_{CNT}$ (2) where: m_{CB}^{0} - mass fraction of CB in the rubber composition according to the original recipe. After simple transformations of the system of equations (1) and (2), we obtain the determination of the ratio of the masses of CNT and HCRM: $m_{CNT}/m_{CH}=K\times(\alpha-2\rho_{RUB}\times S_{CB}\times d_{CNT})/\{2\rho_{RUB}\times d_{CNT}\times S_{CNT}[1-(S_{CB}/S_{CNT})^2]\}$ (3), where: $K = m_{CB}/m_{CH}$ - CB output ratio, $\alpha=m_{RUB}/m_{CB}^{0}$ and $m_{CB}^{0}=K\times m_{CH}$. And, the content of the composite filler in the rubber composition, in phr of rubber: $m_{CB+CNT}= m_{CB}^{0}\times\{1+ (\alpha-2\rho_{RUB}\times S_{CB}\times d_{CNT})\times(1- S_{CB}/S_{CNT})/ (2\rho_{RUB}\times d_{CNT}\times S_{CNT}\times[1-(S_{CB}/S_{CNT})^2]\}$ (4) The calculated ratios of CNTs and HCRM and the content of the composite filler were used for the synthesis of the composite filler CB@CNT and the production of rubber compositions based on synthetic rubber NBR 3365 and natural rubbers SMR and SMR 20. The determined mechanical characteristics showed their increase in the series from the CB filler, the calculated content of mixtures of CB and CNTs and composite CB@CNT for all three systems and in comparison, with analogues. This shows the correctness of the assumptions made and the effectiveness of the use of CB@CNT synthesis in in situ mode.

KEYWORDS: Rubber composition, Carbon black, Carbon nanotubes, Nanosized carbon fillers, Hydrocarbon raw materials

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T1-19 POSTER

The electrophysical and mechanical properties relationship of epoxy-based fiberglass composites with carbon nanotubes

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Products made from electrically conductive fiberglass are widely used as electromagnetic shields and antistatic coatings. The functional fillers of such materials include special grades of carbon black, graphite, carbon fibers. Particular attention is paid to the use of carbon nanotubes (CNTs), which are characterized by high conductivity and enhanced mechanical strength. The aim of this work was to investigate the electrophysical and mechanical properties of fiberglass plastics based on epoxy resin (ER) with varying CNT content in different regions of the samples.

To form the composites, four layers of ST-48 glass fabric, EPOLAM 5015 RESIN epoxy resin were used. The CNTs were dispersed using a three-roll mill, with CNT concentrations ranging from 0 to 0.5% in the polymer. Samples of size 150×150×1.5 mm were formed by infusion pressing. Measurements of conductivity were carried out using alternating current in the frequency range to 100 kHz using the two-contact method. The mechanical properties of the fiberglass plastics were determined under tension using an R-50 tensile testing machine.

The non-linear behavior of conductivity with respect to CNT content indicates the presence of a percolation transition in the system at approximately 0.1% (0.0006 volume fraction). For composites with a CNT content of up to 0.25% (2,5times the percolation threshold), an increase in tensile strength values is observed; with a further increase in content, the tensile strength decreases while the conductivity increases. In the content range of 0.3-0.5% (significantly exceeding the percolation threshold), the tensile strength decreases due to a reduction in the specific adhesion of the polymer to the CNTs (insufficient liquid polymer surface to wet the CNTs, resulting in increased porosity). At the optimal CNT content, the tensile strength exceeds that of composites without CNTs by more than 1.6 times.

Analysis of the electrophysical characteristics of composites indicates a significant difference in their properties across different regions. The highest values of conductivity are observed in the central parts of the fiberglass plastics, as are the highest values of tensile strength. Lower values at the periphery of the samples (by approximately 10%) are due to the orientation and filtration of CNTs during composite formation. At the same CNT content, the flexural strength is higher for sample regions that have higher electrical conductivity, provided the CNT content is less than2,5 percolation thresholds. It has been shown that up to a CNT content of 2.5 times the percolation threshold, both conductivity and tensile strength increase; with a further increase in CNT content, electrical conductivity increases while tensile strength decreases. The decrease in tensile strength upon addition of carbon nanotubes, equal to 2.5 percolation thresholds, is associated with a decrease in the specific adhesion surface area during wetting of carbon nanotubes with polymer

KEYWORDS: Carbon nanotubes, Conductivity, Fiberglass, Epoxy resin, Mechanical properties

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T1-20 E-POSTER

Decoration of copper foam with silver nanostructures by galvanic replacement

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The oxygen reduction reaction (ORR) is one of the processes that limits the application of fuel cells and secondary metal-air batteries. The main reason for this is the insufficient efficiency of existing electrocatalysts. The most active among them, based on platinum, are hindered in scalability due to the high cost and limited natural resources of this metal. Therefore, research aimed at finding non-platinum ORR electrocatalysts is highly relevant. One alternative is cathodes based on significantly cheaper silver, which is second only to platinum and palladium in terms of O_2 binding energy. Emphasis is placed on nanostructures, bimetallic systems, and high specific surface area [1].

In this work, the possibility of forming catalytically active ORR cathodes (Ag/Cu_{foam}) based on silver nanostructures deposited on the surface of commercial copper foam by the galvanic replacement method is demonstrated. The latter is effective for depositing metal nanostructures onto the surface of 3D sacrificial metals [2, 3]. Silver was deposited from solutions of (1) $AgNO_3$ and (2) ammine complexes $[Ag(NH_3)_2]^+$. It is shown that in the first case, the formation of discrete nanoparticles (<50 nm) and dendrites is typical, while in the second case, structures range from nanoparticles (<20 nm) and their agglomerates to porous nanofilms. A relatively uniform distribution of the silver deposit over the entire surface of the copper foam is observed. The main parameters influencing the geometry of the deposited nanoparticles and the degree of surface coverage with silver are the concentration of hydrated and complex ions and the duration of galvanic replacement. A dependence of electrochemical ORR activity measured using the obtained Ag/Cu_{foam} cathodes on the morphology of the nanostructured surface has been established. The synergistic effect of the Ag-Cu bimetallic system and the positive impact of a large specific surface area are demonstrated.

KEYWORDS: Electrochemistry, Electrocatalysis, Oxygen reduction reaction, Galvanic substitution, Silver nanoparticles

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T1-21 E-POSTER

Formation and confinement of nanoparticles in a mid-frequency rectangular-wave discharge

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Nanoparticles (NPs) synthesized in acetylene plasma are of interest not only from a fundamental perspective but are also considered promising carriers of antibiotics for targeted delivery. In most studies reported in the literature, experiments are performed with horizontally aligned electrodes, and the formed NPs are confined within the discharge volume by high electric fields of the near-electrode regions, either in RF capacitive discharges or in the cathode sheath of DC glow discharges.

We investigate NPs formation in a bipolar mid-frequency rectangular-wave discharge, where the discharge tube is oriented horizontally while the electrodes are mounted vertically. The inner diameter of the tube is 80 mm, and the distance between the plane electrodes is 76.2 mm. NPs formed in the plasma were deposited both on a glass slide for optical microscopy placed at the bottom of the tube and on separate TEM support grids positioned on the same slide. Bipolar rectangular-wave voltage with peak-to-peak amplitude up to 1300 V and frequencies in the range of 17-200 kHz were applied to one of the electrodes. Acetylene was introduced into the discharge chamber with the pressure in the range of 0.05-1 Torr.

Since the NPs are too small to be directly observed with the naked eye, laser light scattering diagnostics were employed. The laser beam was expanded into a flat light sheet using a cylindrical lens. This approach enabled visualization of 2D cross-sections of the NPs cloud, while scanning the light sheet allowed reconstruction of its 3D structure.

In DC glow discharge, the NPs cloud is typically narrow and localized within the negative glow region, confined by a potential well. In contrast, in the bipolar mid-frequency rectangular-wave discharge, the NPs cloud was found to be significantly broader. During the positive phase of the voltage pulse, the driven electrode acts as an instantaneous anode, while the opposite electrode serves as an instantaneous cathode; during the negative phase, their roles are reversed. Electrons and positive ions rapidly respond to the alternating electric field. However, negatively charged NPs, due to their large mass and inertia, respond primarily to the time-averaged electric field. The spatial distribution of the time-averaged potential exhibits a maximum between the boundaries of two cathode sheaths formed near the instantaneous cathodes. Consequently, a wide potential well is established in this region, enabling both formation and long-term confinement of NPs, which was confirmed experimentally. The width of the potential well, and correspondingly the NPs cloud, increases with decreasing pulse frequency and increasing peak-to-peak voltage.

Transmission electron microscopy revealed that the NPs are predominantly spherical with diameters of 100-200 nm. They are rarely isolated; instead, they tend to form elongated chains of complex morphology, often assembling into fractal-like agglomerates with sizes of several micrometers.

KEYWORDS: DC glow discharge, Acetylene, Formation and confinement of nanoparticles, Potential well

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T1-22 E-POSTER

Hall-Petch effect in the intense plastic deformation zone during FSW of magnesium alloys

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In previous studies, the formation of a stress-strain state during friction stir welding (FSW) of Mg alloys was modeled as a thermodynamic macro process at three linear speeds and a constant rotation rate [1, 2]. A 300% increase in the elastic modulus (E) and microhardness (H) in the stir zone was observed at the minimum linear welding speed. The elasticity values were used in the residual stresses and deformation model. The indentation data characterizes the stiffness of interatomic bonds [3], and residual stresses are the macroscopic result of plastic deformation and thermal gradients. Hence, the next study was to supplement the vision of the stress-strain state formation mechanism during FSW through visualization of the atomic structure of the Mg-Al alloy by the MD method (Chemsite 3.1.) and to study the Hall-Petch effect [4], according to which the hardness increases with a decrease in the grain size in the core zone of the FSW joint. Also, the inverse Hall-Petch effect was determined, in which the dependence of strengthening due to grain refinement is disrupted. Indentation was carried out according to ISO 14577-1:2015 with automatic determination of microhardness (H) and elastic modulus (E) by a trihedral Berkovich indenter on a computerized hardness tester.

Structural-phase components of the alloys with 92.6-95.1% Mg and 3.8-5% Al: the main solid solution α-Mg matrix, hexagonal close-packed atomic lattice, E = 44-45 GPa; intermetallic β-$Mg_{17}Al_{12}$ (formed upon cooling from the liquid state in the eutectic zone), cubic atomic lattice, E = 65-95 GPa [5]. During FSW five gliding modes are activated in the hexagonal crystal lattice of the α-Mg matrix, which causes extreme degrees of deformation without destruction of the material shape. The denser β-$Mg_{17}Al_{12}$ phase with cubic crystal lattice is a hard and brittle intermetallic phase, which provides strengthening in Mg-Al alloys due to plasticity (Young's modulus increases with increased pressure), i.e. resistance to volumetric and shear deformations and stiffness increase. The phase does not deform up to the brittle-plastic transition at a temperature of 300°C.

Thermodynamic processes during FSW form a typical dense junction of the mixing zone with the thermo-mechanically affected zone on the advancing side. The base alloy contains a typical rolled microstructure with coarse grains, which is preserved in the heat-affected zone. The non-uniform field of the plastic flow of metal changes the microstructure radically, so the lowest level of hardness is observed here, which makes it a critical zone for tensile failure. Local flows of a close-to-nanoscale texture (inv. Hall-Petch effect) with reduced hardness are formed at the top of the stirring zone, and at the bottom of the core (nugget zone) the crushed texture has a 300% increase in hardness. Thus, reducing the level of the stress-strain state with no Hall-Petch effects determines the most effective of the three FSW modes.

KEYWORDS: Hall-Petch effect, FSW, Stir zone, Hardness, Mg alloy

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T1-23 E-POSTER

Stability of secondary phase in Zr-Sn alloys under irradiation: Phase-field modeling

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We present a comprehensive phase-field study of microstructure evolution in Zr-Sn alloys with explicit consideration of point defects and irradiation effects. The model is formulated within a thermodynamically consistent framework based on the Gibbs free energy functional, incorporating configurational entropy, excess interaction terms, and vacancy contributions. Both equilibrium and irradiation-induced processes are analyzed, including defect production, recombination, clustering, and elastic interactions with the matrix.

At the stage of thermal treatment of solid solution the model predicts phase separation of a supersaturated solid solution with the formation of Sn-enriched precipitates od secondary phase. Numerical simulations demonstrate that these domains nucleate and grow due to diffusion-driven instabilities, followed by a coarsening regime governed by diffusion-limited kinetics. The mean particle size exhibits an algebraic growth law, and the resulting size distribution remains close to Gaussian with moderate dispersion. Equilibrium vacancies are shown to localize preferentially within domains of secondary phase, indicating strong coupling between compositional and defect fields.

It is shown that irradiation significantly modifies microstructure stability depending on the dose rate. At low dose rates, the phase structure remains largely stable, with only minor interface broadening due to ballistic mixing. Vacancies are redistributed within existing precipitates without substantial alteration of phase morphology. In contrast, at elevated dose rates, pronounced microstructural changes occur, including partial dissolution of secondary phase precipitates at early stages and subsequent reformation driven by radiation-enhanced diffusion. Nonequilibrium vacancies tend to form high-density clusters within Sn-rich regions, indicating the onset of defect aggregation and potential loop formation.

Statistical analysis based on concentration dispersions and domain size evolution reveals that irradiation induces nontrivial kinetic regimes. In particular, increased dose rates lead to a reduction in compositional fluctuations and enhanced vacancy clustering. The competition between ballistic mixing and radiation-enhanced diffusion governs the long-time behavior, resulting in stationary microstructures characterized by modified precipitate sizes and distributions.

The proposed model provides a consistent description of coupled phase transformation and defect dynamics in Zr-Sn alloys and can be used to predict microstructure stability under irradiation, which is essential for understanding the performance of nuclear fuel cladding materials.

KEYWORDS: Zr-Sn alloys, Phase-field model, Radiation-induced defects, Microstructure evolution

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T1-24 E-POSTER

Phase-field modeling of radiation effects in Nb-Sn alloys: Stability of the A_{15} phase and defect-driven microstructure evolution

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A comprehensive phase-field model is developed to investigate microstructure evolution and radiation effects in binary Nb-Sn alloys with a focus on the formation and stability of the A_{15} (Nb_3S_n) phase. The model is based on a thermodynamically consistent Gibbs free energy functional that incorporates chemical contributions, configurational entropy, excess interaction terms, and gradient energy effects. The system is described using coupled conserved fields corresponding to Nb and Sn concentrations, as well as vacancy concentration, allowing for a detailed representation of diffusion-driven phase transformations.

Vacancy formation, vacancy-atom interactions, and their coupling with local composition are explicitly included, enabling the transition from a binary to an effective ternary (Nb-Sn-vacancy) system. The model is further extended to describe irradiation conditions by incorporating production of nonequilibrium point defects, their recombination, annihilation at sinks, and clustering into defect loops. A reaction-rate theory framework is employed to capture the interplay between defect dynamics and microstructure evolution.

Numerical simulations are performed to study the precipitation of the A_{15} phase during thermal treatment of solid solution and its subsequent evolution under neutron irradiation. During the thermal treatment the system undergoes phase decomposition with the formation of A_{15} domains enriched in tin, exhibiting growth and coarsening behavior consistent with experimental observations. Under irradiation, a pronounced dissolution of A_{15} domains is observed at low doses, followed by defect-driven coarsening and morphological transformations at higher doses. Tin segregation and vacancy trapping lead to the formation of elongated structures and spatial redistribution of defects.

Statistical analysis reveals a decrease in niobium ordering within the A_{15} phase and enhanced tin segregation under irradiation. The evolution of vacancy concentration demonstrates preferential accumulation within A_{15} domains. The mean size of A_{15} particles significantly decreases with increasing dose, indicating radiation-induced destabilization of the ordered phase.

KEYWORDS: Phase-field modeling, Nb-Sn alloys, A15 phase, Radiation effects, Microstructure evolution

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T1-25 E-POSTER

Kinetics and key features of electrophysical properties in diluted aqueous colloidal solutions of $C_{60}@\{H_2O\}_n$ fullerene complexes

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Diluted aqueous colloidal solutions of $C_{60}@\{H_2O\}_n$ prepared using the cryogenic vacuum-sublimation method were studied with respect to the kinetics of their dielectric loss tangent (δ) and permittivity (ε) [1]. A stock colloidal solution of hydrated fullerene $C_{60}@\{H_2O\}_n$ containing 3 mg of C_{60} per liter was prepared by melting the solid hydrate phase produced by co-condensation of fullerene vapor and water on a liquid-nitrogen-cooled substrate. Dilute solutions of $C_{60}@\{H_2O\}n$ were obtained by adding a $C_{60}@\{H_2O\}n$ solution with a base concentration to pure distilled water and subsequent stirring with a magnetic stirrer for 1 minute. In this way, solutions with relative concentrations to the base of 1:10, 1:100, and 1:1000 were obtained. Changes in the dielectric loss tangent and permittivity over time were studied for each solution in the frequency range of 100-104 Hz. Measurements showed that the dielectric loss tangent of the colloidal $C_{60}@\{H_2O\}_n$ solution is significantly higher than that of pure water, with its maximum shifted toward higher frequencies. This effect is presumably associated with the formation of metastable spherical hydration layers around fullerene molecules, caused by donor-acceptor interactions between H_2O molecules and the C_{60} surface [2]. The permittivity of the $C_{60}@\{H_2O\}_n$ solution was also found to be higher than that of pure water, which is most likely due to the enhanced polarization of H_2O molecules induced by fullerene molecules. A gradual increase in both the dielectric loss tangent and permittivity was observed over time. This behavior can be attributed to the progressive formation and growth of hydration shells around C_{60} molecules. The magnitude of the observed effect depends on the concentration of fullerene in the solution and may be of interest for further biophysical investigations.

KEYWORDS: Hydrated fullerene $C_{60}@\{H_2O\}_n$, Colloidal aqueous solutions, Dielectric loss tangent, Hydration shells, Fullerene-water interactions

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T1-26 POSTER

A robust software platform for high-resolution morphometric analysis of AFM data in nanostructured materials and nanoelectronics

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An advanced software framework has been developed for automated morphometric analysis of nanostructures based on atomic force microscopy (AFM) images and deployed on the Streamlit Cloud platform. The proposed application enables a fully automated end-to-end image analysis workflow by integrating computer vision techniques, classical statistical methods, and modern machine learning approaches.

The functionality of the framework includes statistical analysis of AFM images, multilevel image segmentation for object identification across varying intensity thresholds, and comprehensive characterization of the extracted structures, including their geometric properties and spatial arrangement. In addition, clustering algorithms based on multiple morphometric descriptors have been implemented. In particular, the incorporation of the K-Means algorithm ensures efficient separation of objects in a multidimensional feature space, allowing for clear discrimination between primary nuclei and mature nanocrystallites.

The software is specifically designed for high-resolution morphometric analysis of nanostructured surfaces. It incorporates preprocessing capabilities such as image cropping to focus on regions of interest, filtering of segmented objects based on size criteria, exclusion of edge-located structures (which is critical for microscopy data), and implementation of periodic boundary conditions for the analysis of numerical simulation results describing the spatial evolution of physical systems.

The developed framework has been validated using experimental AFM images of nanostructured surfaces. The integrated analysis performed within the application demonstrates high reproducibility of topological parameters, confirming the robustness of the platform as a reliable tool for predicting the properties of advanced nanomaterials for nanoelectronic applications. The obtained results show strong agreement with experimental observations, while statistical verification confirms the adequacy of the derived distributions.

The use of a fully automated analysis pipeline significantly enhances the reliability of the results by minimizing operator-dependent bias and ensuring reproducibility.

KEYWORDS: Nanostructured thin films, Morphometric analysis, Statistics, Machine learning

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T1-27 E-POSTER

Peculiarities of the crystal structure and electron transport properties of CoFeBMoGeMn high-entropy thin-film alloy

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High-entropy alloys (HEAs) belong to a class of advanced multifunctional materials, which typically consist of five or more elements in approximately equal molar ratios (equiatomic HEAs) [1]. Non-equiatomic alloys have recently gained popularity; in these alloys, the elements are present in different molar ratios, allowing for a more flexible approach to developing alloys with unique functional characteristics that equiatomic alloys cannot achieve [2]. By varying the concentrations of individual components, it is possible to produce not only solid solutions but also intermetallics and ceramic compounds. This opens a wide range of possibilities for optimizing functional properties.

The high-entropy thin film $Co_{10}Fe_{31}B_{10}Mo_{32}Ge_8Mn_9$ (hereafter all compositions are given in atomic percent) was deposited onto glassy carbon substrates at room temperature using a magnetron sputtering co-deposition technique from three independent sources ($Mo_{78}Ge_{22}$, $Co_{20}Fe_{60}B_{20}$, and Mn with target purity 99.99%) in an Orion 8 system. The base pressure in the vacuum chamber was 7×10^{-8} Torr. During deposition, the chamber was filled with high-purity argon (99.999%, Messer) at a flow rate of 18 cm^3 min^{-1}, maintaining a constant working pressure of 3 mTorr. The average deposition rate was approximately 0.6 nm·min^{-1}. The films were annealed in an Ar+H_2 (2%) atmosphere using a tubular furnace under continuous gas flow. The heating rate during annealing was 5 °C min^{-1}. The microstructure of the HEA films was investigated using a JEOL 2100F UHR transmission electron microscope (TEM) operated at 200 kV.

Analysis of the crystal structure of HEA films was performed after deposition and annealing at 300, 450, and 650 °C. It was demonstrated that the crystal structures of the as-deposited and annealed at 300 and 450 °C samples are amorphous. Two diffuse rings corresponding to the (111) and (200) planes of the cubic structure, with interplanar spacings d_{111} = 0.232 nm and d_{200} = 0.142 nm, can be identified in the diffraction patterns. These data are close to the face-centered cubic structure of Mo. After annealing at 650 °C, significant changes occur in the crystal structure of the samples. The results of the diffraction pattern analysis indicate the formation of a multi-phase composition comprising tetragonal, hexagonal, and cubic crystal structures.

The nature of the temperature dependence of the resistivity during heating confirms that defect healing and the recrystallization process occur during heat treatment. A metallic-like temperature dependence of resistivity is observed during sample cooling. Consequently, the charge-transport processes in the HEA films are driven by the scattering of conduction electrons at grain boundaries, impurities, and phonons, which is typical of electrically continuous metallic films. The high defectiveness of the sample structure results in a resistivity of about 10^{-6} fi·m. The temperature coefficient of resistance is of the order of 10^{-4} °C^{-1}.

KEYWORDS: High-entropy thin-film alloy, Crystal structure, Annealing, Resistivity, Temperature coefficient of resistance

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T1-28 E-POSTER

Morphology of island-like films obtained by electron beam evaporation

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The study of the surface morphology of island films is a highly relevant field in modern solid-state physics, materials science, and nanotechnology. This is because the physical properties of thin films in the early stages of growth differ significantly from those of continuous films and solid materials [1]. The substrate with the island film deposited on it constitutes a single, substantially heterogeneous system in many physical processes. It is necessary to take into account the properties of the film-substrate interface, as well as the properties of the substrate's surface layer. Besides, an important characteristic of films is their non-equilibrium shape and structure. Consequently, once the growth process is complete, various relaxation processes take place within the islets, the kinetics of which depend, in particular, on external influences. As a result of these irreversible changes, the film's physical properties tend towards thermodynamic equilibrium values [2].

Technologically, magnetron sputtering and electron beam sputtering are used to form nanoisland systems. The fundamental difference between these methods, which determines the properties of the resulting structures, lies in the particles' energies and the angles at which they strike the substrate. In our case, the island-like structures of ferromagnetic metals (Fe, Co, Ni) and alloys (Fe_xNi_{100-x}, Co_xFe_{100-x}) were obtained by exposing a polished glass substrate to a vapor stream of these metals for (1-10) seconds. The diffusive mobility of the atoms on the substrate was limited, as the film was deposited onto a neutral, non-oriented substrate at a temperature close to room temperature.

Based on electron microscopy results, it can be concluded that during film deposition, a large number of fine crystallization nuclei form and grow simultaneously. As a result, the unburned films, regardless of their composition and thickness, exhibited virtually identical structures. The islands are irregularly shaped and measure 2-5 nm, whilst the gaps between them appear as channels of roughly the same width, 1-2 nm. Thus, the Folmer-Weber growth mechanism is at work in the films. Structurally, the increase in the effective thickness of the films manifests itself solely in an increase in the density of the islands.

Significant morphological changes in the nanoisland systems occur following annealing at 700 K and are determined by their effective thickness. At a small effective thickness of 3-5 nm, the only change observed is an increase in the size of the islands to 10-20 nm due to coalescence. At the same time, the total number of islets is reduced by a factor of 3-5, leading to an increase in channel width to 2-7 nm. At an effective thickness of 6-7 nm, a similar pattern is observed, with a higher island density and narrower channels of 2-5 nm. Subsequently, as the effective thickness increases to 8-10 nm, a 'bridge-like' structure forms in both pure metal films and alloy films.

KEYWORDS: Island films, Morphology, Magnetic materials, Electron-beam evaporation

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T1-29 POSTER

Nanotextured ammonium dihydrogen phosphate for NLO applications

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The design of novel materials is significant and intriguing task. One of the possible approaches for new structures creating is composition of two or several materials in specific way. Such a task can be resolved by providing of guest material into host matrix. The concept of the present research is creation of nanostructured material that is porous template filled with crystallites. To prepare the defined composition, nanoporous anodic alumina oxide (AAO) membranes and ammonium dihydrogen phosphate (ADP) compounds were used. Somewhat similar investigations are presented in works [1, 2]. In this research we examined new techniques of sample preparation, that leads to exceptional structural and functional characteristics of obtained materials. The synthesis process of nanostructures based on AAO template filled with ADP as well as structural and non-linear optical (NLO) properties of synthesized material was studied. The formation of crystalline nanoarchitectures was established via scanning electron microscopy and X-ray diffraction methods. The performed research on the synthesized samples shows the formation of ADP nanoarchitectures which exhibits structural sustainability and NLO efficiency. Therefore, the integration process of functional material with nanoporous membrane represent a method for creation of nanotextured composition with origin physical properties.

KEYWORDS: Ammonium dihydrogen phosphate (ADP), Nonlinear optics, Anodic alumina templates, Nanocomposites

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T1-30 E-POSTER

Influence of magnetic field post-treatment on electrical properties of polymer composites with hybrid filler

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The wide range of properties exhibited by polymer composites makes them suitable for use in a variety of applications. Thermoplastic-based composites can be processed and treated after formation. Thus, the formed composite structure can be modified by remelting the material and creating a new structure in the melted state. The aim of this work was to investigate the effect of random and segregated distribution, followed by treatment of the samples in a magnetic field, on the electrical properties of polymer composites. For the study, an LDPE thermoplastic polymer matrix and two types of filler were selected: dispersed nickel (2 vol. %) and a hybrid nickel/anthracite mixture (1/1 vol. %). The statistical 3D distribution was obtained using a disc-type micro-extruder, and the segregated 3D structure was obtained by mixing the polymer and filler powders with the following hot compaction. The one-dimensional 1D structure was obtained by treatment of the composites with the 3D statistical and segregated distribution in a magnetic field at 140 oC in the melted state. The magnetic induction at the sample location was 0.5 T. The DC electrical conductivity of the composites was determined using an E_6-13A teraohmmeter, and the dielectric constant, was measured at a frequency of 1 kHz using an E_8-4 digital capacitance meter. Optical microscopy revealed that the samples' treatment in a magnetic field significantly affected their morphology. The ferromagnetic Ni filler aligned itself within the polymer melt along the magnetic field lines. This significantly impacted the electrical properties of the composites, with the dielectric constant's dependence on electrical conductivity being empirically established and analytically described. The influence of the samples' treatment in a magnetic field on these parameters was also demonstrated, particularly the dielectric-conductor transition was observed in a composite with a 1D structure based on a 3D segregated composite containing 2 vol.% of Ni. Composites with hybrid filler demonstrate a stronger dependence of the dielectric constant on the electrical conductivity.

KEYWORDS: Polymer composites, Hybrid fillers, Electrical conductivity, Magnetic-field alignment, Segregated structure

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T1-31 POSTER

Delineate the role of interaction in biosensing: size-tuned metal nanoparticles controlling enzyme activity for smart biosensors

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The nanomaterial-based biosensors require a precise understanding of nano-bio interactions, particularly the influence of nanoparticle size on enzyme structure and function. In this work, we report a comprehensive investigation of size-dependent interactions between silver nanoparticles (AgNPs; 5-100 nm) and urease, a model metalloenzyme, employing spectroscopic, thermodynamic, and activity-based analyses. Interaction studies revealed a strong dependence of binding affinity and inhibition mechanism on nanoparticle size. Small AgNPs (5 nm) exhibited the highest binding affinity (Kd ~66 nM), inducing significant conformational alteration in urease, as confirmed by circular dichroism. In contrast, intermediate sizes (20 and 50 nm) showed weaker binding (Kd ~712 and 616 nM) and minimal structural perturbation. Notably, larger AgNPs (100 nm) demonstrated strong binding (Kd ~171 nM) without significant conformational change, suggesting inhibition via surface adsorption and active-site masking. Thermodynamic profiling using isothermal titration calorimetry highlighted distinct interaction modes: exothermic binding for 5 and 100 nm particles, and endothermic signatures for mid-sized nanoparticles, attributed to hydration layer formation at the nano-bio interface. The enzyme inhibition assays demonstrated that both smallest and largest nanoparticles achieve maximum inhibition at low concentrations, albeit through distinct mechanisms- structural denaturation and steric blocking, however, intermediate sizes are less effective. This study establishes nanoparticle size as a critical design parameter governing enzyme interaction pathways, binding thermodynamics, and functional inhibition. The findings provide a framework for engineering nanomaterial-enabled biosensors and therapeutic inhibitors with tunable activity, highlighting the importance of size-controlled nanostructures in advanced biomedical and environmental applications.

KEYWORDS: Silver nanoparticle, Urease, Nano-Bio interaction, Enzyme inhibition

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T1-32 E-POSTER

Electrospun PCL scaffolds as local amikacin delivery systems: From quantitative incorporation analysis to verification of antimicrobial activity

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Electrospun nanofibrous scaffolds represent one of the most promising platforms for local drug delivery purpose due to their high porosity and morphological similarity to the extracellular matrix [1, 2]. Polycaprolactone (PCL), as a biopolymer with well-modified mechanical properties and a predictable degradation rate, shows great potential for use as such a matrix [3]. The use of electrospun PCL matrices for amikacin incorporation is considered a strategy to overcome limitations associated with drug's high hydrophilicity and short half-life. This enables the transformation of short-term antibacterial action into a prolonged therapeutic effect [4, 5].

In this study, we performed a quantitative assessment of amikacin incorporation into electrospun PCL scaffolds and verified their antimicrobial potential.

PCL scaffolds were synthesized via electrospinning at voltage of 18000 V using a rotary collector at distance of 13 cm, rotation speed of 600 rpm and solution flow rate 2 ml/h. Lyophilized amikacin was introduced directly into the electrospinning solution. A 3:1 mixture of chloroform and dimethylformamide was used to dissolve the PCL. Quantitative determination of amikacin loaded into the membrane was carried out using liquid chromatography coupled with tandem mass spectrometry (LC-MS/MS). To evaluate antimicrobial activity using the disk-diffusion method, the PCL scaffolds were punched into ø 6 mm discs. Growth inhibition zones were quantified for reference strains of *S. aureus, E. coli*, and *P. aeruginosa.*

The mean of amikacin drug loading, calculated based on chromatographic analysis data, was 4,10 ± 0,71%, with Encapsulation Efficiency of 79,8 ± 13,7%. These values confirm the successful retention of amikacin within the polymer matrix, which is critical for overcoming its pharmacological limitations, such as extreme hydrophilicity and a short half-life.

Amikacin-loaded PCL scaffolds demonstrated pronounced antimicrobial activity against *S. aureus, E. coli,* and *P. aeruginosa*. The formation of large inhibition zones (exceeding 20 mm) around scaffold discs confirms sufficient diffusion of amikacin from hydrophobic PCL matrix into the aqueous environment of agar. The slightly smaller growth inhibition zones around PCL-amikacin scaffolds compared to standard paper amikacin disks can be considered indirect evidence of a controlled delivery system in operation, where the PCL scaffold acts as a depot, limiting diffusion rate and ensuring a gradual, metered release of antibiotic throughout the incubation period. PCL scaffold creates a reliable amikacin depot potentially capable of maintaining concentrations above the minimum inhibitory level directly at the infection site for at least several days, what is significantly reduces the risk of systemic toxicity typical for aminoglycosides, and is an effective solution for enhancing wound treatment efficacy and patient safety.

KEYWORDS: Electrospun PCL scaffolds, Amikacin, Antimicrobial activity

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T1-33 POSTER

Catalytic decomposition of ammonia over graphene-based nanocomposites for green hydrogen production

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The transition to a carbon-neutral economy requires the synthesis and development of improved and efficient hydrogen storage and transport vectors. Ammonia has recently become a potential candidate due to its high hydrogen density and carbon-free composition. However, the well-known kinetics of ammonia decomposition are often limited by the high temperatures required as well as the high cost of the noble catalysts often used in the process.

This study explores the design of novel graphene-based nanomaterials as high-surface area supports for transition metal nanoparticles commonly used in ammonia catalysis (e.g., Ni, Co). These considerations, together with the good electronic conductivity and chemical stability of graphene oxide, demonstrate a significant improvement in the catalytic activity of Ni and Co supported on reduced graphene oxide for hydrogen production.

This study discusses the synergistic effects based on the interaction between the graphene network and metal nanoparticles, as the latter promote electron transfer, reducing the activation energy for N-H bond cleavage [1].

Regarding structural optimization, through the doping process and, we obtained a superior metal dispersion and superior thermal stability, preventing sintering of metal nanoparticles at operating temperatures specific for ammonia decomposition (450-700°C) [2], by considering a green chemistry method for synthesis.

This research highlights the potential of graphene-based engineered catalysts to provide a cost-effective and scalable solution for COx-free hydrogen generation, indicating and positioning graphene materials close to the forefront of the hydrogen economy infrastructure in Europe.

KEYWORDS: Graphene, Ammonia decomposition, COx-free hydrogen, Heterogeneous catalysis

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T1-34 E-POSTER

Effect of ball-milling time on In-situ formation of reinforce boride phases in AlCrTiNbVB high-entropy alloys during electron-beam sintering

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Composite materials based on high-entropy alloys (HEAs) with in-situ inclusions of refractory compounds exhibit excellent mechanical properties, wear resistance, corrosion resistance, and other desirable characteristics [1, 2]. At the same time, a key challenge in developing such composites is the processing technology, particularly the preparation of feedstock materials (powder mixtures, compacts) and the high-temperature in-situ reactions between metallic components (Cr, Ti, Nb, V, etc.) and nonmetallic elements (B, Si, C) [3].

This study investigates the effect of mechanical alloying (MA) time on the in-situ phase formation, structure and hardness of AlCrTiNbVB HEAs consolidated by high-speed electron-beam sintering (EBS). AlCrTiNbVB HEAs were produced by MA of elemental powders using a Retsch PM_{100} planetary mill for 1, 2, 10, and 20 hours at 400 rpm in the petrol medium. The as-prepared powders were consolidated by EBS using ELA-6 equipment under identical conditions.

After 1, 2, and 10 h of MA, the powder consists of two solid solutions (Nb- and Cr-rich) and an Al_8V_5 intermetallic phase. After 20 h of MA, the structure evolves into two solid solutions enriched in Cr/Nb and Al/V, respectively. The Cr/Nb-enriched solid solution exhibits a nanostructured state, as evidenced by an average crystallite size of ~15 nm determined by XRD analysis. This behavior is characteristic of nanostructure formation in HEAs during MA [4, 5]. A noticeable fraction of ultrafine WC particles, obtained from the milling media, is also detected and confirmed by XRD and SEM analysis.

After EBS, the alloys exhibit a composite structure consisting of a solid solution matrix and fine boride particles. This structure results from component interactions, in-situ reactions, and the extremely high-speed sintering process (up to 3 min, including heating and cooling). At the same time, the chemical composition, size, and morphology of boride particles strongly depend on the MA time. After 1-10 h of MA and subsequent consolidation, elongated, needle-like Ti/Nb-based boride particles are formed in-situ in AlCrTiNbVB HEA. With the increase in MA time, particle fragmentation begins, leading to the formation of small, irregularly shaped particles. In comparison, after 20 h of MA and subsequent consolidation, the in-situ formation of ultrafine, cube-shaped high-entropy boride particles is observed, as confirmed by SEM and EDS analysis.

The structure evolution is directly associated with the formation of a nanostructured solid solution matrix during MA and EBS, combined with the sluggish diffusion effect of HEAs. In addition, the increasing fraction of finely dispersed boride particles and their progressive morphological and chemical changes contributes significantly to dispersion strengthening. As a result, the average hardness of the AlCrTiNbVB HEA increases from 7.36 to 12.29 GPa for powders milled for 1 and 20 h, respectively.

KEYWORDS: High entropy alloys, In-situ formation, Composite, Boride inclusions

ACKNOWLEDGEMENTS: This research was supported by the project of the Ministry of Education and Science of Ukraine, state registration number 0124U000913.

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T1-35 POSTER

Fabrication and experimental characterizations of an SU-8 composite enhanced with silver micro/ nano-inclusions

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In recent years, various nano-inclusions, including metallic NP, organoclays, carbon nanotubes (CNTs), and graphene, have attracted considerable research interest for nanocomposite development. Owing to their enhanced physicochemical and functional properties, these materials have found applications across many fields, including microelectromechanical systems (MEMS), electronics [1-2], medicine, aerospace, automotive engineering, and packaging technologies [3-4].

In this paper, we present the fabrication of a nanocomposite material based on SU-8 polymer matrix reinforced with Ag micro/nano-scale inclusions. The polymeric matrix employed in this study is the epoxy-based photoresist SU-8. This material was selected due to its excellent photopatternable properties, which make it highly suitable for the fabrication of MEMS and related microscale devices. First, the Ag particles were characterized using scanning electron microscopy-SEM. The particle diameter ranged from 300 nm to 3-5 μm, with an average particle size of about 900 nm. Subsequently, SU-8 2050 was selected as the polymeric matrix due to its high viscosity and its capability to produce layers with a wide range of thicknesses.

The nanocomposite material was prepared through the physical blending of functionalized silver particles dispersed in a wet solution with the SU-8 polymer matrix. In order to achieve a homogeneous dispersion of the metallic inclusions, the composite mixture was subjected to ultrasonic treatment, with the sonication time optimized accordingly. Additionally, manual homogenization was performed to further improve particle distribution within the matrix. The obtained nanocomposite was spin-coated onto a silicon wafer to obtain a layer with a thickness of approximately 20 μm. Furthermore, several thermal treatment processes were carried out, following the hard baking thermal treatments at 95 ^{o}C and 185 ^{o}C used for SU-8 photoresists. Hard baking is used to enhances the stability and durability of patterned resist structures during subsequent processing steps. Optical and SEM characterizations were performed to evaluate the homogeneity and morphological properties of the fabricated composites. Energy Dispersive X-ray Spectroscopy (EDS/EDX) analyses were carried out for the compositional characterization of the material. Experimental measurements of the elastic modulus of the nanocomposites were conducted following the thermal treatments applied to the fabricated nanocomposites. An increase in the elastic modulus was observed with increasing hard-bake temperature. The obtained measurements results were subsequently compared with those corresponding to the pristine SU-8 polymer in order to assess the influence of the Ag micro/nano-inclusions and thermal treatments on the mechanical properties of the materials.

Due to their improved mechanical properties, the developed nanocomposites show significant potential for advanced applications, as for nanosensors and MEMS/NEMS.

KEYWORDS: Nanocomposite, Silver, Metals, Mechanical properties

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T1-36 POSTER

FTIR-DFT approach at the synthesis of silver-containing chalcogenide nanoparticles

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The coordination of metal ions with ligands plays a key role in the wet chemical synthesis of semiconductor nanoparticles (NP) but remains poorly understood at the molecular level. In particular, the mechanisms of interaction between silver ions and amino acids as biologically relevant and environmentally safe ligands, such as N-acetylcysteine (NAC), require detailed spectroscopic and theoretical investigation. We address the problem of determining the preferred coordination mode of Ag^+ with NAC in aqueous media.

Using a combination of Fourier transform infrared (FTIR) spectroscopy and density functional theory (DFT) calculations, we found that silver ions are predominantly coordinated simultaneously with the thiol sulfur atoms and the carbonyl oxygen atoms of NAC, although most studies report coordination of the ion with the sulfur atom only [1, 2]. Comparison of experimental and calculated IR spectra shows that this coordination mode reproduces key spectral features at the characteristic frequencies. Importantly, experimental observations show that the formation of nanoparticles occurs under both acidic (pH ≈ 3) and neutral (pH ≈ 7) conditions. Accordingly, the DFT results indicate that the preferred coordination mode of Ag^+ with NAC remains unchanged in these environments. Furthermore, the results demonstrate that Ag^+ coordination can induce intramolecular proton transfer from the thiol to the carboxyl group.

These data contribute to a deeper understanding of metal-ligand interactions in amino acid systems and are relevant for controlling the stages of the synthesis of silver-containing chalcogenide nanoparticles. In a broader sense, the combined FTIR-DFT approach provides a robust framework for studying coordination mechanisms in complex molecular systems and reveals nanoparticle nucleation processes.

KEYWORDS: FTIR, DFT, Metal-ligand coordination, Wet chemical synthesis, Semiconductor nanoparticles

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T1-37 E-POSTER

Nanofibers of titanium phosphate modified by "green" silver nanoparticles as a perspective antibacterial nanocomposites

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Nanofibres have attracted a great deal of attention over the last two decades due to their unique properties, which make them appealing for use in various areas of medicine. Typically, different polymers can be easily fabricated with a fibrous morphology. However, these nanofibres generally perform poorly in adverse conditions such as high temperatures, irradiation, scratching and erosive solvents. A good alternative could be fibrous titanium phosphate (TiP) nanomaterials, which are chemically stable, low toxicity, biocompatible, formable, corrosion resistant, with excellent ion exchange properties for easy incorporation of target agents, e.g., antibacterial compounds

The aim of this work was to obtain the p-phase of crystalline titanium phosphate (p-TiP) in a fibrous form to use as a support for 'green' synthesized silver nanoparticles (AgNPs) in various antibacterial applications. The π-TiP solids were prepared via the sol-gel method followed by microwave-assisted hydrothermal treatment using the reaction between a titanium chloride (2M $TiCl_4$) and a phosphoric acid (1.6M H_3PO_4). Structural and microscopic studies, using X-ray diffraction, transmission (TEM), and scanning (SEM) electron microscopy data, confirm the formation of fibrous π-phases and their enrichment, with an average particle size of around 100 nm.

The affinity of the π-TiP nanoparticles toward antibacterial agents such as AgNPs was studied in static conditions. Previously, the series of AgNPs solutions was obtained using Melissa extracts (70% alcohol) and silver(I) acetate (AgAc) solution with various concentrations (1, 5, and 10 mM). The variables affecting the synthesis of AgNPs, including precursor concentration, reducing extract concentration, temperature, and reaction time, were investigated. TEM images demonstrated that the obtained AgNPs were spherical in shape with an average size of 10 to 15 nm. The as-synthesized AgNPs were incorporated into the π-TiP nanofibers. The successful formation and stability of the π-TiP/AgNPs nanocomposites were confirmed by various techniques. TEM images of π-TiP/AgNPs nanocomposites indicate uniform distribution of monodisperse AgNPs without changes in the starting size. Also, FTIR spectroscopy and TGA indicated the significant contribution of polyphenol extract components to the chemical composition of π-TiP/AgNPs nanocomposites.

Finally, the antibacterial tests showed that π-TiP/AgNPs nanosystems have excellent antibacterial activity against gram-negative (Escherichia coli) and gram-positive (Staphylococcus aureus) bacteria. The π-TiP/AgNPs nanofibers are effective for the prohibition of the growth of different bacteria and, therefore, are expected to be used as stable antibacterial materials.

KEYWORDS: Titanium phosphate, Nanofibers, Silver nanoparticles, Antibacterial nanocomposite

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T1-38 E-POSTER

Structural and defect evolution in nanostrcutured spinel ceramics under phase modification

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Spinel-type ceramics have attracted considerable attention due to their wide range of functional applications. In particular, $Cu_{0.1}Ni_{0.8}Co_{0.2}Mn_{1.9}O_4$ ceramics exhibit pronounced temperature sensitivity, making them suitable for negative temperature coefficient (NTC) thermistors, high-precision temperature sensors, and inrush current limiting devices [1].

The sintering process plays a key role in determining both the structural and electrical properties of these materials, as it governs phase composition in the bulk and near-surface regions. A reduction in the NiO phase fraction has been found to significantly suppress thermal aging, ensuring resistance stability within 3%. To further improve long-term performance, chemical modification using metallic additives has been implemented. These additives, primarily located in intergranular regions, stabilize cation distribution within grains and mitigate thermally activated degradation processes. The strong correlation between structural features and thermal behavior highlights the need for advanced characterization techniques.

In this study, positron annihilation lifetime (PAL) spectroscopy was employed to investigate microstructural evolution, as it is highly sensitive to regions of reduced electron density. However, interpretation of PAL data requires careful consideration of crystallographic factors and grain boundary effects, necessitating a comprehensive analytical approach. This method provides detailed insight into defect distributions and grain-pore interactions within the ceramics [2].

Ceramic samples were prepared via controlled sintering with varying NiO content ranging from 1% to 12%. Microstructural analysis revealed that increasing NiO concentration promotes grain growth, grain coalescence, and modification of defect structures. PAL measurements showed that positron trapping rates strongly depend on NiO content. At 8% NiO, defect fragmentation enhances positron trapping efficiency, whereas at 10% an optimal balance between structural stability and defect concentration is achieved. Further increase to 12% results in excessive grain merging, reducing grain boundary density and consequently decreasing positron trapping efficiency.

These results demonstrate that the nanostructure of $Cu_{0.1}Ni_{0.8}Co_{0.2}Mn_{1.9}O_4$ ceramics is highly sensitive to NiO phase distribution and its interaction with grain boundaries. The observed variations in positron trapping correlate with microstructural evolution and reflect the influence of thermal conditions during sintering on defect formation. It is established that a NiO content of 10% provides optimal structural stability and minimizes defect-related degradation. The combination of PAL spectroscopy with conventional characterization techniques enables a deeper understanding of ceramic behavior at the nanoscale. These findings contribute to the development of advanced spinel ceramics with improved performance for temperature-sensitive electronic applications.

KEYWORDS: Spinel ceramics, NTC thermistors, NiO phase, Free-volume defects, Positron annihilation lifetime spectroscopy

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T1-39 POSTER

Optical characterization of carbon nanodots produced from coffee waste via green synthesis using visible spectroscopy and Rayleigh scattering

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Carbon nanodots (CDs) are emerging as promising nanomaterials for bioimaging, sensing, and photocatalysis due to their exceptional photoluminescence, biocompatibility, and chemical stability [1]. Their quantum-confined optical properties and low cytotoxicity make them attractive alternatives to conventional semiconductor quantum dots and organic dyes. However, nanoscale verification of CDs typically relies on expensive electron microscopy techniques such as TEM and AFM, limiting accessibility for researchers with constrained budgets [2]. The development of cost-effective optical methods capable of supporting nanoscale characterization remains an important challenge in sustainable nanomaterial research.

Here we show that standard visible spectroscopy (450-850 nm), when systematically coupled with Rayleigh scattering analysis, can provide a complementary and cost-effective approach for supporting nanoscale verification of CDs synthesized from coffee waste-an abundant biomass source-via green thermal carbonization at 220°C. Coffee grounds were first thermally treated in an oven at 220°C, followed by aqueous extraction. The obtained suspension was purified by high-speed centrifugation (12,000 rpm, 25 min) to remove macroscopic residues and then filtered through a 0.22 µm membrane to eliminate larger aggregates, improving colloidal stability. We obtained stable colloidal solutions exhibiting blue/turquoise photoluminescence under 365 nm UV excitation, qualitatively indicating optical behavior characteristic of carbon nanodots [3].

Quantitative Beer-Lambert analysis of systematic dilution series (1:100 to 1:1000) using an Ocean Optics spectrometer with quartz cuvette in 180° transmission geometry yielded high optical linearity (R^2 = 0.9917 at 480 nm), demonstrating colloidal stability and potential for concentration-dependent optical sensing applications. In addition, we applied the classical Rayleigh scattering model ($I \propto 1/\lambda^4$) to optical extinction data in the long-wavelength region (600-800 nm), where absorption contributions are expected to be lower and scattering effects become more relevant [4]. High correlations ($R^2 > 0.95$) obtained across all concentrations support the interpretation that the particles responsible for optical extinction are substantially smaller than the incident wavelength, consistent with nanodot-like morphology without relying solely on electron microscopy.

Our results suggest that visible spectroscopy, combined with mathematical modeling, may serve as a useful complementary method to electron microscopy for supporting nanoscale verification. This approach can make CD synthesis validation more accessible for laboratories lacking expensive facilities, contributing to sustainable nanomaterial development from waste streams [5]. The high Beer-Lambert linearity indicates suitability for optical sensing, while the observed photoluminescence suggests potential for photocatalytic and bioimaging-related applications.

KEYWORDS: Carbon nanodots, Green synthesis, Rayleigh scattering, Visible spectroscopy, Coffee waste valorization

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T1-40 E-POSTER

Fabrication and characterization of ceramic thick-film nanostructures for sensor applications

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The use of thick-film ceramic materials based on mixed transition-metal manganite systems, combined with humidity-sensitive nanostructured $MgAl_2O_4$ ceramics, is a promising approach for developing multifunctional electroceramic sensors [1]. These materials enable simultaneous detection of temperature and humidity due to their tailored electrical and structural properties [2]. This study focuses on the fabrication and structural characterization of thick-film nanostructures with dual sensitivity.

The investigated systems include spinel-structured manganites with different conductivity types: $Cu_{0.1}Ni_{0.8}Co_{0.2}Mn_{1.9}O_4$ (p-type), $Cu_{0.1}Ni_{0.1}Co_{1.6}Mn_{1.2}O_4$ (p^+-type), and dielectric $MgAl_2O_4$ (i-type). These materials were selected for their structural compatibility and ability to form stable multilayer architectures. Humidity-sensitive layers were deposited onto pre-formed temperature-sensitive films, enabling integration of different sensing functions within a single device.

Various multilayer configurations, including p-p^+, p-p^+-p, and integrated p-i-p^+ structures, were successfully fabricated within a single technological cycle. This approach simplifies processing and ensures reproducibility while allowing functional combination of temperature and humidity sensing elements.

Microstructural analysis shows that $MgAl_2O_4$ humidity-sensitive films possess a porous structure distinct from the Al_2O_3 substrate with Ag electrodes. The films contain fine pores that facilitate water vapor diffusion and capillary condensation at the nanoscale. Larger macropores enhance moisture transport from the environment into the bulk material, improving sensor response.

In contrast, $Cu_{0.1}Ni_{0.8}Co_{0.2}Mn_{1.9}O_4$ films exhibit a higher concentration of clustered macropores. This structural feature is consistent with that of bulk ceramics of the same composition, indicating that bulk microstructural characteristics are preserved in thick-film form. The use of spinel-structured ceramics ensures good interlayer adhesion, structural stability, and dense interfaces within multilayer systems. Controlled porosity and compatible crystal structures contribute to stable electrical behavior and improved sensor performance. Overall, the results demonstrate that manganite-based and spinel-structured ceramic thick films are highly suitable for integrated temperature and humidity sensors. Their tunable electrical properties and engineered porosity enable the development of compact, reliable, and multifunctional sensing devices for environmental monitoring applications.

KEYWORDS: Thick-film ceramics, Spinel manganites, $MgAl_2O_4$ nanostructures, Humidity sensors, Temperature sensors

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T1-41 E-POSTER

Heat transfer analysis of SWCNT-reinforced polymer-based refractory nanocomposites

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Refractory nanocomposites are advanced materials characterized by high thermal resistance, chemical stability, and strong mechanical performance, making them suitable for extreme environments such as aerospace, energy systems, and metallurgy. Among them, carbon nanotube (CNT)-reinforced composites have attracted significant interest due to the exceptional thermal, electrical, and mechanical properties of CNTs, which enhance the performance of conventional refractory matrices [1,2].

This study investigates the thermal behavior of refractory nanocomposites containing 0.5% single-walled carbon nanotubes (SWCNTs) using an automated measurement approach. The experiments are based on a steady-state heat flow method, where thermal conductivity is evaluated by analyzing the temperature gradient along cylindrical samples subjected to controlled heating and cooling cycles. The setup includes a resistive heater, two thermocouples, and a thermal shielding system to ensure stable conditions. Data acquisition and real-time monitoring are performed using LabVIEW software.

The results show that SWCNT incorporation significantly improves the thermal properties of the polymer matrix. Infrared thermography reveals a well-defined temperature gradient and efficient heat distribution. Samples with a 2-hour dispersion time demonstrate better thermal stability compared to those with 1-hour dispersion. This is reflected in a more uniform temperature field and reduced thermal fluctuations. The maximum temperature difference reaches 55°C for the 2-hour samples, while it is about 50°C for the 1-hour samples. Overall, increasing dispersion time by one hour improves heat transfer efficiency and enhances fire resistance by approximately 15%.

The automated measurement system minimizes experimental errors by ensuring precise control of testing conditions. Potential inaccuracies caused by heater displacement or improper thermocouple positioning are reduced through careful system design and calibration. The use of high-precision sensors and a LabVIEW-based acquisition system ensures reliable and reproducible results.

Thermal imaging confirms that SWCNT-reinforced nanocomposites provide more uniform heat distribution, reducing localized thermal stress and improving material durability. Enhanced thermal conductivity and stability indicate strong potential for applications requiring high-temperature resistance, including aerospace structures, fire-resistant coatings, and industrial sensing systems. Overall, the study demonstrates that SWCNT-reinforced refractory nanocomposites are promising materials for high-temperature applications. The proposed automated methodology offers an efficient and reliable approach for evaluating thermal properties and supports further development of advanced refractory materials.

KEYWORDS: Refractory nanocomposites, Carbon nanotubes, Thermal conductivity, Steady-state heat flow method, Automated measurement system

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T1-42 E-POSTER

Rutin-loaded hydrogels for skin repair: Antioxidant and antimicrobial properties

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The development of biomaterials for the treatment of skin defects, including burns, ulcers, and other wounds, remains a highly relevant area of modern regenerative medicine. Skin serves as an essential barrier and protective function, and its damage may lead to serious complications, including infection and fluid loss [1]. The effectiveness of biomaterials for skin repair depends on their composition and structure [2]. Among the most promising materials for the treatment of skin defects are hydrogels, owing to their high biocompatibility, ability to maintain an optimal moist wound environment, and capacity to incorporate bioactive compounds and therapeutic agents. Their strong adhesion to the skin surface also makes them suitable for treating wounds of various shapes. Among biopolymers, gelatin, collagen, chitosan, fibrin, and alginates are widely used for biomaterial fabrication because of their favorable regenerative properties, ability to promote cell adhesion, and support for new tissue formation. In recent years, research has increasingly focused on the development of intelligent biomaterials capable of actively modulating immune responses and cellular metabolism.

It has been shown that biomaterial properties such as hydrophilicity, porosity, and the presence of immobilized inorganic nanoparticles significantly affect the rate of wound recovery and regeneration [3]. It is established that wound healing is associated with increased levels of reactive oxygen species (ROS), which degrade extracellular matrix (ECM) proteins and may delay the healing process [4]. Therefore, the use of antioxidants is of particular interest. Among them, rutin is a flavonoid that reduces oxidative stress in wounds, improves microcirculation, stimulates tissue regeneration, exhibits moderate antibacterial activity, prevents lipid peroxidation, and protects proteins and DNA [5].

The aim of this study is to determine the antioxidant and antimicrobial properties of rutin incorporated into an alginate-gelatin matrix with immobilized inorganic particles.

Alginate-gelatin wound dressings doped with nanosized calcium-deficient hydroxyapatite particles were synthesized. Rutin was introduced into the matrix in two ways: i) by adding it to the working suspension during synthesis (at a concentration of 4% of the volume of the working mixture); ii) by saturating the finished biomaterial with an aqueous 4% solution of rutin. The results showed that the antioxidant activity (AOA) of the prepared composites was 94% with rutin introduced during synthesis and 92% with saturation. The addition of rutin increases the antimicrobial activity: The zone of bacterial growth inhibition (ZOI) is 23 mm, compared to the control, where the ZOI is 20 mm (sample size - 11 mm).

Based on the obtained physicochemical and biological characteristics, the developed materials show considerable promise for the treatment of inflammatory skin wounds and are currently undergoing further studies.

KEYWORDS: Wound healing, Hydrogels, Antioxidant activity, Inorganic particles, Skin regeneration

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T1-43 POSTER

Aligned PCL electrospun membranes for nerve guidance conduits

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Peripheral nerve injuries are a common problem in medicine due to their high prevalence, diverse etiologies, and the incomplete functional recovery [1]. Artificial nerve guidance conduits (NGCs) represent an advanced strategy for the treatment of extensive peripheral nerve injuries, and their development remains a major focus in regenerative medicine [2,3]. Electrospun polycaprolactone (PCL) membranes considered among the most promising candidates for this purpose [4]. PCL exhibits favorable mechanical strength and elongation at break [5]. But, traditional randomly-oriented electrospun PCL membranes do not allow to support directed axonal regeneration by guiding nerve growth. The aim of the study was to develop aligned electrospun PCL membranes with properties suitable for guiding nerve regeneration.

PCL was dissolved in a 3:1 chloroform/dimethylformamide (CHL/DMF) mixture under continuous stirring with a magnetic stirrer for 2 h. Electrospinning was carried out at an applied voltage of 15-21 kV using G-22 needles. The distance between the needle tip and the drum collector maintained at 13-16 cm. The collector rotation speed was set to 600 rounds per minute (RPM) for the control sample (S_1) and 1000 RPM (S_2), 2000 RPM (S_3), and 3000 rpm (S_4) for the experimental ones. The structural features and morphology of the obtained membranes were evaluated using scanning electron microscopy (SEM) (Hitachi TM-3000, Japan) operated at an accelerating voltage of 15 kV in backscattered electron (BSE) mode. Morphometric analysis of the SEM images was performed using ImageJ software.

All PCL membrane samples exhibited a fibrous morphology; however, their structural characteristics varied depending on the collector rotation speed. In general, increasing the rotation speed resulted in a reduction in fiber diameter, from 0.39 ± 0.13 µm in S_1 to 0.051 ± 0.05 µm in S_4. At the same time, the membranes showed differences in fiber thickness uniformity, with the highest uniformity observed for S_2, while S_3 and S_4 demonstrated a broader distribution of fiber diameters. The analysis of fiber orientation also demonstrated clear structural differences between the samples. S_2 showed the most pronounced unidirectional fiber alignment, as confirmed by the lowest coefficient of variation in fiber orientation angles. S_4 exhibited a partially ordered structure, whereas S_3 showed weak anisotropy. In contrast, S_1 demonstrated a predominantly random fiber arrangement.

Overall, increasing the collector rotation speed provided effective control over the morphology of electrospun PCL membranes, including fiber diameter, and fiber orientation. Among the fabricated samples, S_2 demonstrated the most favorable combination of structural features, particularly improved fiber uniformity and pronounced unidirectional alignment. These characteristics make S_2 the most promising membrane configuration for applications requiring guided tissue regeneration.

KEYWORDS: Electrospinning, Aligned nanofibers, NGCs, PCL nanofibers

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T1-44 E-POSTER

Mechanical response of irradiated niobium-tin alloy with nanoscale A_{15}-phase precipitates: Phase-field modeling

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Niobium-Tin alloys containing nanoscale precipitates of the A_{15} intermetallic phase attract considerable interest as advanced structural and functional materials due to their high mechanical stability, radiation resistance, and potential applications in extreme environments. In the present work, a phase-field approach is developed to investigate the mechanical response of two-phase Nb-20 at.% Sn alloys containing nanoscale A_{15} precipitates before and after irradiation.

The model combines thermodynamic free-energy formalism with nonlinear elasticity theory and explicitly accounts for the coupled evolution of local composition fields, vacancy concentration, and elastic displacement fields. Radiation-induced nonequilibrium vacancies are incorporated through defect-strain coupling terms, while elastic mismatch between the matrix and A_{15} precipitates is described using composition-dependent elastic moduli and periodic nonlinear shear energy. Dynamic evolution of the elastic fields is described by the lattice momentum equation coupled with phase-field kinetic equations.

Numerical simulations were performed for both pre-irradiated and post-irradiated alloys with nanosized precipitates of A_{15}. Mechanical behavior was investigated under monotonic shear loading, cyclic shear deformation, and uniaxial compression/tension. The simulations demonstrate that irradiation leads to a pronounced increase in yield strength and ultimate strength, indicating radiation-induced hardening of the Nb-Sn alloy. Under shear loading, the yield stress increases, while the ultimate strength increases from after irradiation. Similar strengthening effects are observed under compressive and tensile loading.

Spatial analysis of elastic fields reveals that plastic deformation is governed by the nucleation and propagation of slip lines associated with pairs of edge dislocations. These defects preferentially nucleate in the softer Nb matrix and are strongly influenced by nanoscale A_{15} precipitates, which act as barriers for dislocation motion and promote stress localization. Under cyclic loading, hysteresis loops and residual stresses are observed, with irradiated samples exhibiting reduced plastic strain accumulation and enhanced cyclic hardening.

The obtained results demonstrate that irradiation-induced defect structures together with nanoscale A_{15} precipitates substantially modify the deformation mechanisms in Nb-Sn alloys by suppressing dislocation mobility and increasing resistance to plastic flow. The developed approach provides a useful framework for predicting the mechanical performance of radiation-resistant nanostructured superconducting and structural materials.

KEYWORDS: Numerical modeling, Deformation, Elastic fields, Strength

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T1-45 POSTER

Theoretical analysis of the geometry of graphene scrolls

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The global market is experiencing an unprecedented surge in foldable electronics innovations. Among the materials enabling this technological leap, graphene has emerged as a promising material, owing to its inherent flexibility, bendability, and elasticity, positioning it as a key component in the fabrication of these devices. This work proposes a theoretical model to advance our knowledge of the mechanisms of graphene scrolling. Through this model, we study the minimum length of graphene required to form a particular number of scrolls by examining the energy cost. The model takes into account the bending rigidity of graphene and the van der Waals (vdW) interaction energy between carbon atoms within the graphene sheet. The Lennard-Jones potential is employed within the model to evaluate the vdW interaction energy arising from the graphene interlayer interactions during the scrolling formation. Then, the scrolling conformation of graphene is presented as parametric solutions derived from variational techniques adopting the Ritz method. The findings of the proposed model are subsequently compared with experimental data reported in the literature, and the comparison demonstrates good agreement in terms of the inner and outer radii of the scroll, number of coils, and total length. The model predicts that the total length of graphene scrolling structures containing one to five coils varies from 6.0 to 70.7 nm, depending on both the number of coils and the model parameters. For example, the total length of a three-coil graphene scroll with a bending rigidity of 1.2 eV [1], is calculated to be 27.5 nm, which lies well within the experimentally reported range of 18.1-36.7 nm [2]. The theoretical approach presented here holds the potential to significantly reduce the time and cost associated with trial-and-error experiments in characterizing graphene scrolling behavior, with direct implications for the design of next-generation foldable electronic devices.

KEYWORDS: Graphene, Mathematical model, Variational calculus, Scrolling conformation, Foldable electronics

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T1-46 POSTER

Förster resonance energy transfer in restricted geometry

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Non-radiative energy transfer in luminescent systems based on the dipole-dipole interaction mechanism proposed by Förster [1] has been widely employed as a nanoscale spectroscopic ruler. This approach provides valuable information on the conformational distributions of biologically active macromolecules and has found applications in bioimaging analysis, evaluation of targeted drug therapies, biosensing, and antenna systems. Particularly intriguing are studies of Förster Resonance Energy Transfer (FRET) in spatially confined systems. In such cases, theoretical descriptions developed for macroscopic systems cannot be applied directly. Here, we present a description of FRET in systems of limited volume and well-defined geometry, specifically spherical [2,3] and cylindrical structures. A theoretical model describing the dependence of FRET on system parameters, including spatial dimensions, numberof fluorophores, and the properties of a specific donor-acceptor pair, has been developed and presented, and Monte Carlo simulations were performed to investigate the energy transfer behavior.

KEYWORDS: Förster resonace energy transfer, Restricted geometry, Spherical nanostructures, Cylindical nanostructures, Monte Carlo simulations

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T1-47 E-POSTER

Advanced nanocomposites based on fibers titanium phosphate with "green" AgNPs for multifunctional environmental applications

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Hazardous materials such as organic, inorganic, radioactive, biological, and physical are found in environmental water. The environmental remediation of wastewater has remained a paramount concern for researchers over the past few decades. The solution to this problem may be the development of multifunctional advanced materials. Among various inorganic frameworks, fibrous titanium phosphate (TiP) stands out as a support matrix due to its high surface area, ion-exchange capacity, and stability. These structural attributes make it an ideal matrix for the impregnation of functional guest species, such as silver nanoparticles (AgNPs), which are renowned for their potent biocidal and remediation properties.

In this work, an effective and cheap inorganic nanocomposite based on fibrous titanium phosphate with embedded AgNPs (TiP@AgNPs) was first developed for potential multifunctional environmental applications. The AgNPs were prepared by "green" synthesis using CH_3COOAg solution and Melissa officinalis extract (EtOH, 70 %). The biosynthesized AgNPs were characterized through a series of instrumental methods. The UV-Vis spectrum of the AgNPs exhibited a λmax at 425 nm. The size of biosynthesized AgNPs is estimated to be ~ 15-18 nm according to the TEM method. Additionally, the as-prepared AgNPs exhibited nucleoprotective properties due to the formation of a 'core-shell' structure, which prevented the aggregation of the resulting nanoparticles. As expected, AgNPs could be stored for more than 1 year at room temperature. The TiP@AgNPs nanocomposite was prepared by in-situ treatment of nanofibres with biosynthesized AgNPs. TEM data of TiP@AgNPs show that the AgNPs are distributed uniformly and monodispersely across the surface of fibres. The TiP@AgNPs nanocomposite exhibited potent antibacterial activity against both Gram-positive (*S. aureus*) and Gram-negative (*E. coli*). The Gram-negative strain proved more susceptible, with minimum inhibitory concentration and minimum bactericidal concentration of 0.5-1.0 mg/mL and 1.0 mg/mL, respectively. Furthermore, when utilizing TiP@AgNPs as sensors for Hg^{2+} ions detection in both double-distilled and deionised waters, the limits of detection (LOD) were determined to be 0.030 μM and 0.025 μM, respectively, within a wide linear range (0.05-2.00 μM). Thus, the as-prepared nanocomposite demonstrates multifunctionality as a highly sensitive sensor for Hg^{2+} ions detection in various water matrixes and a potent antibacterial agent.

KEYWORDS: Fibrous titanium phosphate, Silver nanoparticles, Green synthesis, Antibacterial activity, Hg 2+

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T1-48 POSTER

Biowaste-derived carbon dots integrated with metal-organic frameworks for printable biosensing platform

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Biosensing devices play a crucial role in diverse fields such as disease diagnosis, pharmaceutical research, and the identification of pathogens and contaminants in biological samples. Notably, electrochemical biosensors dominate the market due to their broad applicability in healthcare and environmental monitoring. Combining the nanomaterials, characterized by high surface area, excellent conductivity, and tunable properties, further improves sensor performance by enhancing sensitivity, selectivity, and reproducibility.

In this study, carbon dots derived from citrus peel biowaste (BWCDs) are integrated with metal-organic frameworks (MOFs) where BWCDs provide rich surface functionality, while MOFs contribute highly porous and adjustable architectures that facilitate effective antibody immobilization. The resulting BWCD-MOF heterostructures are structurally and compositionally characterized and optimized to be formulated into a printable ink for biosensor fabrication. Finally, in order to enhance the performance of the biosensors a technique, wiz scanning electrochemical microscopy is explored to lower the limits of detection for tumor necrosis factor-alpha (TNF-alpha), an important pro-inflammatory cytokine linked to early diagnosis and progression of diseases such as Alzheimer's disease, sepsis, and cancer.

KEYWORDS: Biosensor, Heterostructures, Immobilization, Detection, Cytokines

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T1-49 E-POSTER

Enzymatic Processing of Hemp (Cannabis sativa) with Industrial Enzymes

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Cellulose, the most abundant biopolymer on Earth, offers innovative solutions in diverse areas, particularly in the form of micro-/nanofibrillated cellulose (MFC/NFC). While cellulose is traditionally sourced from cotton or wood pulp, industrial hemp has emerged as a structurally superior and technologically feasible alternative. Furthermore, hemp cultivation is significantly more ecologically sustainable, yielding a higher volume of cellulose per hectare per year compared to traditional forestry or cotton plantations.

Within plant tissues, raw hemp cellulose fibers are bound together by an intricate matrix of non-soluble polysaccharides and aromatic compounds, primarily consisting of lignin, pectin and hemicellulose. Historically, the extraction of these fibers relied heavily on resource-intensive water retting and harsh chemical treatments. However, the selective removal of the non-cellulosic components via targeted enzymatic degradation offers a highly sustainable and economically attractive alternative. Yet, the costs of the purified enzymes make them hardly suitable for industrial scale processing of the plant biomass.

On the other hand, industrial grade enzymes are widely used in agroindustry for animal nutrition by softening plant-based forage for better digestibility and higher nutrition values. Consequently, this project aimed at developing optimized protocols for the enzymatic processing of industrial hemp using affordable industrial grade enzyme preparations. Hemp biomass was harvested at technical maturity at the experimental fields of the Institute of Bast Crops NAANU in Hlukhiv, Ukraine. Enzyme preparations Xylanase, Pectinase, Ladozym Respect Ultra and Cellozym Ultra were purchased from Enzim Biotech LTD, Ladyzhyn, Ukraine.

We found that treatment of hemp fibers with Cellozym Ultra (CU) enzyme mix yielded the fibers with the lowest percentage of the final dry fibers in relation to the wet input biomass (11.33%), which suggested the most active digestion of lignocellulose. This treatment also resulted in the softest fibers in comparison to other treatments. The CU treated fibers were processed using blending in water followed by drying, milling and grinding in a Super Mass Colloider (Masuko, Japan). Optical microscopy revealed that the obtained gel contained MFC/NFC. Sedimentation analysis suggested that the gel had a colloidal nature. This study demonstrated feasibility of the biocatalytic approach to process industrial hemp using industrial enzymes to replace harsh chemical treatments. To the best of our knowledge, this study was the first to obtain MFC/NFC from hemp using industrial grade enzymes. Overall, the enzymatic processing of plant fibers using affordable industrial enzymes represents a significant advancement in sustainable processing technology, directly facilitating the broader application of advanced hemp-derived cellulose and its derivatives.

KEYWORDS: Biocatalytic processing, Industrial grade enzymes, Microfibrillated cellulose, Nanofibrillated cellulose, Sustainability, Valorization

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Track 2

MXenes: Physics, Chemistry, and Applications

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T2-01 INVITED

From flakes to functions: design-driven MXene platforms for energy and bio-interfaces

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Two-dimensional MXenes have rapidly evolved from laboratory curiosities to versatile platforms for multifunctional devices, yet translating their exceptional intrinsic properties into robust technologies remains a central challenge. In this invited talk, I will present a design-driven approach to MXene-based materials, spanning synthesis, scalable assembly, and integration into functional architectures for energy storage, tissue engineering, cancer therapy, and anti-icing/deicing applications.

I will first discuss how rational selection of MXene chemistry, flake morphology, and interface engineering enables high-performance, flexible, and environmentally benign nanocomposites for electromagnetic shielding and next-generation energy storage, highlighting our recent work on MXene-cellulose nanofiber and MXene-polyimide systems. Building on these concepts, I will then show how structure-property control-via electrophoretic deposition and tailored surface terminations-can be leveraged to create mechanically robust, conformal coatings and layered architectures, offering a pathway from batch synthesis to scalable, industry-relevant manufacturing. I will further explain how surface modification of MXene tunes its compatibility with polymer matrices and enhances supercapacitance, providing guidelines for optimizing electrochemical performance. Finally, I will outline emerging opportunities where MXene's unique combination of metallic conductivity, hydrophilicity, and photothermal/electrothermal responsiveness is harnessed for cancer therapy and anti-icing/deicing coatings, pointing to strategies that couple multiphase design with multifunctionality to address reliability, stability, and safety requirements in real-world environments.

By connecting fundamental design rules with application-specific constraints, this talk aims to provide a coherent framework for engineering MXene-based systems that bridge the gap between laboratory prototypes and practical devices.

KEYWORDS: MXene, Surface modification, Tissue engineering, Electrode, Cancer therapy

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T2-02 INVITED

MXenes for environmental remediation: from fundamental science to sustainable solutions

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Pollution control and environmental remediation remain major global challenges. In recent years, MXenes have attracted increasing attention across diverse research fields, including environmental remediation [1]. However, the practical implementation of MXene-based materials in existing technologies or as replacements for conventional materials requires precise control over physicochemical properties and long-term stability [2]. In particular, the surface chemistry of MXenes plays a decisive role in determining their adsorption behavior, catalytic activity, selectivity, and interaction with target pollutants. Functional groups such as -O, -OH, and -F can provide active sites for the capture of heavy metal ions, organic dyes, pharmaceutical residues, and other emerging contaminants. At the same time, a layered structure facilitates rapid ion diffusion and provides an abundant accessible surface area, thereby enhancing removal efficiency and reaction kinetics. These characteristics make MXenes attractive candidates for the development of efficient and selective adsorbents and sensors [3,4].

In this study, $Ti_3C_2T_x$ MXene was synthesized using a minimally intensive layer delamination (MILD) etching protocol, followed by comprehensive characterization of its key physicochemical properties. After evaluating the structural, morphological, and surface characteristics of the synthesized MXene, the material was used to develop an efficient, reusable adsorbent for environmental remediation. The adsorption kinetics and equilibrium isotherm models were further investigated to elucidate the underlying mechanisms governing the adsorption performance of $Ti_3C_2T_x$ MXene. In addition, various strategies were examined to improve the stability and shelf-life of MXenes, thereby broadening the practical implementation potential. The results demonstrated that selected modifications can effectively suppress MXene oxidation in aqueous environments while preserving its performance.

KEYWORDS: MXenes, Wastewater treatment, Stability

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T2-03 ORAL

Novel ligand coordinated Ti_2CTx MXene/Cd-MOF composite for improved hydrogen evolution

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The search for sustainable alternative energy sources is widely regarded as a key approach to addressing the growing energy crisis and environmental challenges. Among the proposed solutions, hydrogen production via photocatalytic water splitting using sunlight stands out as a practical and promising strategy [1]. However, achieving high efficiency requires the development of advanced photocatalysts that can effectively harvest solar energy across a broad range of the visible spectrum, promote efficient charge separation, facilitate electron transport, suppress charge recombination, and maintain long-term stability while remaining environmentally benign. To design a new composite photocatalyst candidate, MXene and MOF materials were combined. MXenes are a recently developed class of two-dimensional materials composed of transition metal carbides, nitrides, or carbonitrides. They are characterized by a large specific surface area, diverse surface functional and terminal groups, exceptionally high electrical conductivity, numerous active sites, intrinsic hydrophilicity, strong mechanical properties, and notable chemical stability [2]. Metal-organic frameworks (MOFs) are hybrid inorganic-organic materials consisting of metal cation centers interconnected by organic ligands, forming extended network structures [3]. MOFs are selected for photocatalytic hydrogen production due to their high surface area, tunable band gap, and controllable, functionalizable crystalline structures.

In this study, a novel Cd-based MOF/Ti_2CT_x MXene heterostructure was developed as a potential high-performance photocatalyst. A new Cd-MOF was synthesized using a six-armed, phosphorus- and nitrogen-rich hexatopic ligand, and subsequently combined with Ti_2CT_x through three different methods: ligand-bridged assembly (forming covalent coordination), in situ growth, and physical mixing. Photocatalytic hydrogen evolution experiments conducted under simulated sunlight ($\lambda > 420$ nm) demonstrated that the ligand-bridged Ti_2CT_x/Cd-MOF heterostructure achieved the highest activity, with a hydrogen production rate of 3505 μmol h^{-1} g^{-1} representing a 2.3-fold enhancement over the bare Ti_2CTx and Cd-MOF. The superior performance is attributed to the covalent ligand-bridging strategy, which significantly improves interfacial electron transfer and migration, as well as to the synergistic interaction between the MOF and MXene components.

Overall, this work provides a compelling example of designing efficient photocatalytic heterostructures through covalent coordination strategies and contributes valuable insights toward meeting the increasing demand for hydrogen as a clean and sustainable energy carrier.

KEYWORDS: MXene, MOF, Photocatalyst, Hydrogen energy, Water splitting

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T2-04 ORAL

Glassy-carbon-assisted electrochemical etching of MAX phases: Control, limitations, and opportunities

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Electrochemical etching of MAX phases is increasingly considered a promising and safer alternative to conventional MXene synthesis routes relying on concentrated HF [1], yet recent studies clearly indicate that this approach still requires substantial optimization to deliver materials with well-controlled and reproducible structures [2,3]. Reported protocols often struggle with incomplete removal of the A layer, the concurrent formation of carbide-derived carbon, and a narrow processing window between selective etching and destructive oxidation of the $M_{n+1}X_n$ backbone.

In our setup, a glassy carbon crucible acts as the working electrode, a glassy carbon rod serves as the counter electrode, and an Ag/AgCl/0.1 M KCl electrode is used as the reference. The MAX phase is electrochemically etched in an aqueous electrolyte containing tetramethylammonium tetrafluoroborate dissolved in sulfuric or phosphoric acid, which provides a fluorine-containing anion without the use of bulk HF solutions and allows tuning of the proton activity and ionic strength. The process is performed for 48 h at a constant potential of 2 V versus Ag/AgCl, enabling a gradual weakening and removal of the A-layer while maintaining a well-defined electrochemical driving force. This controlled potential regime is intended to minimize uncontrolled corrosion and over-oxidation that frequently accompany purely galvanostatic or two-electrode configurations.

Scanning electron microscopy reveals the formation of layered, accordion-like morphologies characteristic of MXenes, with expanded interparticle gaps indicative of successful interlayer opening. Raman spectra exhibit bands typical of MXene phases, confirming preservation of the M(n+1)Xn framework and substantial removal of the A element from the parent MAX phase. At the same time, the extended etching time and relatively high anodic potential promote defect generation and local over-oxidation, which we highlight as an intrinsic limitation of the current protocol and a key target for further optimization.

By juxtaposing our results with the existing electrochemical etching literature, we discuss the main advantages (HF-free operation, potential tunability, access to diverse surface terminations) and drawbacks (possible defect-rich products, competing side reactions, sensitivity to electrolyte composition) of this route toward "greener" MXene synthesis. We argue that a carefully designed three-electrode configuration with a glassy-carbon working vessel provides a convenient platform to systematically map the etching window in terms of potential, time, and electrolyte chemistry, and thus to rationally tailor electrochemical protocols that can realistically compete with HF-based methods in terms of safety and MXene quality.

KEYWORDS: MXene, Electrochemical etching, Glassy carbon, Chronoamperometry, HF-free

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T2-05 ORAL

Effect of different surface terminations and single atom catalyst on MXene's reactivity for water dissociation: A density functional theory investigation

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Transition metal carbides (MXenes), a class of two-dimensional (2D) materials, are a promising candidate for catalytic applications due to their remarkable surface reactivity. Numerous theoretical and experimental studies clearly illustrated that surface termination and its variation have a great influence on the catalytic performance of MXenes. Motivated by recent advances in MXene-based catalysis by Kolos et al. [1] and Gouveia et al.[2], we are studying the water dissociation reaction on a set of MXene (M_2CT_2, where M represents transition metals such as Sc, Ti, V, and Cr, while T refers to functional group O and F) by performing density functional theory (DFT) calculations. Our primary goal is to investigate the impact of different surface termination groups, both in their pristine and defective (vacancy) forms, on MXene's reactivity as a catalyst for water dissociation. Furthermore, one of the effective methods that increases catalytic activity is single-atom catalysis (SAC). SAC maximizes the atomic efficiency of metals and offers a different way to adjust the activity and selectivity of catalytic reactions by dispersing or coordinating a single atom with surface atoms of appropriate support [3]. In this context, we additionally investigate the impact of Pd as a SAC anchored on specific MXene surfaces to analyze how its presence changes the reaction geometry of the water molecule and dissociation energy on the MXene surface. We aim that this work will provide valuable insight for improving MXenes in catalytic processes.

KEYWORDS: MXenes, Water gas shift reaction, Density functional theory, Catalysis

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T2-06 ORAL

High-throughput study of mixed-termination effects in MXenes: from electronic structure to transport

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High-performance computing strongly accelerated computational screening in the prediction of nanomaterial properties. Two-dimensional materials represent such a platform for tuning material properties through atomic-scale modifications, with MXenes representing a prominent class due to their metallic conductivity, hydrophilicity, and chemically active surfaces.[1] Their properties are strongly influenced by surface terminations, which are inherently present and difficult to control experimentally. The most common terminal groups (F, O, OH, Cl) have a significant impact on the stability, electronic structure, optical properties, and transport properties of M_2CT_2 (M = Sc, Ti, V, Cr) MXenes.[2,3] While prior studies have focused on idealized, uniformly terminated systems, experimental samples exhibit mixed surface compositions, leading to large variations in reported properties, particularly electrical conductivity. A systematic understanding of how mixed terminations determine intrinsic material behavior is still lacking.[4,5]

We have addressed these issues by quantifying the effects of mixed surface terminations on the electronic structure and transport properties of M_2CT_2 MXenes. We show that terminal groups on opposite sides of the MXene are effectively independent, and that the properties of the material are governed primarily by the overall surface composition rather than by specific surface patterns. To address the large configurational space of mixed terminations, we employ a high-throughput computational approach combining efficient parallelization strategies with a self-developed code for automated generation of structural variations. This enables systematic sampling of a wide range of compositions and configurations while maintaining computational feasibility. The observed independence of surface terminations further reduces the effective configurational complexity, as variations in surface arrangement have a negligible impact on cohesion energy and band structure. At the same time, semiconducting MXenes exhibit extreme sensitivity to conduction-inducing terminations, with concentrations as low as ~1% sufficient to close the band gap, explaining the difficulty of their experimental realization. Transport calculations yield conductivities on the order of 300 kS/m and show nearly constant carrier relaxation times, enabling simplified treatment of mixed systems. These results establish a direct link between surface composition and measurable properties in MXenes.

KEYWORDS: MXenes, Ab-initio, Surface functionalization, Mixed termination, Transport properties

ACKNOWLEDGEMENTS: This work has been produced with the financial support of the European Union under the LERCO project (number CZ.10.03.01/00/22_003/0000003) via the Operational Programme Just Transition and the University of Ostrava (number SGS01/PrF/2025). The computations were performed at IT4Innovations National Supercomputing Center through the e-INFRA CZ (ID:90254).

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Posters

T2-07 **POSTER**

Reproducible colloidal stability of Au@MXene nanohybrids via ionic environment modulation for biosensing applications

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2D nanomaterials have attracted significant attention due to their unique physicochemical properties and potential in advanced sensing technologies. Among these, MXenes are particularly promising owing to their high surface area, excellent electrical conductivity, and tunable surface chemistry. However, their colloidal stability-especially after surface functionalization - remains a critical limitation for practical applications. MXene-based nanohybrids, such as Au-decorated Ti_3C_2TX MXenes, have been widely explored to enhance functionality in biosensing platforms. In our system, gold (Au) nanoparticles are formed in situ on MXene flakes via self-assembly. However, nanoparticle incorporation and surface modification processes can alter surface charge characteristics, reduce dispersion stability and limit effective utilization. This issue is further compounded by the lack of systematic reproducibility studies in MXene-based systems. Here, we address the instability of Au@MXene nanohybrids and propose a reproducible strategy to control their colloidal behavior. We demonstrated that controlled ionic environment engineering through citrate addition effectively restores and enhances colloidal stability, achieving a zeta potential of approximately -45 mV. Reproducibility, validated through triplicate experiments, demonstrates consistent particle size and surface charge distributions, addressing a key gap in MXene research. These findings provide a simple and effective approach for stability engineering in MXene-based nanohybrids, facilitating reliable functionalization for biosensing applications. More broadly, this work offers practical insights into the integration of 2D nanomaterials into robust nanodevice platforms.

KEYWORDS: Ti_3C_2T X, MXene nanohybrids, Colloidal stability, Ionic environment control, Gold nanoparticles (AuNPs)

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T2-08 POSTER

Synergistic electrochemical performance of Ti_2VC_2Tx MXene and carbon confined metal phosphide heterostructures for advanced energy storage

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The rapid growth of portable electronics and electric vehicles has increased the demand for advanced energy storage systems with high power density, large charge storage capacity, and long cycling stability. Two-dimensional transition metal carbides and nitrides, known as MXenes, are promising electrode materials because of their metallic conductivity, hydrophilic surfaces, tunable surface terminations, and surface-controlled charge storage. Among them, $Ti_2VC_2T_x$, a M_3X_2-type MXene, is especially attractive because vanadium incorporation into the titanium carbide lattice improves electronic structure and redox activity. This bimetallic configuration enhances electrochemical reactivity compared to monometallic MXenes. However, pristine MXenes still suffer from nanosheet restacking, which reduces ion accessibility and active surface area, limiting practical capacity.

In this work, we developed a composite electrode by combining $Ti_2VC_2T_x$ MXene with carbon-confined copper phosphide (Cu_3P@C), derived from a copper-based metal-organic framework (MOF) through pyrolysis. A series of $Ti_2VC_2T_x$/Cu_3P@C composites with different ratios were systematically studied to identify the best balance between the high conductivity and pseudocapacitive behavior of MXene and the high specific capacity of Cu_3P. In this structure, MXene sheets form a continuous conductive network for fast electron transport and buffer the volume changes of Cu_3P during repeated ion insertion and extraction. Meanwhile, the Cu_3P@C phase provides additional redox-active sites, increasing overall charge storage capacity.

Electrochemical characterization using cyclic voltammetry, galvanostatic charge-discharge, and electrochemical impedance spectroscopy shows that the $Ti_2VC_2T_x$/Cu_3P@C heterostructure effectively suppresses MXene restacking and increases the number of electrochemically accessible active sites. Interfacial coupling improves charge transfer kinetics and enables a synergistic storage mechanism combining MXene pseudocapacitance with faradaic redox reactions from Cu_3P. The presence of multiple redox-active metals (Ti, V, and Cu) also provides richer redox chemistry, improving capacity and expanding the operational potential window.

Overall, this study demonstrates that integrating bimetallic MXenes with carbon-confined metal phosphides is an effective strategy to overcome the limitations of individual electrode materials. By improving interface engineering and ion-accessible surface design, $Ti_2VC_2T_x$-based composite electrodes show strong potential for high-rate pseudocapacitive energy storage and next-generation battery technologies.

KEYWORDS: Ti2VC2Tx, MXene, MOF mediated structures, Copper phosphide, Bimetallic MXenes

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T2-09 POSTER

Synergistic enhancement of photocatalytic formaldehyde degradation via CeO_2/Ti_3C_2 MXene hybrid

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Formaldehyde is a major indoor air pollutant posing severe health risks, driving the need for efficient and sustainable removal technologies[1]. In this work novel MXene-based hybrid nanostructure integrating Ti_3C_2Tx MXene with CeO_2 was reported for enhanced HCHO degradation under ambient conditions. Ti_3C_2-MXene is known for its excellent electronic conductivity and optical properties which act as a promising co-catalyst for the development of efficient photocatalysts[2].CeO_2 was synthesized using solgel method giving a particle size of less than 5-20 nm and the hybrid was synthesized via chemical mixing[3].

Upon exposure to solar light, CeO_2/Ti_3C_2 hybrid demonstrates superior degradation efficiency of nearly 80% as compare to bare CeO_2 (58%) in 240 min which is 1.4 times than bare CeO_2. The enhanced performance of the CeO_2/Ti_3C_2-MXene hybrid is attributed to the formation of a Schottky junction at the interface and increased surface area of 26.794m2/g, which facilitates the transfer of photogenerated electrons promoting efficient charge separation and suppressing electron-hole recombination which leads to faster oxidation of HCHO into CO_2 and H_2O. This study provides new insights into the design of MXene-based hybrid systems for air purification and underscores their potential in environmental remediation applications

KEYWORDS: HCHO, CeO2, Photocatalysis, Degradation efficiency, Catalytic performance

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T2-10 E-POSTER

Reversible sequestration and competitive desorption of resveratrol on Ti_3C_2Tx MXenes

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The key concept in the design of 2D nanomaterials for drug and bioactive compound delivery is to achieve a balance between payload retention and local release to minimise premature elimination and systemic toxicity. $Ti_3C_2T_x$ MXenes are promising nanocarriers, but their dynamic interactions with hydrophobic payloads and systemic transport proteins require further study. This work aims to elucidate a time-dependent, competitive desorption mechanism in a ternary system consisting of $Ti_3C_2T_x$ MXenes, the hydrophobic polyphenol trans-resveratrol (3,5,4'-trihydroxystilbene, Res), and bovine serum albumin (BSA).

UV-visible, steady-state, and synchronous fluorescence spectroscopy studies showed formation of a complex in binary systems ($Ti_3C_2T_x$-BSA, $Ti_3C_2T_x$-Res, BSA-Res) and in a ternary system, consisting of BSA introduced to $Ti_3C_2T_x$ MXenes pre-incubated for 1 h with Res. Dual-wavelength fluorescence spectroscopy at excitations 278 nm and 300 nm was employed to monitor emission states of BSA and Res, respectively, during 1-hour and 24-hour incubations at physiological temperature (37^0C). Short-term incubation indicated that $Ti_3C_2T_x$ MXenes rapidly adsorbed Res and acted as a "kinetic sponge", holding a significant portion of the polyphenol, thereby decreasing its initial release and its interaction with BSA.

In contrast, long-term incubation resulted in a complete reversal of this effect: the 24-hour ternary system exhibited synergistic quenching (Stern-Volmer quenching ratios F_0/F=4.10, compared to the 3.27 in binary BSA-Res system) and an expansion in binding stoichiometry (number of binding sites n=1.32 compared to the 0.75 in binary BSA-Res system). Following 24 h of thermodynamic equilibration, $Ti_3C_2T_x$ MXenes released more than 90% of Res into BSA. The ternary $Ti_3C_2T_x$-Res-BSA complex exhibited decreased fluorescence intensity with increasing Res concentration (1.56-12.5 μg/ml) and a red shift (bathochromic) in wavelength, suggesting changes in BSA - polar environment around tryptophan residues. These results demonstrate that $Ti_3C_2T_x$ MXenes induced conformational unfolding of BSA, exposing previously inaccessible hydrophobic pockets and increasing its binding capacity for Res.

Thus, $Ti_3C_2T_x$ MXenes may serve as affinity-responsive, time-release nanocarriers that protect hydrophobic small molecules during initial circulation and enhance their target bioavailability.

KEYWORDS: Ti3C2Tx, Nanocarriers, Fluorescence quenching, Bovine serum albumin, Resveratrol

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T2-11 POSTER

Enhancing the electrochemical performance of MOF anodes through MXene integration

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Rechargeable lithium-ion batteries (LIBs) require electrode materials that combine high capacity, fast charge transport, and long-term cycling stability. Although metal-organic frameworks (MOFs) possess high surface areas, tunable porous structures, and abundant ion-storage sites, their practical application is restricted by poor electrical conductivity, structural instability, and pore collapse during repeated cycling. Similarly, MXenes exhibit excellent electrical conductivity, large surface area, and favorable redox activity, but their electrochemical performance is limited by oxidation and layer restacking [1-4]. To overcome these drawbacks, this study developed MXene@MOF composite anodes by integrating $Ti_3C_2T_x$, Nb_2CT_x, and V_2CT_x MXenes with MOF-5 and ZIF-67 frameworks. The hybrid architecture was designed to enhance electrical conductivity, strengthen electrode-electrolyte interactions, and improve structural stability through the formation of a stable solid electrolyte interphase. Electrochemical evaluations in half-cell and full-cell LIB configurations showed that ZIF-67-based composites outperformed the corresponding pristine materials, with the ZIF-67@Nb_2CT_x anode delivering the best performance, achieving a reversible capacity of approximately 510 mAh g-1 after 1000 cycles together with excellent rate capability and low charge-transfer resistance. In contrast, MOF-5-based composites exhibited performance comparable to the pristine MOF-5. These findings demonstrate that MXene-MOF hybridization is an effective strategy for developing high-capacity and durable LIB anodes.

KEYWORDS: Anode electrode, Energy storage, Lithium-ion battery, MXene, ZIF-67

ACKNOWLEDGEMENTS: The authors gratefully acknowledge the financial support provided by the Scientific Research Projects Coordination Unit of Van Yuzuncu Yil University under Project No. FBA-2026-12854.

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Track 3

Quantum Materials, Devices, and Phenomena

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T3-01 INVITED

Exciton-stimulated emission of a SnO thin film on a Sn plate formed by Nd:YAG laser oxidation

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Tin oxide (SnO) crystal is an indirect band-gap semiconductor with Eg=0.9 eV, but intensive luminescence takes place at direct transition with energy Eg = 2.5-3.6 eV, and 98 meV exciton binding energy at room temperature. Therefore, it has been successfully used in optoelectronics, energy storage devices, and sensors [1]. However, there is no significant research or clear indication in the literature suggesting that SnO thin films are capable of or have been used for lasing. Therefore, the aim of our investigation is to find the conditions under which SnO thin film can be used for lasing. A plate of Sn with 99.5% purity was irradiated with pulses of the Nd: YAG laser at a wavelength of λ=1064 nm, and the frequency of repetition of laser pulses was 10Hz. The irradiation of 5 lines with intensities I_1=6 GW/cm2, I_2=5.5GW/cm2, I_3=3 GW/cm2, I_4=3.6 GW/cm2 and I_5min= 2 GW/cm2 were used in experiments. Photoluminescence (PL) spectra and relaxation spectra were measured using femtosecond laser excitation (τp = 180 fs) at λ = 266 nm, with a regulated excitation pulse fluence in the 8 μJ/cm2-1.7 mJ/cm2 range. The PL spectra were measured with 20 ps temporal resolution. The diameter of the laser beam spot was 125 μ. The structural properties and phase composition of the films were studied using a Raman spectrometer in backscattering geometry at room temperature [2]. The phonon excitation was induced with an Ar+- laser (λex = 514.5 nm). XRD structural characterization was performed on a Rigaku SmartLab diffractometer (Japan) equipped with a scintillation detector SC-70. An optical microscope with UV illumination of the sample was used to visualize invisible (transparent) SnO thin films. It was found that all irradiated zones exhibit a typical SnO crystal PL spectrum with two bands: an excitonic band at a maximum wavelength of 375 nm and a defect-related band at 450 nm. The relation intensities of these bands Iex/Idf determine the quality of the crystal [3] and the highest is 100 for 5 zone. It means that the best crystallinity of the SnO thin film is obtained at Nd: YAG laser irradiation intensity of 2 GW/cm2 and is characterized by exciton-stimulated emission at λ=375 nm. The lasing emission threshold is Ith = 0.8 mJ/cm2 when excited by a femtosecond laser at λ = 266 nm. It was found that the best crystallinity of the SnO thin film is obtained at Nd: YAG laser irradiation intensity of 6 GW/cm2 and is characterized by exciton-stimulated emission at λ=375 nm. The lasing emission threshold is Ithr = 0.8 mJ/cm2 when excited by a femtosecond laser at λ = 266 nm.

KEYWORDS: Nd, YAG laser, Sn laser, Laser oxidation, Visualization

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T3-02 INVITED

Explore flat-bands with artificial atomic lattices

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Flat-bands yield electrons in the band with vanishing group velocity and divergent effective mass, promoting strong correlation physics. Previous investigations only found a rather limited number (~10) of 2D flat-band lattices with the number of the sites in an unit cell less than 10. In addition, the flat bands of many well-known lattices, such as Lieb and kagome lattices are obtained with the nearest neighbor (NN) hopping only. The adding of the higher order NN hopping, however, strongly influences the flatness of the band and the originally predicted flat-band is no longer flat.

In this talk, I will present our recent studies of flat-bands with artificial atomic lattices. In Fe adatom on Ag(111), we found a surface state assisted long range hopping between adatoms, where the hopping shows an inverse square dependence with their separation rather than the commonly thought exponential one [1]. With this system, we demonstrate a band compression effect with can effectively compress the bandwidth of a particular band and convert it to a flat band [2]. Further, we show a general method for realizing flat bands based on mathematical optimization and symmetry analysis. The method allows us to find over 1000 flat-band lattices, implying flat-band structures are far more abundant than previously thought [3]. Moreover, in a joint tight-binding and experimental efforts, we demonstrate a convenient approach to tune the Flat-band energy in an almost continuous manner [4]. These findings suggest that the artificial atomic structures can serve as an interesting playground to explore the rich flat-band physics.

KEYWORDS: Flat-bands, Artificial atomic lattices, Scanning tunneling microscopy, Atomic manipulation

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T3-03 INVITED

From charge to emerging quantum states: rare-earth complexes on surfaces

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Complexes containing rare-earth ions attract great attention for their technological applications, ranging from spintronic devices to quantum information science. In the rare-earth-based molecules, the interaction between the metal atom and local electronic states plays a vital role in determining their properties. This can be exploited by engineering molecular ligands to tailor them for desired applications. These molecular ligands not only protect the rare-earth atoms from the surrounding environment but also influence their electronic and magnetic properties [1,2]. We have designed a variety of rare-earth (Eu, Tb, Er, La, and Lu) based molecular complexes and studied their self-assemblies on noble metal surfaces using low-temperature scanning tunneling microscopy (STM) and tunneling spectroscopy combined with synchrotron X-ray experiments. We are able to form molecular complexes that retain the charge state of rare-earth ions on metallic surfaces, opening their potential applications in a solid-state environment. In some rare-earth clusters, the self-assembled structures are formed by electrostatic and dispersive interactions [3]. Many of these complex assemblies are chiral and exhibit exotic properties on metallic surfaces, including quantum superposition and internal Stark effects. Internal polarizability induced by counterions is also investigated, not only on individual complexes on metallic surfaces, but also on artificially assembled complex structures using STM molecular manipulation schemes [4].

KEYWORDS: Rare-Earth, STM, Synchrotron X-rays, Atomic manipulation, Metal surfaces

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T3-04 INVITED

Quantum energy teleportation and effective thermodynamics

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Whether quantum informational resources can be converted into energy is a fundamental physical question, and it is also a question closely connected to the development of quantum technology. Quantum energy teleportation (QET) is a protocol in which energy is extracted at a distant location by performing projective measurement, classical communication, and feedback operation on the ground state of a quantum many-body system with entanglement. Since thermodynamics involving measurement and operation is incomplete, the information-thermodynamic and quantum-thermodynamic understanding of QET is still insufficient. This study clarifies the first and second laws of effective thermodynamics. The entire system is a quantum system at zero temperature, but the subsystem from which energy is extracted experiences effective temperature effects due to interactions with other subsystems. First, in relation to the first law of thermodynamics, the ways in which heat and work are defined were clarified. Next, in relation to the second law of thermodynamics, it was proven that the upper bound of locally extractable energy can be transformed into the same form as the famous Sagawa-Ueda inequality. To effectively advance the above research, we employed a Kitaev quantum liquid-like one-dimensional spin model. This model has interactions that differ for each bond, which allows us to clearly describe how the non-commutativity of feedback operations and interactions affects energy control. Our results are based on specific models and are by no means general, but it can be said that this is a valuable study in the sense that it provides mathematically rigorous results on issues that many researchers in this field are interested in, such as the definitions of work and heat in quantum thermodynamics and the second law of information thermodynamics.

KEYWORDS: Quantum energy teleportation, Entanglement, LOCC, Information thermodynamics, Kitaev quantum spin liquid

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T3-05 INVITED

Kondo screening and entanglement of spin states on graphene nanoribbon

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Exploring the spatial dependence of mediated exchange interactions is very useful to understand the mechanism of magnetic ordering and entanglement of spin states. The confined structure and low spin-decoherence channel of 7-armchair graphene nanoribbon (7-AGNR) offer a suitable platform to partially isolate the effect of substrate and visualize the competition between exchange interactions and Kondo screening. Herein, we use scanning tunneling methods to map the spatial dependence of local density of states between two unpassivated sites across the terminus of 7-AGNR. A well-pronounced pair of delocalized Kondo resonances were observed which gradually decay away from the scattering centers but still visible at any point along the line profile. This ubiquitous presence of Kondo effect indicates mediated exchange interactions that may lead to magnetic ordering or exotic coupling between spin states. Although thermal decoherence weaken the signal intensity, temperature dependence shows that the interaction effects remain detectable at relatively high temperature of 15K. As the coupling strength of the two delocalized moments could be tuned by electric field, this system offers a great potential for applications in devices employing quantum information processing.

KEYWORDS: Graphene nanoribbons, Spin states, Exchange interactions, Scanning tunneling microscopy

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T3-06 INVITED

Investigation of spin systems and evolving quantum states using quantum programming

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Evolving quantum states of spin systems that can be described by weighted graphs G(V,E) are considered [1]. The study focuses on the geometrical properties of these states. In particular, the velocity, curvature, and torsion are obtained analytically for the general case of quantum states corresponding to graphs of arbitrary structure. We establish relationships between these quantum characteristics and the classical properties of the corresponding graphs [1]. We show that the velocity of quantum evolution is related to the sum of the weighted vertex degrees in a graph obtained by squaring the edge weights of G(V,E). The curvature depends on the sums of products of edge weights corresponding to square subgraphs in the graph. The torsion depends on sums of products of edge weights forming triangular subgraphs in the graph. The geometric characteristics of quantum graph states are evaluated using quantum programming on IBM quantum computers for the particular case of spin systems [1].

Quantum entanglement plays a crucial role in quantum information science and is one of the key resources for quantum computing and quantum programming. The entanglement distance for evolving quantum states of spin systems described by the XXZ model is investigated both analytically and by means of quantum-computing methods [2]. In addition, the speed of evolution of a two-spin system governed by the XXZ model is examined. The quantum-computational results are consistent with the theoretical predictions.

Multi-qubit quantum states associated with bi- and tripartite graphs are also considered. We establish a direct connection between the entanglement properties and the degrees of the graph vertices [3,4]. Furthermore, relationships between quantum correlators, the numbers of odd- and even-degree vertices, and the numbers of closed cycles of order four are determined. Based on these findings, quantum protocols are developed for evaluating the properties of bi- and tripartite graphs [3,4].

KEYWORDS: Spin systems, Quantum states, Quantum programming

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T3-07 ORAL

Nanowire and nanoaperture probes of quantum turbulence in superfluid helium

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Liquid helium (^{4}He) is a essential quantum fluid and an important platform for studying macroscopic quantum phenomena at low temperatures. In its superfluid phase, helium supports so called quantum turbulence composed of quantized vortices with a core size of approximately 1 Å. Understanding the system on the quantum scale requires the development of nanoscale detector architectures.

In this work, we investigate superconducting Nb-Ti nanowires and fabricated silicon nitride nanoaperture-based structures as probes of quantum turbulence and Josephson oscillations in superfluid helium. Nanowires with characteristic dimensions on the order of hundreds of nanometers provide a sensitive platform for detecting vortex-induced dissipation and vortex interaction with oscillating structures, as well as the description of turbulent flows including in the superfluid counterflow regime. In parallel, we have developed and are working to employ nanoaperture arrays to realize superfluid ^{4}He quantum interference devices (SHeQUIDs), where two helium reservoirs are weakly coupled via the nanostructured constrictions at temperatures starting below the superfluid transition.

One limitation in the current state of the art is the lack of local, scalable detectors capable of resolving effects present in superfluid helium with high precision at mesoscopic length scales. We show that nanowire-based sensors provide enhanced spatial sensitivity to turbulence-induced changes in the superfluid ^{4}He environment compared to conventional micron-scale probes. In addition, nanoaperture SHeQUID devices will enable novel phase gradient meters to be integrated in superfluid flow experiments as well as unparallelled gyroscopy via the Sagnac effect.

Our results show improved sensitivity in comparison with previously used sensor architectures, enabled by the reduced dimensions and scalability of nanofabricated devices rather than a fundamentally new detection principle.

More broadly, our results show that nanostructured devices are powerful instruments for exploring the vast landscape of physical phenomena related to vortex dynamics and quantum turbulence.

KEYWORDS: Superfluid helium, SHeQUID, NEMS, Quantum turbulence

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Posters

T3-08 **POSTER**

Adaptive SPADE: superresolving optical imaging for dynamic nanosystems

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One of the topics of primary interest in contemporary optics and metrology is superresolution techniques, which allow for efficient resolution below the Rayleigh limit. Recent advances in quantum metrology demonstrate that spatial mode demultiplexing (SPADE) followed by photon counting is quantum optimal for estimating the separation between two weak incoherent sources [1]. While this has drawn significant attention to the technique, the main research focus has concentrated on astronomical applications [2], despite early suggestions for its use in microscopy [1]. In our work [3], we explore the potential application of this method to resolving sources in solutions where Brownian motion presents a major challenge to imaging, an effect that is unavoidable in biological systems. Through Fisher information analysis, we show that utilizing an adaptive scheme with realignments on a properly tuned timescale allows for preserving the optimal quantum scaling of error with separation. We also discuss the realignment time that enables near-optimal scaling while being more feasible for experimental realization. Our findings could help adapt SPADE to examining synthesized nanostructures, e.g., by counting the number of attached fluorophores, or for tracking molecular systems in living cells.

KEYWORDS: Superresolution imaging, Spatial mode demultiplexing (SPADE), Quantum metrology, Photon counting

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T3-09 POSTER

Review of research on the energy state distribution of charge carriers in nanocrystalline films

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The translational symmetry of the distribution of elementary charge systems (electrons or holes) is broken in the technical and technological procedures for obtaining nanoscopic samples. The essential differences of these structures compared to bulk ones are significantly changed fundamental physical properties, primarily due to small nanoscopic dimensions (with the effect of dimensional quantization) along one direction, but also due to the existence of two boundary surfaces with changed basic physical, or energy parameters (confinement effects). All this is included in the model of an ultrathin crystalline film with charges in the crystal lattice. Using the method of quantum and temperature-dependent Green's functions, we determined the energy spectrum and spatial distribution of the energy states of these charges in accordance with the variable boundary conditions. The most significant result of this analysis carried out here provided an explanation of the fact that the critical temperature of superconductors increases when they are produced as ultrathin films.

KEYWORDS: Ultrathin films, Charges, Energy spectrum, Distribution of energy states, Localized states, Activation, Critical temperature

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Track 4

Electrochemistry of Nanomaterials, and Advanced Energy Storage

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T4-01 INVITED

Nanoscale metal oxide and metal interlayers for anode-free solid-state lithium metal batteries: reactivity and lithium plating mechanisms

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Anode-free solid-state lithium-metal batteries offer exceptional energy density, but their cycle life is limited by low Coulombic efficiency, lithium inventory loss from interphase formation, and nonuniform lithium deposition. Here, we investigate a common design strategy using ~ 20 nm artificial layers on Cu current collectors to control lithium nucleation and growth in cells with poly(ethylene oxide)-based solid polymer electrolytes. Ideally, lithium should plate uniformly either beneath or on top of the artificial layer, thereby minimizing continued parasitic reaction with the electrolyte; however, if top-side deposition is nonuniform, dendritic lithium growth can result. We first study metal oxide coatings, Al_2O_3 and ZnO, which exhibit distinct reaction pathways with lithium. Al_2O_3 undergoes self-limiting lithiation, reducing SEI-related lithium loss but increasing interfacial resistance and nucleation overpotential, with lithium plating beneath the lithiated coating through defects and ion-conducting phases. In contrast, ZnO fully converts to LiZn and Li_2O, lowering nucleation overpotential and promoting lithium deposition on top of the converted layer. Motivated by this favorable lithiophilic behavior, we then examine ~ 20 nm alloy-forming metal seed layers of Ag, Pt, and Au on Cu. Among these, Au provides the greatest improvement in Coulombic efficiency, with further gains achieved by restricting cycling to suppress continuous alloying and dealloying. Together, these results show that both conversion-type oxide interlayers and alloy-forming metal seed layers can direct lithium growth, but achieving highly uniform deposition remains critical for preventing dendrite formation and improving reversibility in anode-free solid-state batteries.

KEYWORDS: Anode-free batteries, Solid-state lithium-metal batteries, Lithium plating, Solid polymer electrolytes, Interphase engineering

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T4-02 INVITED

Forcing gold to become good electrocatalyst by tuning its electronic properties

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Gold is a precious metal regarded as a cornerstone-and sometimes the standard-in investment and finance, primarily due to its scarcity, resilience, and stability. Beyond its financial value, gold's properties such as durability, malleability, and excellent electrical conductivity have enabled numerous industrial applications ranging from aerospace and sustainable energy to computing and healthcare.

However, despite its versatility, gold is a poor catalyst or electrocatalyst. Its high chemical nobility stems from its low reactivity and inability to effectively bind molecules to its surface and facilitate their reactions. Hammer and Nørskov [1] explained this behavior using the d-band theory, which attributes gold's chemical inertness to its fully occupied valence d-band located well below the Fermi level-rendering it unavailable for bonding interactions.

In this work, we demonstrate how the electronic properties of ultrathin gold films can be modified by introducing an underlying layer of a different metal. The proximity of this substrate metal can donate or withdraw electrons from the gold overlayer, thereby enhancing its catalytic activity-particularly toward the oxygen reduction reaction (ORR), a key process in polymer electrolyte fuel cells. Our results show that changes in the electronic structure of gold, measured by X-ray photoelectron spectroscopy (XPS) and Kelvin probe force microscopy (KPFM), correlate strongly with its ORR activity.

KEYWORDS: Oxygen reduction reaction, Electrocatalysis, Gold

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T4-03 INVITED

Identifying active sites for alkaline hydrogen evolution on nickel

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Nickel-based materials are among the most widely used non-precious catalysts for alkaline hydrogen evolution, yet the identity of the catalytically relevant active sites on Ni remains debated. The difficulty arises from the dynamic chemistry of Ni surfaces: metallic Ni, oxides, hydroxides and hydride-like species can coexist, evolve with electrochemical history, and influence both intrinsic activity and the number of available sites. As a result, nominally similar Ni catalysts often show widely scattered HER activities.

In this talk, we present our efforts to identify active sites for alkaline HER on Ni through an integrated workflow combining controlled surface preparation, high-precision electrochemistry, electrochemical impedance spectroscopy, electrochemical simulations, surface-sensitive characterization and data-driven ToF-SIMS analysis. We first examine how relevant Ni surface states form in alkaline media. Cyclic voltammetry, potential-hold experiments and simulations of competing oxidation pathways are used to distinguish between direct adsorption, dissolution-precipitation, nucleation-and-growth and place-exchange mechanisms for the initial formation of Ni (hydr)oxide. The results support a place-exchange pathway in which hydroxide adsorption is followed by oxidation to surface oxygen and incorporation beneath an outer hydroxide-rich layer. ToF-SIMS depth profiling reveals the resulting duplex near-surface structure, with NiO located between metallic Ni and $Ni(OH)_2$-rich surface regions.

This structural understanding provides the basis for correlating surface chemistry with HER activity. Defined Ni, NiO-, $Ni(OH)_2$- and NiH_x-modified surfaces are used to separate the effects of different surface and subsurface states on HER kinetics. A key methodological challenge is to distinguish changes in intrinsic activity from changes in the number of electrochemically available sites. We therefore extend conventional voltammetric and activity-based analysis with impedance-derived descriptors of interfacial kinetics, active-site availability and surface-state evolution.

Finally, we discuss how ToF-SIMS, combined with multivariate analysis and interpretable machine-learning workflows, can provide chemically resolved information on ultrathin, heterogeneous surface regions. Rather than relying on individual marker ions, our approach treats ToF-SIMS depth profiles as fragment-rich hyperspectral datasets and uses denoising, unsupervised fragment grouping, constrained regression and graph-based source assignment to reconstruct chemically meaningful fragment-ion families.

Together, these results illustrate how active-site identification for alkaline HER on Ni requires linking controlled surface chemistry, electrochemical function, impedance-derived site descriptors and chemically resolved near-surface analysis within a single experimentally constrained framework.

KEYWORDS: Hydrogen evolution reaction, Nickel electrocatalysts, Active sites, ToF-SIMS, Electrochemical simulations

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T4-04 INVITED

Computational studies of electrochemical reactions for energy applications

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Understanding electrochemical processes that interconvert chemical and electrical energy is essential for advances in fuel cells, batteries, and microelectronics. Because these processes are governed by complex interactions among electrode surfaces, adsorbates, and interfacial water, first-principles electronic-structure calculations are central to identifying the origins of electrocatalyst activity and stability. We use density functional theory, together with microkinetic modeling and close integration with experiment, to study nanostructured electrocatalysts for water-splitting and oxygen electrocatalysis. A central challenge in electrochemical hydrogen production is the design of oxygen evolution reaction (OER) catalysts that are both active and stable. To establish a computationally informed understanding of iridium electrochemistry in acid, we investigated Ir(111), Ir(100), and Ir(110) surfaces[1]. Density functional theory and microkinetic adsorption-voltammetry simulations were used tointerpret electrochemical measurements and in situ spectroscopy revealing potential-dependent hydrogen, hydroxyl, and oxygen coverages, facet-dependent coadsorption behavior, and the strong influence of lateral interactions and the interfacial water network on adsorption dynamics and reactivity. These results clarify trends in hydrogen oxidation/evolution and oxygen reduction on Ir(hkl) surfaces and refine the atomistic picture needed to design advanced Ir-based materials.We also examine a computational design strategy based on dynamically stable electrocatalysts, in which a PGM-free host couples its structural stability with active species supplied by the electrolyte. First-principles studies of conductive $M_1O_xH_y$, Fe-$M_1O_xH_y$, and Fe-$M_1M_2O_xH_y$ hydr(oxy)oxide nanoclusters (M_1 = Ni, Co, Fe; M_2 = Mn, Co, Cu) show that OER performance emerges from balancing Fe dissolution and redeposition on a MO_xH_y host to sustain dynamically stable Fe active sites.[2] Extending this concept to perovskite oxides, our interfacial model describes an electronically conductive ABO_3 core that supports surface evolution into a hydr(oxy)oxide shell, where dynamically stable Fe(aq) species promote oxygen evolution.[3] Finally, combining first-principles calculations with synthesis and characterization, we investigated how electrolyte Fe and interlayer anions jointly control OER in NiAl layered double hydroxides. While CO_{32}-, Cl-, and Br- interlayers give similar activity in Fe-free electrolyte, calculations and experiment show that added Fe enhances performance by tuning interfacial Fe adsorption, with activity following LDH-Br > LDH-Cl > LDH-CO_3 across Fe concentrations.[4]

KEYWORDS: Density functional theory, Oxygen evolution reaction, Perovskite

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T4-05 ORAL REMOTE

The electrocatalytic cracking of polystyrene (PS) using a high-entropy alloy (HEA) anode and janus particles (JP)

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Traditional methods of catalyzing the conversion of polystyrene to value-added products are costly and not optimized, especially due to incessant coke formation, which leads to a shortened lifespan of catalysts [1]. Thus, the integration of high entropy alloys (HEAs) [2], [3] and Janus particles as a bifunctional catalyst can be a promising method of recovering useful chemicals such as BTX (Benzene, Toluene, Xylene) through enhanced hydrogenolysis and subsequent beta alkyl transfer. Here we investigate the formulation of the FeMnCuCoNi HEA as the anode of the electrocatalytic cell, in which Ni/Fe binary Janus particles are oxidized as a bifunctional catalyst which then act as electrophiles to attack the polystyrene chains. The cathode is composed of RuIr/Ti for traditional Hydrogen Evolution Reaction (HER), which is coupled in an acidic environment using a Bipolar Membrane (BPM). Computational modeling was then used to validate this design and test its function. Through ab initio molecular dynamics (AIMD) simulations, a high degree of polystyrene (PS) adsorption, with a turnover frequency (TOF) of 2.2 s-1 converted by the Ni/Fe binary Janus particles consequently to being oxidized by the HEA anode. Thus, the high entropy anode along with the Ni/Fe binary Janus particles show particular promise for producing efficient and thus industrially plausible electrocatalysts.

KEYWORDS: Catalysis, High entropy alloy, Janus particle, AIMD, Polystyrene

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T4-06 ORAL

Morphology of nanostructured $FeVO_4$ layers - a comprehensive study towards improved photoelectrochemical performance

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Progressive environmental degradation, rapidly growing energy consumption, and the use of access to fossil fuels as an instrument of economic and political influence are just few prominent examples underscoring the importance of research on advanced technologies for high-efficiency energy generation and effective energy storage. Photoelectrochemical (PEC) water-splitting cells are among the most promising approaches to solar energy conversion, enabling the direct generation of hydrogen without the formation of harmful by-products or additional waste.[1] Despite extensive research on semiconducting photoelectrode materials, controlled doping strategies, and engineered surface architectures, PEC device performance remains limited, primarily due to rapid recombination of photogenerated charge carriers.[2]

Our approach to addressing this issue involves the formation of novel nanostructured heterojunction photoanodes composed of well-established anodic WO_3[3, 4], coupled with the promising yet still insufficiently explored $FeVO_4$, whose bandgap should enable high solar-to-hydrogen conversion efficiency.[5] This contribution reports results from the first stage of this study, aimed at optimizing the morphology of the vanadate layer and examining its influence on photoelectrochemical activity. The application of a straightforward hydrothermal synthesis method, combined with simple manipulation of reaction parameters, allowed us to examine various architectures and identifying approaches best suited to our requirements. A systematic study of nanostructured $FeVO_4$ for use in PEC water-splitting cells, together with extensive knowledge of anodic WO_3 properties, may represent a new pathway toward the development of advanced devices capable of overcoming detrimental electron-hole recombination. Comprehensive fundamental research, beginning with the investigation of individual component properties, will enable a deeper understanding of the final complex system and help identify the key factors limiting its efficiency.

KEYWORDS: Photoelectrochemical water splitting, FeVO4 nanoparticles, Photoanodes, Hydrothermal synthesis

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T4-07 ORAL

Shape-directed synthesis of anisotropic gold nanostructures for electrocatalytic oxygen and nitrogen species reduction

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The oxygen reduction reaction (ORR) is a key challenge in low-temperature fuel cells due to sluggish kinetics and strong dependence on catalyst composition, morphology, and support effects. Despite efforts to reduce platinum loadings, efficient ORR catalysis still relies on Pt-based systems. Consequently, the development of alternative electrocatalysts exhibiting high activity, selectivity toward the four-electron pathway, and long-term stability is of considerable interest. In parallel, the electrochemical nitrate reduction reaction (NO_3RR) to ammonia offers a promising route for nitrate remediation, yet is limited by complex multi-electron pathways and competing hydrogen evolution.

In this study, a polyoxometalate-assisted synthetic strategy is employed to control the anisotropy of gold nanostructures as well as the sphericity of gold nanoparticles immobilized on carbon-based supports at low metal loadings. Keggin-type polyoxometalates act as inorganic reducing, stabilizing, and shape-directing agents, enabling surfactant-free synthesis without conventional organic ligands such as PVP, amines, thiols, or surfactants, which block active sites and alter intrinsic catalytic properties. Precise morphology control is achieved by tuning nucleation and growth kinetics through the combined use of mixed reducing agents, gold precursors, polyoxometalates, and silver ions. This enables the formation of anisotropic nanoplates (triangular and hexagonal), nanorods, nanostars, nanoflowers, nanourchins, as well as hollow and concave architectures such as nanobowls and donut-like nanostructures formed via galvanic replacement. In parallel, highly dispersed spherical gold nanoparticles are deposited on carbon-based supports.

Spectroscopic (UV-Vis, FTIR), microscopic (SEM, TEM), and structural (XRD) analyses confirm stabilization of nanostructures during synthesis and removal of polyoxometalate layers under alkaline conditions without altering morphology. Electrochemical diagnostics using cyclic voltammetry and rotating ring-disk electrode (RRDE) measurements reveal pronounced morphology-and support-dependent effects on ORR activity and selectivity. In particular, spherical gold nanoparticles supported on carbon-based supports exhibit low peroxide yields and electron transfer numbers approaching four, indicating a dominant four-electron ORR pathway. Anisotropic nanostructures show distinct activity trends associated with their high density of low-coordinated surface atoms and defect-rich surfaces. Additionally, the materials exhibit enhanced performance toward NO_3RR, favoring multi-electron reduction pathways toward ammonia.

KEYWORDS: Oxygen reduction reaction (ORR), Nitrate reduction reaction (NO_3RR), Gold nanostructures, Anisotropic nanoparticles, Rotating Ring-Disk electrode (RRDE)

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T4-08 ORAL

Impact of post-synthesis atmosphere on the PEC behavior of semitransparent Cu-functionalized TiO_2 nanotubes

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The growing global demand for energy, together with the escalating impacts of climate change, highlights the urgent need for sustainable and efficient energy conversion solutions. Solar energy stands out as a clean, abundant, and renewable resource with strong potential to reduce environmental burden while supporting long-term energy sustainability. Among various solar energy conversion approaches, photoelectrochemical (PEC) systems have attracted significant attention due to their ability to directly convert solar energy into electricity or chemical fuels. Titanium dioxide is one of the most widely studied materials in PEC applications, owing to its excellent chemical stability, mechanical robustness, and cost-effectiveness. Nevertheless, its relatively wide bandgap (approximately 3.2 eV for anatase) limits light absorption mainly to the ultraviolet region, which significantly constrains its overall efficiency. Therefore, strategies aimed at improving the photoactivity of TiO_2 are of considerable interest.

In this work, semitransparent Cu-modified titania nanotube electrodes were prepared by anodizing TiCu co-deposited films and by controlled annealing under air and hydrogen atmospheres. Structural and compositional analyses confirmed the formation of well-aligned nanotube arrays, with distinct distribution of copper nanoparticles in hydrogen-annealed samples and presence of copper oxide species in air-annealed samples. The UV-vis spectra revealed that the absorption band is shifted towards the visible range beyond 400 nm. Additionally, the hydrogen-annealed material demonstrates the highest photocurrent densities, reaching 7 μA cm^{-2} under UV-vis illumination and 3.5 μA cm^{-2} under visible light (at +0.1 V vs. Ag/AgCl/0.1 M KCl), which is approximately 5 times higher in UV-vis and 7 times higher in the visible region compared to the H_2-annealed bare titania. Moreover, the electrode with the highest Cu loading exhibited the highest oxygen evolution reaction (OER) current density of 2.2 mA cm^{-2} at +1.3 V vs. Ag/AgCl/0.1 M KCl, accompanied by intensive gas evolution. Overall, the semitransparent Cu-modified titania nanotube electrodes demonstrate photoactivity and OER performance, suggesting their suitability for applications where light transmission and electrochemical activity are both required.

KEYWORDS: Semitransparent materials, Oxide nanotubes, Oxygen evolution reaction

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Posters

T4-09 **POSTER**

Testing the performance of sea water batteries with solid electrolyte NASICON-type in the presence of recirculated CO_2

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The abundance and durability of renewable natural resources have drawn attention to their use as energy sources. Rechargeable seawater batteries (SWBs) are considered sustainable alternatives to Li-ion batteries due to the use of an unlimited and free source of Na-ion active materials. SWB systems not only benefit from the unlimited source of active materials, but also, thanks to their unique design with the open cathode structure, they significantly manage the heat circulation of the system to ensure safety and longer service life. Seawater Na-CO_2 technologies offer a promising framework for the development of integrated „seawater" systems capable of combining energy storage with CO_2 capture or recovery. In this study, testing experiments were carried out to evaluate the functioning of a NASICON membrane seawater battery cell in the presence of recirculated CO_2. Experiments with CO_2 recirculation have highlighted the complex interaction between sodium storage processes and secondary reactions from the aqueous environment, in particular the evolution of hydrogen (HER). Chromatographic analyses confirmed the formation of H_2 (values between 2.42×10⁻3 and 3.9 ×10⁻3 mL·min⁻¹), and the values of faradaic efficiency (approx.20%) indicate a competition between the target reactions (associated to the CO_2 conversion and/or redox processes of the battery) and the parasitic reactions. The stability of tensions in some regimens and the variation of faradaic efficiency over time suggest that the system is sensitive to local pH conditions, the accumulation of carbonate/bicarbonate species and the nature of the catalyst used (Pt/C). These results validate the functionality of the concept, but also highlight clear directions for optimisation, in particular on catalytic selectivity and reduction of polarisation.

KEYWORDS: Seawater batteries, NASICON membrane, CO_2 conversion, Redox processes

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T4-10 POSTER

Raman-correlated electrocatalytic H_2O_2 sensing at fragmented graphene oxide / gold nanourchin hybrid

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Electrochemical detection of hydrogen peroxide (H_2O_2) is essential for monitoring oxidative processes in biological, environmental and technological systems. In this work, we develop non-enzymatic H_2O_2 sensors based on hybrid layers composed of graphene oxide-related materials and anisotropic gold nanostructures. Our previous study showed that the morphology of gold nanoparticles and the defect structure of graphene oxide (GO) strongly influence the electrocatalytic reduction of H_2O_2. Among gold nanospheres, nanobowls and nanourchins (AuNURs), the nanourchin morphology provided the highest amperometric response, especially after coupling with electrochemically reduced graphene oxide (ERGO), due to the combination of a highly developed gold surface, sharp edges, and improved charge transport in the carbon layer [1].

Here, we extend this concept by introducing fragmented graphene oxide (fGO) and electrochemically reduced fragmented graphene oxide (ERfGO) as supports for gold nanourchins. Fragmentation is used as a structural strategy to increase the density of exposed edges, defects and accessible oxygen-containing sites, while reducing diffusion limitations within the hybrid sensing layer. The materials are deposited on glassy carbon electrodes and characterized by electron microscopy, Raman spectroscopy and electrochemical methods. The amperometric response toward H_2O_2 is evaluated in phosphate buffer at near-neutral pH, and the sensor performance is correlated with Raman parameters describing disorder, graphitic domains and oxygen-related structural features.

The fGO/AuNURs hybrids exhibit enhanced sensitivity compared with analogous non-fragmented GO-based layers. The effect is further amplified after electrochemical reduction, indicating that the most favourable sensing architecture requires a balance between defect density, accessible adsorption sites and electrical conductivity. Raman analysis supports this interpretation: an increased contribution of defect-related bands, together with preservation of conductive carbon domains, accompanies the improved H_2O_2 reduction currents. These results confirm that fragmentation of graphene oxide is not only a morphological modification but also an effective route to tune the electrocatalytic interface.

The study highlights the synergistic role of GO defects and AuNURs morphology in non-enzymatic peroxide sensing. The proposed fragmented ERfGO/AuNURs platform offers a promising pathway toward highly sensitive, stable and enzyme-free electrochemical sensors for hydrogen peroxide and related reactive oxygen species.

KEYWORDS: Graphene oxide, Gold nanoparticles, Raman spectroscopy, Electrocatalysis, Hydrogen peroxide

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T4-11 POSTER

Electrochemical control of chloramphenicol adsorption at gold nanostructures using EC-SERS

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Nanostructured noble-metal electrodes provide a versatile platform for studying molecular processes at electrochemical interfaces, particularly when optical signal amplification is combined with potential control. In this work, gold nanoparticle-modified screen-printed electrodes were used as model nanostructured interfaces for investigating the electrochemical adsorption behavior of chloramphenicol, a broad-spectrum antibiotic of environmental and analytical relevance.

Electrochemical surface-enhanced Raman spectroscopy (EC-SERS) was applied to monitor potential-dependent changes occurring at the gold/electrolyte interface in phosphate buffer solution. By varying the electrode potential, the interfacial conditions were tuned in a controlled manner, allowing changes in the adsorption state of chloramphenicol to be followed through its enhanced vibrational response. The recorded spectra show characteristic bands related to the aromatic moiety and functional groups of the molecule, while their relative intensities depend strongly on the applied potential. These changes indicate that the electric field at the nanostructured gold surface affects both the adsorption configuration of chloramphenicol and the efficiency of Raman signal enhancement.

The results demonstrate that gold nanoparticle-modified electrodes can serve not only as signal-enhancing substrates, but also as electrochemically tunable nanointerfaces for probing molecular adsorption phenomena. This approach provides insight into charge-transfer and adsorption-related processes at plasmonic metal nanostructures and supports the rational development of electrochemical-spectroscopic sensing platforms for antibiotic residue detection.

KEYWORDS: EC-SERS, Raman, Chloramphenicol, Gold nanoparticles

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T4-12 POSTER

Low-temperature precipitation synthesis of $Na_3V_2Ox(PO_4)2F_3$-x nano- and microparticles with tunable morphology for sodium-ion battery cathodes

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Sodium-ion batteries have emerged as a promising alternative to lithium-ion systems due to the natural abundance, low cost, and wide geographical distribution of sodium resources[1]. Among the various cathode materials investigated, sodium vanadium fluorophosphates (NVPF, $Na_3V_2O_x(PO_4)_2F_{3-x}$, where $0 \leq x \leq 2$) have attracted particular attention owing to their high operating voltage (ca. 3.8-3.9 V vs Na^+/Na^0), robust structural stability, high theoretical specific capacity (ca. 128 mAh g^{-1}) and favorable Na^+ diffusion pathways[2]. These features make them strong candidates for post-lithium energy storage systems.

In this work, $Na_3V_2O_x(PO_4)_2F_{3-x}$ materials were synthesized via a precipitation method under a variety of controlled conditions, including variations in temperature, pH, use of surfactants and solvent modifications. The synthesis involved the use of a reducing agent not previously reported for NVPF preparation. Importantly, the obtained materials crystallize directly from solution in the desired phase without the need for high-temperature calcination, highlighting the efficiency and scalability of the method. By systematically tuning these parameters, both nano- and microparticles with diverse and distinctive morphologies were obtained. Notably, a unique hierarchical morphology resembling pinecone-like structures was achieved, offering increased surface area and potentially enhanced electrochemical accessibility. The resulting materials were comprehensively characterized using scanning electron microscopy and powder X-ray diffraction, while their electrochemical performance in Na-ion cells was evaluated in terms of high-rate capability and cycling stability. The best-performing materials delivered a high specific capacity close to 120 mAh g^{-1} at a current rate of 0.1 C and retained over 95% of their capacity after 100 cycles at 2 C.

This study demonstrates that precipitation synthesis of NVPF using a proposed reducing agent is a versatile approach for obtaining particles with tunable morphology and favourable electrochemical performance.

KEYWORDS: Sodium-Ion batteries, Cathode material synthesis, Sodium vanadium fluorophosphate (NVPF), Precipitation synthesis

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T4-13 POSTER

Effect of synthesis conditions on morphology of Cu-doped lithium-nickel oxide for cobalt-free lithium-ion batteries

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The development of high-energy-density, cobalt-free cathode materials is a critical priority for the next generation of lithium-ion batteries due to the economic and environmental concerns associated with cobalt.[1] Lithium nickel oxide ($LiNiO_2$, LNO) is a primary candidate for these applications, offering a high theoretical specific capacity of 275 mAh g-1, which is comparable to current nickel-manganese-cobalt (NMC) technologies.[2] However, LNO suffers from significant structural instability caused by the disordering of lithium and nickel atoms, a phenomenon known as "cation mixing" resulting from the similar ionic radii of Li+ and Ni_2+.[3] Furthermore, multiple phase transitions during lithium intercalation induce mechanical strain, leading to particle cracking and surface deterioration.[4]

This study investigates the effect of particle size and morphology of copper-doped LNO to enhance the structural and electrochemical stability of this material. Copper was selected due to its similar ionic radius to Li+ and Ni_2+ ions, what enables the potential for stabilization of crystal lattice.[5] Copper is also highly available worldwide, low cost, and can be sourced from recycling. The research specifically compares two distinct precursor synthesis methodologies for tailoring particle characteristics: a solid-state mechanochemical route utilizing high-energy ball-milling and a co-precipitation method. The synthesized precursors were calcined with lithium hydroxide under oxygen atmosphere to promote formation of a well-ordered layered crystal structure.

The physicochemical properties of the resulting materials were characterized using X-ray powder diffraction with Rietveld refinement to determine phase purity and the degree of cation disordering. Additionally, morphological analysis via electron microscopy and surface area determination through N_2 adsorption method (BET) were conducted to correlate synthesis parameters with particle distribution. Electrochemical performance was evaluated in half-cell configurations against metallic lithium, focusing on specific capacity and capacity retention.

X-ray diffraction studies demonstrate successful formation of Cu-enriched phase ($LiNi_1$-xCuxO2). Comparative analysis of SEM images and BET results indicates that the synthesis route significantly influences the final size distribution of material particles, which is a crucial parameter to optimize for high-rate electrochemical performance in lithium-ion setup.

KEYWORDS: Lithium-ion batteries, Cathode materials, Lithium-nickel oxide, Copper-doping, Energy storage

ACKNOWLEDGEMENTS: This research was funded by the National Science Centre, Poland, under grant number 2025/57/B/ST5/03718.

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Track 5

Multifunctional Thin Films and Advanced Coatings

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T5-01 INVITED

Cu-driven structural evolution of layered chalcogenide thin films towards Cu-rich telluride nanostructures

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Copper tellurides are promising materials for thermoelectric [1] and memory technologies, [2] yet their functional properties are governed by atomic-scale structure, defects, and phase evolution that remain insufficiently understood. In this talk, I will discuss complementary studies on Cu-driven structural evolution in layered chalcogenide thin films [3] and on the atomic-scale structure of Cu-rich telluride nanostructures [4].

Starting from epitaxial Sb_2Te_3, room-temperature magnetron sputtering of Cu triggers interdiffusion and the formation of disordered Cu-Sb-Te nanolayers within the layered host [3]. The extent of this transformation depends strongly on sputtering pressure: lower Ar pressure increases the kinetic energy of incoming Cu species, enhances Cu incorporation, expands the Sb_2Te_3 lattice, and promotes Cu-Sb-Te formation. Monte Carlo simulations support this interpretation by showing that gas-phase scattering suppresses the high-energy fraction of the Cu flux at higher pressure. Further metal deposition drives a nearly complete conversion of Sb_2Te_3 into a previously unreported $Cu_7(Sb_{0.4}Te_{0.6})_4$ phase. Atomic-resolution scanning transmission electron microscopy (STEM), combined with chemical analysis and image simulations, reveals an epitaxial layered structure dominated by 3 Te building units, but also containing 2 Te units, Sb/Te antisite defects, and Cu vacancies. These observations enable a structural model for a layered hexagonal phase that is related to, yet distinct from, known trigonal Cu_7Te_4 polymorphs. Upon thermal treatment, Sb out-diffuses and oxidizes, while the Cu-Sb-Te phase transforms into layered Cu_7Te_4.

In a complementary atomic-scale study of thermally reacted Cu/Sb_2Te_3-based systems prepared from thicker Sb_2Te_3 films, the as-formed layered Cu_7Te_4 nanostructures were resolved in detail by aberration-corrected STEM [4]. Two related trigonal configurations composed of distorted close-packed Te layers separated by vacancy layers were identified: a double-layered structure with 2 Te layers per nanoscale building unit and a triple-layered structure with 3 Te layers per unit. While the double-layered configuration is consistent with established models, the triple-layered Cu_7Te_4 represents a newly identified structural variant that can occur in both ordered and Cu-vacancy-disordered forms. Both structures exhibit stacking faults, twin boundaries, dislocations, and local transition regions, demonstrating that short-range rearrangements of the Cu sublattice, together with subtle Te displacements, enable structural conversion between the two motifs.

Together, these studies provide a coherent picture of Cu-driven evolution from Sb_2Te_3 to defect-rich layered Cu_7Te_4 via metastable Cu-Sb-Te phases and show how atomic-scale disorder and nanoscale building units can be exploited to tailor chalcogenides for thermoelectric and memory applications [5].

KEYWORDS: Thin films, Layered chalcogenides, Copper tellurides, Phase transformation, Structure analysis

ACKNOWLEDGEMENTS: The authors thank A. Mill for TEM lamella preparation, H. Bryja for the growth of epitaxial Sb_2Te_3 thin films as well as T. Pröhl and P. Hertel for DC magnetron sputtering. We acknowledge the financial support by the German Research Foundation (DFG 448667535). The authors thank the European Regional Development Fund and the State of Brandenburg for the Themis Z microscope (part of the Potsdam Imaging and Spectral Analysis (PISA) facility).

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T5-02 INVITED

Interpretable grey-box AI for plasma-deposited thin films in the era of EUV lithography

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The introduction of extreme ultraviolet (EUV) lithography has placed stringent requirements on plasma-deposited thin films used in advanced semiconductor manufacturing, including dielectric layers, hard masks, and functional nanocoatings. At EUV-relevant dimensions, thin-film growth is governed by complex and strongly coupled plasma-surface interactions, where nanoscale structural uniformity, stress, and defect control become critical challenges [1-3].

In this invited talk, we present an interpretable grey-box artificial intelligence (AI) framework for plasma-deposited thin films, designed to meet the demands of the EUV lithography era. The framework integrates plasma physics, materials science, and data science by combining machine learning with physically grounded descriptors derived from plasma diagnostics. In particular, we employ plasma-material information science (PaMIS) to construct features from optical emission spectroscopy (OES) that are causally linked to thin-film growth and properties, rather than relying solely on external process parameters [4, 5].

Explainable machine-learning techniques are incorporated to identify key plasma species and reaction pathways governing deposition kinetics and materials evolution, enabling mechanistic insight beyond black-box optimization. Furthermore, diversity metrics originally developed in statistical physics are introduced to quantify plasma chemical diversity and to relate it to variations in thin-film structure and stress at the nanoscale. This analysis reveals that plasma-state diversity plays a decisive role in stabilizing thin-film growth and controlling material variability under EUV-relevant conditions.

The proposed grey-box AI approach provides a data-efficient and physically interpretable methodology for accelerating R&D of plasma-deposited thin films. By preserving scientific insight while leveraging AI, it offers a scalable pathway for materials design and process control in next-generation EUV lithography.

KEYWORDS: Thin film, Plasma process, Machine learning, OES

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T5-03 INVITED

Plasma-assisted synthesis of hybrid nanomaterials for enhanced SERS performance

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Surface-enhanced Raman scattering (SERS) spectroscopy has emerged as an indispensable tool for molecular detection, with applications ranging from forensics or food quality control to pharmaceutical development or medical applications [1]. While traditional SERS platforms rely on the electromagnetic enhancement of noble metal nanostructures (Au, Ag, or Cu), recent advancements have highlighted the potential of non-plasmonic materials, such as metal oxides and certain conducting polymers [2-5]. These materials, whose SERS performance is primarily due to a chemical enhancement mechanism via photo-induced charge transfer, often offer superior stability and lower costs, though they typically exhibit lower SERS activity than their metallic plasmonic counterparts. From an application standpoint, the trade-off between high sensitivity and chemical stability remains a significant challenge. This study addresses this gap by utilising plasma-assisted deposition techniques to engineer advanced SERS-active hybrid metal-metal oxide and metal-polymer coatings. The experimental strategy involved the controlled decoration of various substrates with sputter-deposited plasmonic metal nanostructures (Ag or Au), including:

· Metal oxide films prepared by magnetron sputtering or metal oxide nanoparticles synthesised via magnetron-based gas aggregation sources

· Polymeric films (quaterthiophene) deposited through plasma-assisted vacuum thermal evaporation.

Comprehensive analysis reveals that coating composition and morphology are in all cases critical to SERS performance. Furthermore, it is shown that under optimised conditions, these heterostructures yield signal enhancements that exceed those of pure plasmonic, metal oxide, or polymeric materials. Notably, in systems involving TiO_2, Nb_2O_5, or WO_3, the produced heterostructures also exhibit UV-induced recyclability, adding a layer of multi-functionality. These findings provide a novel pathway for developing advanced, stable, highly sensitive, and robust SERS sensors.

KEYWORDS: SERS, Plasma-assited deposition, Hybrid nanomaterials

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T5-04 INVITED

High-throughput manufacturing of 2D nanomaterial coatings on polymer films for flexible electronic applications

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Scalable nanomanufacturing of two-dimensional (2D) materials coating on polymer substrates remains a critical challenge for flexible electronic systems. Current approaches often require multistep processing, harsh surface treatments, or are incompatible with continuous manufacturing. To this end, we report a water-based, high-throughput dip-coating strategy for the direct deposition of graphene oxide (GO) and related 2D nanomaterials onto hydrophobic polymer films without surface pre-treatment. The process employs amphiphilic reactive macromolecular super-spreaders (RMS) that conformally encapsulate GO sheets. This modification enables thermodynamically driven, interface-directed assembly of uniform nanoscale layers on low-energy polymer surfaces. Our method allows accurate control of coating thickness, from single layers to multilayer films. It is achieved by tuning the RMS composition, suspension concentration, and withdrawal rate. Subsequent chemical reduction yields conductive reduced graphene oxide (rGO) coatings with conductivities approaching ~103 S/cm. The films exhibit high optical transparency and strong adhesion to polymer substrates, such as polypropylene, polycarbonate, and Kapton. Electro-mechanical testing shows stable electrical performance under repeated bending, with minimal degradation after cyclic deformation. The process is continuous, scalable, and compatible with industrial coating techniques. It avoids toxic solvents and aggressive surface modification steps. This improves environmental compatibility and manufacturing efficiency. Our approach can be applied to other 2D materials, including transition-metal dichalcogenides and MXenes. It can, thus, enable the fabrication of heterogeneous multilayer assemblies with tunable electronic properties. In conclusion, this work establishes a direct link between processing conditions, nanoscale structure, and functional properties of 2D coatings on flexible substrates. It provides a versatile and scalable nanomanufacturing framework for integrating diverse 2D materials into next-generation flexible and wearable electronic devices.

KEYWORDS: Graphene oxide, Conductive coatings, Felxible electronics, Polymer films, 2D materials

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T5-05 INVITED

Well-defined molecular films as a platform for probing molecular properties on the surface

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Well-defined two-dimensional (2D) thin films consist of complex molecules, such as stimuli responsive molecules and chiral molecules, are recognized as effective platforms for investigating molecule-substrate interfaces and single-molecule functions [1,2].

For example, it is well known that the 2D-crystallization of chiral molecules on achiral substrates can transfer chirality to the surface. In such systems, the giant spin polarization phenomena associated with chiral molecular ordering, which is known as chirality-induced spin selectivity (CISS), have been reported and are actively studied.

On the other hand, formation of molecular films is based on relatively weak interactions compared to inorganic materials, resulting in a high degree of structural freedom and often leading to complex ordered structures and structural instability [3]. As a result, there are limited studies in which the relationship between detailed structural characterization at interfaces and the resulting functional properties has been examined.

In this presentation, to precisely determine the ordered structures of molecular films and elucidate the relationship between the molecular ordering and its properties, we used scanning tunneling microscopy (STM), scanning tunneling spectroscopy (STS), and distortion-corrected low-energy electron diffraction (LEED) [4]

First, we fabricated on ferrocene-based molecular complexes periodically arranged on a crown ether monolayer. We observe reversible molecular motion induced by voltage application and discuss the nanoscale sliding motion of molecule originating from the modulation of intermolecular interactions [5]. Second, we examine the two-dimensional crystallization of chiral molecules on achiral substrates. In this study, helicene molecules with a helical structure are adsorbed onto an Au substrate, and their ordered structures are carefully characterized. Based on these observations, we experimentally demonstrate that mirror-imaged growth governed by substrate symmetry can also occur in systems without commensurability [6]. These two studies suggest that precise definition of ordered structures in complex molecular systems provides new insights into molecular unique properties.

KEYWORDS: Surface science, Organic thinfilms, Chirality, Stimuli-responsive molecule

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T5-06 INVITED

Femtosecond laser microstructuring of titanium membranes for enhanced photocatalytic and photoelectrochemical applications

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TiO_2-based photocatalysts and photoelectrodes remain among the most widely studied materials for solar-driven energy conversion, owing to their chemical stability, low cost, and favorable band alignment for water splitting reactions [1]. However, the practical efficiency of TiO_2 photoanodes is often limited by insufficient light absorption and a low density of active surface sites, which restricts charge generation and transport at the semiconductor-electrolyte interface [2].

Femtosecond laser ablation is a versatile, single-step, and scalable technique for producing hierarchical micro- and nanostructures directly on metallic surfaces without the use of masks, templates, or chemical etchants [3]. Under linearly polarized ultrashort pulse irradiation, self-organized surface patterns and pyramidal micro-relief can be generated, dramatically increasing the effective surface area and light-trapping capability of the treated material. In this work, femtosecond laser ablation was combined with atomic layer deposition (ALD) to fabricate binder-free, hierarchically structured Ti-TiO_2 membrane photoanodes for photoelectrochemical (PEC) water splitting [4].

Laser processing of titanium foil produced a highly ordered array of micro-pyramids, which was subsequently conformally coated with TiO_2 layers of tunable thickness (10 and 100 nm) and crystallinity via ALD. Among the tested configurations, the 100 nm TiO_2 coating exhibited superior photoelectrochemical performance, attributed to enhanced crystallinity, optical absorption, and charge transport. The optimized membrane achieved a photocurrent density of ~27 μA $cm^{-}Z$ at 1.4 V vs. NHE and an incident photon-to-current conversion efficiency (IPCE) of ~31% at 275 nm, corresponding to a threefold increase in applied bias photon-to-current efficiency (ABPE) compared to the uncoated laser-textured sample. These results demonstrate that femtosecond laser microstructuring, combined with conformal ALD coating, is a scalable and reproducible strategy for engineering high-performance, binder-free photoanodes and photocatalytic surfaces for solar hydrogen production.

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T5-07 ORAL

Implementation of high-performance superlattice-like phase-change memory via sputtering deposition

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As the demand for next-generation storage class memory (SCM) with high-speed and low-power characteristics intensifies, phase-change memory (PCM) has emerged as a promising technology. However, conventional Ge-Sb-Te (GST)-based devices continue to face persistent challenges, such as excessive power consumption and degraded thermal stability during aggressive scaling. To address these bottlenecks, this study proposes a synergistic approach that integrates strategic material doping with a superlattice-like (SLL) architecture to maximize device switching performance.

First, we developed a Ta-doped Sb_2Te_3 (TST) materials designed to enhance both amorphous and thermal stability [1]. The incorporation of Ta atoms into the Sb_2Te_3 matrix effectively accelerates crystallization speed while suppressing grain growth, thereby mitigating the resistance drift and spontaneous data loss common in traditional chalcogenides. This doping strategy ensures a sufficient thermal margin, enabling reliable phase-transition control and superior data retention even in high-temperature environments.

From a nano-structural perspective, the optimized TST material was interleaved with $TiTe_2$ (TT) layers to realize an SLL configuration [2]. By fine-tuning the sputtering parameters, we optimized the fabrication of high-quality SLL films. Structural analysis via XRD and HR-TEM confirmed well-aligned c-plane growth and the formation of distinct van der Waals gaps at the TST/TT interfaces. This SLL structure induces a robust thermal confinement effect by utilizing the low thermal conductivity of the TT layers to block vertical heat dissipation, which significantly lowers switching energy and enhances cycling stability.

The resulting TST/TT SLL-based PCM device achieved a high-speed operation with a 15 ns pulse width and an ultra-low-power characteristic with a critical power density of 1.27 μW/nm. Notably, the SLL architecture yielded a 24.4% reduction in the phase-change threshold power compared to bulk TST devices, while simultaneously demonstrating exceptional endurance. These findings suggest that the TST/TT SLL architecture offers a viable and highly efficient pathway for the next generation of high-density data storage solutions.

KEYWORDS: Superlattice-like structure, Phase-change memory, Sputtering deposition, Doping, Storage-class memory

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T5-08 ORAL

Ferroelectricity and hole transport property of organic semiconductors

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Benzo[b]benzo[4,5]thieno[2,3-d]thiophene (BTBT) derivatives are organic semiconductors known to exhibit high hole mobility due to the formation of two-dimensional electronic structures. In this presentation, we report on the phase transition behavior, molecular assembly structures, semiconductor properties, and ferroelectric properties of alkylamide-substituted organic ferroelectrics, R-BTBT-NHCOC$_{14}$H$_{29}$ (**1**: R = H and **2**: R = C$_8$H$_{17}$).[1, 2]

The temperature- and frequency-dependent dielectric constants of **1** and **2** show the transition to SmE and SmC phases at 412 and 431 K, respectively, and melting at 468 and 479 K. The real part of the dielectric constant of **2** decreases monotonically with increasing temperature and shows a sharp frequency-dependent increase in dielectric constant from around 390 K. The dielectric constant of **1** is also affected by the temperature and frequency. This behavior is due to the activation of thermal motion of polar amide groups; both *P*-*E* curves of **1** and **2** show the hysteresis behavior of ferroelectrics near the solid-liquid crystal phase transition point, and the remanent polarization values and coercive electric field at 418 K and 0.1 Hz in 2 are 11.7 μC cm^{-2} and E_c = 3.36 V μm^{-1}, respectively. Top-contact OFET devices were fabricated using the high-temperature deposited thin films **1** and **2**, and both showed p-type semiconducting output characteristics. The mobility of the deposited film **2** was 1.01×10^{-3} cm^2 V^{-1} s^{-1}.

KEYWORDS: Ferroelectricity, Organic semiconductor, Hydrogen-bond, Dynamics

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T5-09 ORAL

Ion energy effects on the formation of a 2D zirconium carbide during magnetron sputtering

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2D transition metal carbides, nitrides and carbonitrides, so-called MXenes, gain increasing attention in materials science due to their exceptional physical properties. [1] Among them, zirconium carbide (ZrC) based MXenes are noteworthy for their predicted semiconducting behaviour. [2,3] Currently, the most common method of their preparation is acid etching. However, this approach limits the final morphology and size of prepared 2D flakes and thus their physical properties. [1,4] In contrast, physical vapor deposition (PVD) techniques offer improved control over the resulting chemical composition and morphology. [5] In this work, we investigate the effect of the energy delivered by ions formed in magnetron plasma on the amount of 2D ZrC phase formed at the C/Zr interface. The samples are prepared by magnetron deposition of ultrathin carbon layers (with maximal thickness of 2.5 nm) onto pre-deposited zirconium layers. By varying the working gas (Ar) pressure, the energy of ions was modified. The ion energy distributions (IEDs) analyzed with Hiden EQP 500 reveal, that the most energetic ions within the C target magnetron discharge are $^{12}C^{+}$ ions, with mean energy 76.4 eV at a pressure 0.56 Pa. By depositing carbon onto the Zr surface, $^{12}C^{+}$ ions carry enough energy to allow the formation of the ZrC phase at the C/Zr interface. With an increase in the pressure from 0.42 to 0.85 Pa, the $^{12}C^{+}$ ions become more thermalized, leading to a decrease in their total delivered energy into the growing layer. This trend correlates with the XPS results, which indicate a reduction in the Zr-C bonding fraction (in at. %) with increasing pressure. Our findings explain the formation process of the ZrC phase at the C/Zr interface and further demonstrate that ion energy is a key parameter controlling the ZrC phase formation during magnetron sputtering.

KEYWORDS: MXenes, Magnetron sputtering, Zirconium carbide, Ion energy distribution function, XPS

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T5-10 ORAL

Design of plastic crystalline materials via control of ionic and molecular motions through solid-solution formation

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Solid solutions and alloys are widely used strategies for tuning the properties and functions of inorganic materials. According to the Hume-Rothery rule, atoms or ions with less than ~15% difference in size are generally miscible. While atomic sizes vary only moderately, material properties such as electronic configuration, spin state, and electronegativity can change significantly, enabling precise property control and even the emergence of new phases near composition boundaries.

In contrast, organic crystals exhibit much greater structural diversity, and their properties are governed by a delicate balance of molecular shape, intermolecular interactions, and electronic states. Although substitutions with halogens or heteroatoms may satisfy size-based miscibility criteria, they rarely induce substantial changes in physical properties. Furthermore, organic solid-solution formation typically relies on solution recrystallization, which imposes strict requirements on structural compatibility, such as lattice parameters and symmetry.

Despite these limitations, combining the structural diversity of organic molecules with solid-solution strategies offers a promising route to expand the accessible design space of molecular crystals. In particular, such approaches may enable exploration of multidimensional composition-structure-property relationships and uncover materials that fill the "gaps" in conventional molecular design.

In this presentation, we report new strategies for solid-solution design using structurally mismatched molecular pairs, which have comparable sizes but different symmetries. We demonstrate that such molecules become miscible when incorporated as molecular cations in ionic crystals.[1, 2] In addition, mechanochemical mixing provides an alternative route to achieve solid-solution formation.[3] These results highlight a new approach to overcoming shape constraints and open up new possibilities for the design and functional control of organic mixed crystals.

KEYWORDS: Solid solution, Ferroelectrics, Plastic crystals

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T5-11 ORAL

Formation of ultrathin and highly stable aromatic monolayers on silver surface-three legs are better than one

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Surface functionalization using self-assembled monolayers (SAMs) is an effective strategy to tailor the morphology and electronic coupling of organic semiconductors (OSCs) at metal interfaces in organic electronic and photovoltaic devices. For optimal performance, such interlayers should be ultrathin, highly conductive, and composed of upright-oriented aromatic molecules, while also maintaining high thermal and chemical stability during OSC deposition and device operation [1-5]. In this work, we investigate the thinnest achievable aromatic SAMs on silver, a highly conductive electrode material. The studied systems are based on molecules with a thickness equivalent to a single phenyl ring and employ either conventional monodentate anchoring or triptycene-based, tridentate surface anchoring geometry.

A combination of surface-sensitive techniques, including X-ray photoelectron spectroscopy (XPS), infrared reflection-absorption spectroscopy (IRRAS), near-edge X-ray absorption fine structure (NEXAFS), and temperature-programmed desorption monitored by XPS, was used to comprehensively characterize the chemical composition, molecular orientation, bonding configuration, and thermal stability of the formed layers. Spectroscopic results confirm the formation of well-defined, upright, ultrathin (~0.8 nm) monolayers in both cases, with full engagement of anchoring groups, enabling a direct comparison of the two architectures.

Thermal desorption and chemical stability analyses reveal that monodentate systems exhibit lower stability, whereas triptycene-based tripods form significantly more robust monolayers. Notably, these ultrathin tridentate SAMs display stability comparable to, or exceeding, that of much thicker monodentate layers. This approach provides a promising pathway for interface engineering in organic electronics, with potential to enhance device performance.

KEYWORDS: Self-assembled monolayers, Triptycene, Thermal stability, Chemical stability, Spectroscopy

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T5-12 ORAL

Dithiocarbamate-based self-assembled monolayers - the preparation method has a crucial impact on structure and stability

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Dithiocarbamates (DTCs) are a promising class of molecules in which a bidentate anchoring group is used to functionalize metallic surfaces through the formation of self-assembled monolayers (SAMs). So far, two main strategies for the deposition of DTC SAMs have been employed interchangeably in the literature. In the first approach, the DTC compound is generated in situ via the condensation of a secondary amine with carbon disulfide directly in the presence of the metal substrate. In the second approach, a stable DTC salt precursor is synthesized beforehand and subsequently used to form monolayers from solution whenever required. Despite the extensive use of both methods, their direct comparison within a single experimental framework has been largely missing. Using the two model DTC SAMs based on phenylpiperidine and phenylpiperazine, we compared these two synthetic approaches for the first time in a single study [1]. We demonstrated that for the most crucial parameters of monolayers, such as packing density and thermal stability, there is a significant difference between the two formation methods, favoring the in situ method, which produces monolayers with high thermal stability (desorption energy ~ 1.5 eV) and packing densities comparable to those of alkanethiols. On the other hand, we demonstrated that the overall chemical stability of DTCs is diminished compared to alkanethiols, which can be slightly improved using the in situ approach.

KEYWORDS: Dithiocarbamates, Self-assembled monolayers, Preparation technique, Thermal stability, Chemical stability

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T5-13 ORAL

Thermally stable aromatic SAMs for highly conductive or highly insulating organic monolayers on metals

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Self-assembled monolayers (SAMs) on metal substrates are a key component of modern interfacial physical chemistry and advanced nanotechnology. The robustness of SAMs strongly depends on their thermal stability, which, together with electrical conductivity, constitutes a critical parameter for applications in molecular and organic electronics as well as photovoltaics.

In this work, we employ a multidisciplinary approach to investigate the structure, thermal stability, and conductivity of SAMs formed on metal substrates (Au or Ag) using various anchoring groups, including thiols, selenols, carboxylic acids, and carbenes.

Our recent results [1-5] demonstrate the formation of thin, well-defined monolayers exhibiting exceptionally high thermal stability. Depending on the molecular system, these SAMs can be either highly insulating or highly conductive, making them promising nanomaterials for the modification of gate or drain/source electrodes in organic field-effect transistors (OFETs).

KEYWORDS: Self-assembled monolayers, Organic electronics, Thermal stability, Conductivity

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T5-14 ORAL

Development of a method for producing self-fluxing nickel-based coatings by detonation spraying

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This study investigated the influence of detonation spraying process parameters on the structure and tribomechanical properties of self-fluxing coatings of the Ni-Cr-Fe-B-Si-C system. The variable parameters included the barrel fill volume (48-68%), the molar ratio of the working gases (O/C = 1.026-1.856), and the delay time between shots (0-1 s). A morphological analysis of the coatings revealed the formation of a characteristic lamellar structure and the dependence of thickness and defects on spraying conditions. It was found that low barrel fill volumes result in a denser structure with minimal porosity, while medium and high barrel fill volumes result in the formation of microcracks due to increased residual stress. Tribological tests have shown that the minimum friction coefficient is achieved at a filling of 48% ($\mu = 0.674 \pm 0.136$) and an O/C ratio of 1.026, but this also results in increased wear. The highest wear resistance is ensured at O/C = 1.856 and an increased delay between shots (up to 1 s), at which the wear intensity decreases to 0.000189 mm3/(N·m). Roughness analysis showed that an increase in the delay between shots leads to a decrease in Ra from 5.00 to 3.60 μm, which is associated with a decrease in the thermal load and improved conditions for coating formation. Maximum hardness (up to 905.6 HV) is achieved with an optimal combination of parameters, ensuring the formation of a dense structure and strengthening phases. It is shown that optimization of detonation spraying parameters requires a compromise between a decrease in the friction coefficient and an increase in wear resistance. The obtained results can be used in the development of technologies for the restoration and strengthening of machine parts.

KEYWORDS: Self-fluxing alloys, Detonation spraying, NiCrFeBSiC, Heat treatment, AISI 321

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T5-15 ORAL REMOTE

Effect of dopant valence on infrared spectra of hafnia and zirconia films

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Doped hafnia and zirconia are widely used as high-k materials in microelectronics, optics, and memory devices, where their functional properties are strongly influenced by defect structure and bonding configuration. Infrared (IR) spectroscopy provides a sensitive probe of these features; however, spectral interpretation remains challenging, especially for doped oxides due to the coexistence of different doping mechanisms.

In this work, the effect of dopant valence on FTIR spectra of HfO_2 and ZrO_2 films was studied. The films were grown on Si substrates by RF magnetron sputtering. Various dopants, namely, isovalent (Si, Ge), subvalent (Er, Nd), and supervalent (Ta), were introduced into the films during deposition, enabling controlled modification of defect structure and bonding.

The obtained results show that isovalent dopants (Si, Ge) do not introduce charge imbalance but lead to bond reconstruction and formation of mixed Me-O-Si or Me-O-Ge units (Me=Hf, Zr). As a result, IR spectra exhibit additional high-frequency absorption bands associated with Si-O (800-1100 cm^{-1}) and Ge-O (600-900 cm^{-1}) vibrations. At the same time, intrinsic Me-O phonon modes in the 250-700 cm^{-1} region undergo a blue shift of ~10-30 cm^{-1} (more pronounced for Si), remaining within the same spectral range while preserving their structure.

In contrast, subvalent dopants (Er, Nd) induce oxygen vacancies for charge compensation, leading to lattice distortion and reduced bond stiffness. This results in a characteristic red shift of vibrational modes by 10-40 cm^{-1} (e.g., 500 → 470-490 cm^{-1}), strong band broadening, and merging of spectral features, particularly in the monoclinic phase, as well as the appearance of weak defect-related bands in the 650-900 cm^{-1} region.

Supervalent dopants (Ta) introduce excess electrons and modify IR spectra via electron-phonon interaction and screening effects. In this case, frequency shifts are relatively small (±5-10 cm^{-1}), while the main changes include redistribution of band intensity, smoothing and asymmetry of spectral features, and moderate broadening. Additional high-temperature annealing (800-900 °C) further differentiates these mechanisms: strongly covalent Si-O bonds ensure high spectral stability, whereas vacancy-rich systems (Er, Nd) exhibit significant restructuring, and Ta-doped films vary mainly due to carrier redistribution. These mechanisms are discussed in detail. The results demonstrate that each dopant class produces a distinct spectroscopic fingerprint and provide a universal framework for interpreting IR spectra and assessing structural stability in HfO_2- and ZrO_2-based thin films. The obtained results are relevant for the development of high-k dielectrics, optical coatings, and resistive memory devices, where precise control of bonding, defect structure, and thermal stability is essential for device performance

KEYWORDS: HfO 2, ZrO 2, Infrared spectroscopy, Dopant valence, Thin films

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T5-16 ORAL

The effect of laser surface hardening on the microstructural characteristics and wear resistance of 9CrSi steel

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Laser surface hardening is a widely used technique for enhancing the wear resistance and durability of tool steels without affecting their bulk properties. It enables localised heat treatment with high precision and minimal thermal distortion. However, the relationship between processing parameters and the resulting microstructure and performance is not well understood for high-carbon chromium steels such as 9CrSi.

In particular, the combined influence of laser power, modulation frequency and scanning speed on microstructure-property-performance relationships has not yet been fully clarified.

In this study, we demonstrate that laser surface hardening of 9CrSi steel produces a martensitic surface layer containing varying amounts of retained austenite, which significantly improves the material's mechanical and tribological properties.

We found that laser processing increases surface microhardness from ~220 $HV_{0.1}$ to 950-1000 $HV_{0.1}$ and reduces the wear rate by more than an order of magnitude under dry sliding conditions. Depending on the processing regime, the hardened layer thickness varies from ~500 to 750 μm, and X-ray diffraction confirms the formation of α′-Fe, γ-Fe, and Fe_3C phases with increased lattice microstrain.

These results demonstrate that scanning speed plays a key role in controlling thermal input, microstructure refinement and hardened layer depth, while the balance between martensite and retained austenite governs friction and wear behaviour. Overall, this study establishes a parameter-microstructure-performance map for laser-hardened 9CrSi steel, providing guidance on how to optimise processing regimes to improve wear resistance and mechanical performance in engineering applications.

KEYWORDS: Laser surface hardening, 9CrSi steel, Microstructure evolution, Retained austenite, Dry sliding friction

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T5-17 ORAL

Development of bifunctional polymer surfaces via fs laser structuring and subsequent chitosan/Cu deposition

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One of the most widely used biomaterials in tissue engineering field is the polylactic acid (PLA). Due to its iseasily customizable properties the scaffolds made from PLA support effectively tissue regeneration. Despite effective PLA biodegradability and biocompatibility characteristics, the polymer lacks antimicrobial activity, which raises the need to further modification of its surface performance for applications in tissue engineering [1,2] In this research, poly lactic acid (PLA) matrices were textured via femtosecond laser processing using a galvanoscanner module. The designed structures exhibited micron sized hierarchical hydrophobic surface structures. Ultra-short laser modification is a non-contact method for modification of a variety of materials. It proceeds with creation of defined, precise with minimal thermal damage processing zones, allowing the creation of well-defined surface structures that affects surface wettability state, surface energy, and subsequently cell-material interactions [3]. The obtained laser textures provide hydrophobic surface behavior, due to formed hierarchical structures which promotes a Cassie-Baxter wetting regime. Additional functionalization of structured PLA by spin coating deposition of a chitosan layer was performed, which altered the wettability states by minimizing the water contact angle after laser processing. The different wetting behaviors of the structures before and after chitosan layer deposition were correlated with the surface structures and wetting states. Comprehensive characterizations of the surface characteristics surface roughness, and wetting dynamics of different textures before and after chitosan layer deposition were done for comparative investigation. In parallel, magnetron sputtered copper (Cu) was deposited onto the femtosecond laser structured PLA matrices, in order to introduce additional antimicrobial functionality. This step additionally provides factors such as Cu loading, distribution, oxidation state, or release kinetics may contribute to overall antimicrobial performance of the designed matrix.. The current study provides a method to combine fs laser structuring with additional functionalization with biopolymer and separately a comparison with metallic thin layer, for obtaining a comparative results in the case of multifunctional surface engineering. However, optimization of the metallic deposition parameters is necessary to achieve effective antimicrobial activity. These findings contribute to the development of advanced biofunctional surfaces for biomedical applications.

KEYWORDS: Biomaterials, Femtosecond laser modification, Tissue engienering, Functionalization

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T5-18 ORAL REMOTE

The fabrication of multi-walled carbon nanotube thin films through laser-assisted growth techniques

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Multiwalled carbon nanotubes (MWNTs) are highly versatile nanostructures with broad industrial utility. This research investigates the application of pulsed laser deposition (PLD)-a technique noted for its ability to produce thin films with superior surface integrity and physical characteristics. Herein, MWNT films were synthesized by laser-ablating compressed targets (6−10 nm×2 \mum) onto glass and Si(111) substrates. Comprehensive structural analysis via XRD and SEM verified film homogeneity and the presence of carbon-specific peaks. Furthermore, surface morphology was evaluated using Atomic Force Microscopy (AFM) to determine RMS roughness and fractal dimensions (DF). By utilizing the k-correlation (ABC) model to analyze Power Spectral Density (PSD) functions, the study characterizes the transition from primary grains to complex aggregates, revealing the fundamental growth mechanisms inherent in PLD-deposited MWNT films. This research explores the morphological dynamics of MWNT thin films fabricated through Pulsed Laser Deposition. By employing Power Spectral Density (PSD) analysis on AFM-derived data, we elucidate the correlation between laser fluence and grain clustering mechanisms. These findings offer a comprehensive understanding of the surface scaling and fractal topology inherent in laser-deposited carbon coating.

KEYWORDS: Multi-Walled carbon nanotubes (MWCNTs), Pulsed laser deposition (PLD), Atomic force microscopy (AFM), Surface topography

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Posters

T5-19 **POSTER**

Towards advanced wear-resistant coatings: tailoring TiXN/NbN multilayers via alloying strategy

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Multilayer nanolaminate coatings based on transition metal nitrides have attracted significant attention due to their ability to exhibit superior mechanical performance arising from interface-driven strengthening mechanisms [1]. In particular, Ti-based multilayers combined with NbN have demonstrated promising properties due to the synergistic interaction between constituent layers [2]. However, a systematic understanding of the role of alloying elements in Ti-based layers on the structural evolution and strengthening mechanisms of TiXN/NbN multilayers remains limited. In this work, a comparative study of TiXN/NbN (X = Zr, Si, Mo) multilayer coatings deposited by cathodic arc evaporation is presented. The influence of alloying element on phase composition, microstructure, and mechanical properties was investigated using advanced structural and mechanical characterization techniques.

The results reveal distinct growth mechanisms depending on the alloying element. TiZrN/NbN coatings exhibit a predominantly columnar structure with coherent growth across interfaces, indicating a strong template effect of NbN layers. In contrast, TiSiN/NbN multilayers demonstrate the formation of amorphous TiSiN nanolayers, which disrupt epitaxial growth and lead to a featureless morphology. TiMoN/NbN coatings show refined microstructure and enhanced tribological performance, associated with solid solution strengthening and grain refinement effects. Despite comparable hardness values, the coatings exhibit fundamentally different strengthening mechanisms governed by the nature of the alloying element. The obtained results highlight that the selection of alloying component in Ti-based layers provides an effective pathway for tailoring microstructure and optimizing mechanical performance of multilayer coatings. This study provides new insights into the design of advanced multilayer coatings with controlled architecture and enhanced functional properties for industrial applications.

KEYWORDS: Protective coatings, TMNs, Alloying, Hardness, Wear-resistance

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T5-20 E-POSTER

Electrical conductivity of thin films of CoNi, FeNi, and CuNi alloys

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This paper presents the results of a study of the electrical conductivity of structurally continuous nanocrystalline films of CoNi, FeNi, and CuNi alloys in the thickness range of 10-200 nm and a wide range of component concentrations. CoNi and FeNi alloy films were obtained by condensation of evaporated initial bulk binary CoNi and FeNi alloys, while CuNi alloy films were obtained by simultaneous, separate evaporation of the components (copper and nickel) in a vacuum of 10^{-4} Pa. Nickel and bulk alloys were evaporated using an electron beam evaporation method using an electron diode gun. Copper was evaporated from a 0.05 mm thick tungsten foil ribbon. The condensation rate was 0.5-1.5 nm/s. Thermal stabilization of the electrical properties of the alloy films was achieved through three heating-cooling cycles in the temperature range of 300-700 K. The dependences of the film electrical resistance on the annealing temperature were studied. For all alloy films, the temperature dependence curves of electrical resistance for the second and subsequent heating-cooling cycles were virtually identical, indicating complete stabilization of the electrical properties of the film samples after the second annealing cycle. A specific irreversible decrease in the electrical resistance of the films after heat treatment was experimentally revealed, indicating ordering of the film structure. It was shown that the nature of the change in electrical resistance depends on both the thickness of the alloy films and the ratio of the alloy components. To explain the observed decrease in electrical resistance during thermal stabilization of the electrical properties of the films of the studied alloys, we used the Wend model, which describes the healing of defects in the crystalline structure of the films and the improvement of structural ordering. Based on this model, crystal structure defect spectra were calculated in films of the studied CoNi, FeNi, and CuNi alloys.

KEYWORDS: Thin films, Nanocrystalline films, Electrical conductivity, Crystal structure defects, Activation energy for defect healing

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T5-21 E-POSTER

Contact mechanics of Pb, Cu, and Al nanoparticles

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Tribological properties of metal nanoparticles (NPs) adsorbed on various surfaces can be unique. Experimentally and numerically, it has been shown that copper, gold, silver, and antimony NPs adsorbed on various substrates can exhibit superlubricity [1], frictional anisotropy [2], and a significant dependence of the friction force on the environmental conditions [3]. Fundamentally, it is expected that a quantitative understanding of the atomistic origins of friction will enable the explanation of well-known macroscopic tribological laws. From a practical point of view, this will facilitate control of adhesion, friction, and wear at the nanometer scale, which is important for the rapidly developing applications of metallic NPs in medicine, pharmaceuticals, cosmetics, catalysts, batteries, sensors for the detection of toxic heavy metals, etc.

In general, the quantitative characterization of tribological properties is based on the concepts of contact mechanics (CM), such as the apparent, absolute, and relative contact areas of surfaces, the average distance between them, the distribution of interfacial distances and forces, topography, in particular, the power spectrum of surface roughness, and root-mean-square roughness [4]. However, unlike the existing knowledge of thermodynamic, optical, and other properties, there is no literature data on the size scaling of CM properties of NPs.

In this work, we investigate the size scaling of the CM properties of Cu, Al, and Pb NPs adsorbed on a suspended graphene substrate using classical molecular dynamics simulations. The large-scale model enabled us to consider NPs with diameters ranging from 1 nm to approximately 50 nm. The simulations suggest that the NPs' contact surfaces are not flat, which is confirmed by the height distributions of the contact surface of NPs that can roughly be subdivided into three parts: a narrow Gaussian spike, the uniform height section, and a Gaussian tail. The surface height can vary by more than 1 nm. In contrast, the distribution of the distances between the surfaces can be approximated by a single Gaussian. The variation in the interfacial gap is only a few Å. The isotropic height power spectral density (PSD) of the contact surface of NPs larger than about 20 nm in diameter exhibits relatively narrow power-law regions. Our simulations suggest that NPs formed on a macroscopically smooth graphene can exhibit random roughness. The results provide a basis for the quantitative description of NP contact mechanics by estimating PSDs that can be used in analytical theories for atomistic systems.

KEYWORDS: Contact mechanics, Graphene, Molecular dynamics, Topography

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T5-22 POSTER

Preparation of TiO_2-Cr_2O_3 composite powder based on nanoparticles using spray drying for atmospheric plasma spraying

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In this study, composite coatings based on TiO_2 and TiO_2-Cr_2O_3 nanopowders were produced by atmospheric plasma spraying for use in high-temperature acid leaching conditions. The initial nanopowders were first agglomerated in an aqueous medium with the addition of polyvinyl alcohol, after which spherical granules were formed from them by spray drying. The coatings were applied to substrates made of corrosion-resistant steel 12Kh18N10T. According to X-ray diffraction analysis, the main crystalline components of the coatings were rutile TiO_2 and Cr_2O_3, with a small amount of Ti_2O_3 present. In coatings formed solely from TiO_2, the rutile phase predominated, whilst anatase was detected in insignificant quantities and brookite was not observed. The predominance of rutile is due to the high-temperature conditions of plasma spraying, which promote the phase transformation of anatase into the more stable rutile modification. The coatings obtained were characterised by a dense structure and low porosity, which is attributed to the optimisation of both the preparation of the powder material and the spraying conditions. The introduction of Cr_2O_3 resulted in a significant increase in the microhardness of the coating to 1015 HV, whereas for the pure TiO_2-based coating this figure was 723 HV.

KEYWORDS: Coatings, Plasma spraying, Wear resistance, Spray dryer

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T5-23 POSTER

Ferroelectric-like double P-E hysteresis of plastic crystalline succinonitrile based on rotational and conformational degrees of freedom

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Organic molecular solid materials often exhibit intermediate phases between solid and liquid states, such as liquid crystal (LC) and plastic crystal (PC) phases, due to the balance of relatively weak intermolecular interactions (e.g., van der Waals and hydrogen bonding interactions). In particular, PC materials, which have the ordered molecular center of gravity with the disordered molecular orientation, i.e. rotational dynamics, are promising candidates for next-generation memory materials due to their dynamic nature [1]. In this study, we focused on succinonitrile (**SN**), which exhibits a PC phase between 233 and 328 K. In addition to the rotational degree of freedom, **SN** possesses conformational degree of freedom; **SN** exhibits two stable conformations with distinct electric dipole moments, gauche and trans conformations, in the PC phase [2]. Because of these peculiar two degrees of freedom, it is expected that **SN** can show unconventional dielectric properties. However, the dielectric properties of **SN** remained largely unexplored. Here we show that **SN** forms a unique polarized orientation state in the PC phase [3]. We discovered that **SN** exhibits hysteresis in the polarization-electric field (*P*-*E*) curves in the PC phase above 240 K. Notably, such *P*-*E* hysteresis curve has not been observed in the PC phase of previously reported ionic plastic crystals although they show ferroelectricity in the low-temperature crystalline phase [1,4]. To the best of our knowledge, this is the first example of ferroelectric-like *P*-*E* hysteresis in a PC phase. Furthermore, current-electric field (*J*-*E*) curves (the first derivative of the *P*-*E* curves) revealed two distinct current peaks corresponding to polarization reversal. This result suggests the existence of two different polarization mechanisms of **SN**, originating from the molecular orientational and conformational degrees of freedom. The discovery of *P*-*E* hysteresis in the PC phase represents a significant leap toward unlocking the latent potential of the PC materials. Moreover, the existence of two different polarization reversal mechanisms is expected to be a key to realizing high-density memory that can use quaternary states, thereby surpassing conventional memories using binary states.

KEYWORDS: Succinonitrile, Plastic crystal, Molecular dynamics, Ferroelectricity

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T5-24 E-POSTER

Influence of acid modification on the protective properties of montmorillonite nanoreservoirs as anticorrosion pigment

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Polymer coatings are widely used to protect aluminium alloys from corrosion [1]. Their long-term effectiveness is due to the presence of anti-corrosion pigments such as chromates. However, chromate pigments are carcinogenic and toxic. A more environmentally friendly alternative to chromates is pigments based on natural minerals, such as aluminosilicates. In particular, aluminosilicate minerals such as montmorillonite have a layered nanostructure and can be used as nanoreservoirs loaded with an anticorrosion inhibitor [2]. The modification of montmorillonite with organic acids improves its protective anti-corrosion properties, making it a promising anti-corrosion pigment.

Therefore, the aim of the work was to obtain eco-friendly anti-corrosion pigment based on montmorillonite nanoreservoirs modified with $CH_3C(OH)(H_2PO_3)_2$ acid and to evaluate their inhibitory efficiency for an AA_{2024} aluminium alloy in an acid rain environment with pH = 4.5.

The anticorrosion pigment based on the montmorillonite nanoreservoirs acid modified was obtained by liquid phase ion exchange. Montmorillonite from bentonite was purgated by the coarse-dispersed phase sedimentation method [3]. The montmorillonite nanoreservoirs acid modified increases the corrosion resistance of the an AA_{2024} aluminium alloy in the acid rain environment. According electrochemical impedance spectroscopy results, it was established that the value of charge transfer resistance (R_{ct}) of the aluminium alloy was $3.4 \cdot 10^4$ $\Omega \times cm^2$, after 24 hours of immersion in the acid rain environment. The addition of acid modified montmorillonite to the environment causes a gradual release of phosphonate anions, adsorbed on the alloy surface through complexation with metal ions. The value of R_{ct} of the aluminium alloy was $8.4 \cdot 10^4$ $\Omega \times cm^2$, after 24 hours of immersion in an inhibited environment.

Thus, acid modification of montmorillonite nanoreservoirs is effectively for corrosion protection of aluminium alloy in an acid rain environment.

KEYWORDS: Montmorillonite, Acid modification, Corrosion, Nanoreservoirs, Polymer coatings

ACKNOWLEDGEMENTS: The work was performed within the project No. 2025.07/0048 "Development of new environmentally friendly inhibitory compositions for protection against tribocorrosion and corrosion fatigue of aluminum alloy structures" of the National Research Foundation of Ukraine.

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T5-25 POSTER

Image segmentation-based quantitative analysis of surface topography in HfZrTiTaNb-cx coatings

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High-entropy ceramics (HECs) are multicomponent solid solutions containing four or more main elements at near-equiatomic concentrations [1]. These materials offer an alternative to the classical development approach, which has been successfully adapted from metallic alloys to ceramic systems. Of particular interest are high-entropy carbides based on Group IV-V metals, which demonstrate high hardness, wear resistance and resistance to extreme operating conditions [2,3]. Their unique properties are due to a combination of strong covalent bonds and pronounced lattice distortion effects arising from their multicomponent composition [4].

In this study, high-entropy HfZrTiTaNb-Cx coatings were deposited by DC magnetron co-sputtering from two independent sources. The carbon content was varied by adjusting the power of the carbon target within the range of 200-600 W. The effect of carbon on the structural and morphological properties was comprehensively investigated using X-ray diffraction (XRD), atomic force microscopy (AFM) and Raman spectroscopy. Surface topography was analysed by image segmentation followed by statistical and morphological analysis of the identified structures.

The results of a quantitative analysis of AFM images show that surface morphology is strongly dependent on carbon content. With increasing carbon content, surface roughness increases and the structure exhibits a non-monotonic evolution, accompanied by the coarsening of nanostructures at high power levels. This behavior may be associated with their coalescence and the formation of a carbon phase at elevated carbon contents.

Raman spectroscopy confirmed the formation of an amorphous spZ-bonded carbon phase at high carbon content, indicating a transition from a single-phase carbide system to a two-phase structure (carbide + graphite-like carbon). XRD confirms a single-phase fcc carbide (Fm-3m) with lattice expansion at higher carbon content. All samples exhibit a predominant (111) texture, characteristic of transition metal carbides.

The obtained results demonstrate the key role of carbon content in determining the properties of HfZrTiTaNb-Cx coatings and confirm their potential for further research into the relationship between structure, morphology and mechanical characteristics.

KEYWORDS: High-entropy carbides, Magnetron co-sputtering, Carbon content, Dual-phase structure, Surface morphology

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T5-26 E-POSTER

Polymer membranes based on polyelectrolyte complexes

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In the modern world, the problem of ensuring access to quality water remains acute. This is due to global challenges such as the growth of industrial production, population growth, climate change, and the reduction of fresh water reserves. Water purification membranes, as a key technology in the field of water purification and reuse, require modernization of production to meet growing needs.

The most common contaminants found in water are heavy metals, synthetic dyes and petrochemical residues. In addition, in recent years, attention has been increasing to micropollutants, in particular pharmaceuticals and personal care products, which is associated with increased awareness of their impact on the environment, public health and the economy.

The structure, thermal, thermomechanical and sorption properties of polyelectrolyte complexes (PECs) pectin-chitosan, pectin-cationic starch and CMC-cationic β-CD were investigated. Using the IR spectroscopy method, it was found that the spectra of all studied polyelectrolyte complexes contain two intense bands in the region of 1417-1423 cm^{-1} and 1616-1623 cm^{-1}, which can be attributed to symmetric and asymmetric deformation vibrations of ionized carboxyl groups, which confirms the formation of polyelectrolyte complexes. Analysis of wide-angle X-ray diffraction patterns of the studied samples showed that pectin and Na-CMC are characterized by an amorphous structure, while cationic starch, chitosan and β-CD have a semi-crystalline structure. The highest degree of crystallinity is characteristic of PECs pectin-cationic starch and is 75%. It was found that the best thermal and thermomechanical indicators are possessed by the polymer system CMC-cationic β-CD (destruction onset temperature 274 °C, glass transition temperature 58.3 °C, relative deformation 18%). It was established that the polymer system pectin-chitosan has a higher sorption capacity for Cu^{2+} and Ag^{+} cations compared to other complexes. In particular, for Cu^{2+} A=2.45 mmol/g, for Ag^{+} A=3.8 mmol/g.

The obtained results confirm the promising use of polyelectrolyte complexes based on polysaccharides as effective materials for creating environmentally friendly membranes for wastewater filtration.

KEYWORDS: Polyelectrolyte complexes, Membranes, Water purification

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T5-27 POSTER

Influence of detonation spraying parameters on the structure and properties of Al_2O_3 coatings

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The present study investigates the influence of detonation spraying parameters on the structure and properties of Al_2O_3 coatings deposited on 10Kh18N9 stainless steel. The coatings were produced using a $CCDS_{2000}$ detonation system at different barrel filling ratios (53%, 58%, and 63%), allowing variation of the process energy parameters. A comprehensive analysis of the phase composition, microstructure, mechanical, tribological, and corrosion properties of the coatings was carried out. It was established that α-Al_2O_3 is the dominant phase in all samples, with a content of 77-80%, which is attributed to the high temperatures of the detonation process. The coatings exhibit a dense and homogeneous structure with a well-defined interface with the substrate. The optimal mechanical properties were achieved at a barrel filling ratio of 58%, where the Young's modulus reached 190 GPa and the hardness was 1362 HV, due to the formation of the most compact structure. This regime also provided the highest adhesion strength. It was shown that the coatings significantly improve the corrosion resistance of the steel by reducing the corrosion current density and corrosion rate. Tribological tests revealed that wear resistance strongly depends on the counterbody material: minimal wear was observed when using ZrO_2, whereas the use of 100Cr6 steel resulted in increased wear intensity. The obtained results demonstrate that optimization of detonation spraying parameters can significantly enhance the performance characteristics of Al_2O_3 coatings, making them promising for the protection of structural materials.

KEYWORDS: Detonation spraying, Al_2O_3 coating, Aluminum oxide, Phase composition, 10Kh18N9 steel

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T5-28 E-POSTER

Packaging polymer materials with antimicrobial activity

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The creation and research of packaging materials based on biopolymers with silver nanoparticles is an urgent task today.

The relevance of packaging materials is due to their important role in maintaining the quality and safety of products, protecting them from external factors and extending the shelf life. The growth of e-commerce and logistics increases the demand for effective packaging, while environmental problems stimulate the development of biodegradable and recyclable materials. Thus, this area is of significant scientific and practical importance.

Using the wide-angle radiography method, it was established that the studied film materials have a semi-crystalline structure and the presence of Ag particles in the formed polymer matrices was confirmed. Morphological analysis of the studied samples showed that a layer of silver nanoparticles with a thickness of ~ 100 nm is formed on the surface of the biopolymer film made of polylactide (spraying time 5 min) with an average size of 5.9 nm; a layer of Ag particles with a thickness of ~ 425 nm is formed on the surface of polymer films based on polylactide and polycaprolactone (PLA-PCL) (spraying time 5 min). It was found that spraying silver nanoparticles on the surface of film packaging biopolymers PLA-PCL leads to a decrease in their temperature of onset of thermal destruction by 6.5 °C. According to differential scanning calorimetry, it was found that as a result of sputtering silver nanoparticles onto the surface of PLA-PCL polymers, the degree of crystallinity increases from 35% to 39%, as well as the melting temperature Tm from 168 °C to 169-170 °C. This effect is associated with the effect of silver particles that penetrate the polymer film to a certain depth and create a nucleating effect during polymer crystallization. In this case, there is no effect of a thin layer of silver nanoparticles on the amorphous phase of the polymer film, since the glass transition temperature of the polymer matrix (T_g) does not change. It was found that biopolymer packaging materials based on polylactide and Ag nanoparticles (sputtering time 3 and 5 min) exhibited a bactericidal effect on microorganisms *S. aureus* and *E. coli* and were inactive against strains of *B. subtilis* and *P. aeruginosa*.

KEYWORDS: Polylactide, Polycaprolactone, Packaging films, Food products

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T5-29 E-POSTER

Antimicrobial PLA/PCL nanocomposite films incorporating silver nanoparticles for bread preservation

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Bread, a staple food for much of the world's population, is highly perishable and prone to mold growth, limiting its shelf life and contributing to food waste. Furthermore, some molds, particularly those of the species Aspergillus niger, produce mycotoxins that are extremely harmful to human health. The use of packaging makes it possible to regulate bread storage conditions and to inhibit the rapid development of contaminating microflora. At the same time, packaging materials must meet a number of requirements, including cost-effectiveness, environmental sustainability, and effective antimicrobial performance. Recent advances in active packaging have focused on biodegradable materials with enhanced antimicrobial functionality achieved through the incorporation of antimicrobial agents such as silver nanoparticles, which inhibit microbial growth via their high surface area and multiple mechanisms of action, including membrane disruption and intracellular interactions [1].

The developed biodegradable PLA-PCL (80:20, w/w) packaging material incorporating silver nanoparticles (5.9 nm particle size, 97 mZ/g specific surface area) via a spraying technique formed a ~100 nm-thick layer and demonstrated the potential to extend the shelf life of bakery products without compromising their quality. An additional enhancement of the antimicrobial properties of the resulting packaging material could be the addition of essential oil to its formula [2, 3]. The use of the developed packaging film reduced moisture loss and preserved crumb elasticity and hydration capacity in wheat bread during storage, consequently slowing the staling process. The use of the proposed packaging made it possible to extend the shelf life of bread by 2 days, while the packaged bread samples retained better freshness by 10% and 14% compared to the control samples after 24 and 48 hours of storage. PLA-PCL films with surface-deposited AgNPs demonstrated strong antimicrobial activity against Staphylococcus aureus and Escherichia coli (13.8-16.5 mm inhibition zones), while control films were inactive. In addition, the films effectively inhibited mold growth on bread samples inoculated with Aspergillus niger and Penicillium chrysogenum conidia.

Overall, the developed PLA-PCL biodegradable nanocomposite film incorporating silver nanoparticles demonstrated effective antimicrobial performance and the ability to extend the shelf life of bakery products without compromising their quality, highlighting its potential for application in active food packaging systems.

KEYWORDS: PLA-PCL films, AgNPs, Active packaging, Antimicrobial activity, Bread preservation

ACKNOWLEDGEMENTS: The work was carried out with the financial support of a grant from the National Research Foundation of Ukraine "Development of packaging materials based on biopolymers with antimicrobial components of natural origin for long-term storage of food products" (Application ID 2025.07/0333).

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T5-30 POSTER

Effect of preliminary mechanical surface treatment on the kinetics of plasma-electrolytic nitriding of chromium-alloyed structural steel

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Plasma-electrolytic nitriding (PEN) is a promising method for surface hardening of structural steels, enabling the formation of wear- and corrosion-resistant diffusion layers, while the kinetics of their formation is governed by both discharge parameters and the initial surface condition of the material [1,2]. It is well known that preliminary mechanical treatment (grinding, polishing, abrasive blasting) alters surface roughness, defect density, and residual stress levels in the surface layer, thereby significantly affecting mass transfer processes; for chromium-containing steels, oxide and carbonitride phases capable of forming diffusion barriers are of additional importance [3,4]. However, the influence of different types of mechanical surface preparation on the kinetics of PEN remains insufficiently studied. In this work, the effect of preliminary mechanical surface treatment on the growth kinetics of the nitrided layer during plasma-electrolytic nitriding of chromium-alloyed structural steel is investigated. Here, we show that an increase in surface roughness and defect density leads to an acceleration of the initial stage of nitriding and an increase in the thickness of the diffusion layer. It is established that samples subjected to mechanical treatment exhibit a higher layer growth rate following a parabolic law, due to an increased effective surface area and a higher number of diffusion paths, whereas polished surfaces are characterized by slower kinetics as a result of a reduced density of active sites and the formation of a stable oxide film. The obtained results refine the current understanding of the role of surface condition in plasma-electrolytic treatment processes and demonstrate the possibility of controlling diffusion processes through mechanical surface preparation. Thus, controlling the surface morphology and structural state is a key factor in optimizing PEN regimes and the properties of the formed layers. The results open up prospects for targeted control of nitrogen saturation kinetics by combining mechanical and plasma-electrolytic treatments, which can be used in the development of hardening technologies for machine components operating under severe wear and high-load conditions, as well as in the design of functional gradient layers with tailored performance characteristics.

KEYWORDS: Plasma-electrolytic nitriding, Preliminary mechanical treatment, Surface roughness, Diffusion kinetics, Chromium-alloyed structural steel

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T5-31 POSTER

Effect of reactive magnetron sputtering parameters on the structure and properties of TiO_xN_γ thin films

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Titanium oxynitride (TiO_xN_γ) coatings were deposited on 316L stainless steel substrates by reactive magnetron sputtering in an Ar-N_2-O_2 gas mixture at a fixed N:O ratio of 1.6. The argon flow rate was considered as the key process parameter, and three sample series were prepared: Ar_{33}, Ar_{25}-28, and Ar_{26} (sccm). The obtained coatings exhibited a dense and uniform microstructure, with thicknesses ranging from 2.13 to 5.51 μm depending on the deposition conditions. X-ray diffraction analysis revealed a multiphase structure consisting of TiN, TiO_xN_γ, and TiO phases, which is typical for titanium oxynitride coatings. Mechanical and tribological tests demonstrated a strong dependence of properties on deposition parameters. The lowest friction coefficient ($\mu \approx$ 0.26-0.28) was observed for the Ar_{26} series, indicating optimal deposition conditions. Electrochemical measurements in 3.5 wt.% NaCl solution showed that the highest corrosion resistance was achieved for the Ar_{25}-28 series (i_corr = 2.82 × 10^{-7} A/cmZ; v_corr = 0.00573 mm/year).

All coatings exhibited a hydrophilic surface with a contact angle of ~50-57°, which is beneficial for biomedical applications. The results demonstrate that controlling the argon flow rate during reactive magnetron sputtering enables targeted tuning of the structure and functional properties of TiO_xN_γ coatings, making them promising for surface modification of vascular implants [1].

KEYWORDS: Titanium oxynitride, Thin protective coatings, Biocompatible surfaces, Corrosion resistance, Mechanical properties

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T5-32 E-POSTER

Effect of soluble and insoluble silicates on the formation and structure of phosphate-based PEO coatings on magnesium

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Magnesium and its alloys are promising materials for biodegradable implants due to their favorable mechanical properties and biocompatibility [1]. However, their rapid corrosion rate significantly limits their clinical application. Plasma electrolytic oxidation (PEO) is a surface modification technique that can enhance corrosion resistance while maintaining biocompatibility [2]. In particular, mixed phosphate-silicate electrolytes involve complex plasma-chemical and electrochemical interactions that strongly influence coating formation kinetics, microstructure, and biological performance. Although silicate-based systems have been widely studied, including both soluble (SS) and insoluble silicates (IS), their comparative effects in combination with different phosphate species remain insufficiently understood [3, 4].

Therefore, the aim of this work is to investigate the properties of coatings formed in electrolytes containing soluble and insoluble silicates, in combination with phosphates.

For PEO treatment of Mg-based implants, we developed three electrolyte formulations: we elaborated following electrolyte composition: SS_1 containing 5 g·dm^{-3} Na_2SiO_3 and 15 g·dm-^{3} Na_3PO_4, SS_2 - 5 g·dm^{-3} Na_3PO_4 and 3 g·dm^{-3} KOH, and IS_1 - 5 g·dm^{-3} Na_3PO_4, 3 g·dm^{-3} KOH, and 50 g·dm^{-3} $CaSiO_3$. The PEO process was conducted under an impulse current up towith a fixed voltage (in 250V, 300V, and 350V), employing with the use of a high-voltage power supply (PWR 800H, Kikusui, Japan). The obtained resulting samples were analyzed by scanning electron microscopy equipped with energy-dispersive X-ray spectroscopy (EDX). The surface wettability was measured by static contact angle (CA) measurements. Cytocompatibility of the PEO coatings was evaluated using MG-63 cells, and cell viability was assessed after 1, 3, and 6 days using a resazurin reduction assay relative to uncoated control samples.

The results demonstrated that soluble silicates significantly accelerated coating formation, while systems containing insoluble silicate particles required higher voltages (up to 350 V). The obtained coatings exhibited a porous morphology. Increased P content led to thicker coatings for the SS_1 sample (3.8 ± 0.7 μm) at 250 V. EDX analysis demonstrated effective incorporation of P, reaching up to 7 at.% for SS_1 at 250 V and for SS_2 and SS_3 at 350 V. Higher Si content was observed only for soluble silicate systems. However, the synergistic effect of insoluble silicates and phosphates improved surface hydrophilicity at higher applied voltages for the SS_3 sample (CA down to ~20°). Biological studies using MG-63 cells indicated that selected coatings, particularly SS_1 and SS_2 formed at higher voltages in particle-containing electrolytes, exhibited cytocompatible properties.

The study highlights the distinct roles of soluble and insoluble silicates in tailoring coating properties.

KEYWORDS: Magnesium, Biodegradable implants, PEO coating, Phosphate, Silicate

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T5-33 E-POSTER

An experimental and theoretical investigation of size effects in electrical resistivity of FeNi(Co) thin-film alloys

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Among various magnetic alloys, Fe-based thin-film alloys, particularly the binary alloys Fe_xNi_{1-x} and Fe_xCo_{1-x}, have received considerable attention. To date, a significant amount of experimental and theoretical work has been accumulated on the study of the structural and phase state, electrical conductivity, magnetic, and magnetoresistive properties of Fe_xNi_{1-x} and Fe_xCo_{1-x}[1-3]. Besides, the electrical properties of thin-film alloys are as important as the magnetic ones. The resistivity value significantly depends on the method and technological conditions used to obtain film alloys.

Binary thin-film alloys Fe_xNi_{1-x} and Fe_xCo_{1-x} with nominal thickness (d) ranging from 15 to 80 nm were deposited using electron-beam evaporation in a high vacuum chamber maintained at a base pressure of 10^{-4} Pa. Bulk alloys Fe_xNi_{1-x} and Fe_xCo_{1-x} with compositions x = 0.2-0.8 served as source materials. Condensation was performed at room temperature (RT) with deposition rates of 0.5-1 nm/s. Film thickness was monitored "in-situ" using a quartz resonator with an accuracy of ±5%. Following deposition, all samples underwent annealing at T_{ann} = 700 K.

Structural characterization revealed that both alloy systems undergo composition-dependent phase transitions upon annealing at 700 K. For Fe_xNi_{1-x} thin-film alloys, the transition from fcc to bcc structure occurs at $x \approx 0.6$, while Fe_xCo_{1-x} films transform from mixed bcc+fcc to single bcc phase at $x \approx 0.3$. The mean grain size exhibits a linear relationship with film thickness ($L \approx k \times d$), with proportionality constants ranging from 0.6 to 2.0 for Fe_xNi_{1-x} and 0.75 to 1.5 Fe_xCo_{1-x}, depending on composition. Electrical transport measurements demonstrated classical metallic thin-film behavior across the investigated thickness range (15-80 nm). Both alloy systems show a monotonic decrease in resistivity and a corresponding increase in temperature coefficient of resistance with increasing film thickness, approaching asymptotic values characteristic of bulk materials. Theoretical analysis using the Tosser-Tellier models conclusively identified grain boundary scattering as the dominant mechanism controlling electrical conductivity in these polycrystalline films. The surface scattering parameter p remains below 0.036 for all investigated compositions, indicating nearly complete diffuse scattering at external surfaces with minimal contribution to overall resistivity. In contrast, reflection coefficients at grain boundaries range from 0.15 to 0.40, indicating a strong dependence on crystallite size and a direct correlation with observed resistivity variations. These studies demonstrate that electrical transport properties can be effectively controlled by manipulating grain size and thin-film thickness, providing valuable insights for designing spintronic devices based on nanostructured magnetic thin films.

KEYWORDS: Thin-film alloys, Electrical resistivity, Size effects, Grain boundary scattering, Temperature coefficient of resistance

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T5-34 POSTER

Oxygen-tolerant SI-ARGET ATRP synthesis of antifouling zwitterionic terpolymer brush nanocoatings

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Biofouling is a major limitation for nanomaterials exposed to complex biological, environmental, and technological media. Nonspecific adsorption of proteins, cells, microorganisms, and matrix components can substantially change surface properties, block designed interfacial functions, and reduce the lifetime and reliability of devices.

Polymer brush nanocoatings are promising antifouling materials because their dense and highly hydrated architecture can minimize nonspecific interactions while preserving chemical functionality. Random terpolymer brushes composed of *N*-(2-hydroxypropyl) methacrylamide (HPMAA), carboxybetaine methacrylamide (CBMAA), and sulfobetaine methacrylamide (SBMAA) have shown excellent resistance to fouling and compatibility with biofunctionalization [1, 2]. However, their synthesis typically relies on surface-initiated atom transfer radical polymerization (SI-ATRP) under inert conditions, which complicates experimental handling and may limit reproducibility and scalability.

Here, we report the first synthesis of poly(HPMAA-*co*-CBMAA-*co*-SBMAA) terpolymer brushes via surface-initiated activators regenerated by electron transfer atom transfer radical polymerization (SI-ARGET ATRP) and compare this approach with classical SI-ATRP. The ARGET method enables polymerization under significantly relaxed conditions, without strict oxygen exclusion, simplifying experimental handling and improving robustness.

The coatings were characterized by infrared spectroscopy (IR), X-ray photoelectron spectroscopy (XPS), water contact angle measurements, atomic force microscopy (AFM), and spectroscopic ellipsometry to assess their chemical composition, wettability, morphology, and thickness. Their resistance to nonspecific fouling was evaluated using human blood plasma as a complex biological challenge, and preservation of functional interfacial performance after biofunctionalization was examined using *Vibrio cholerae* O_1 Ogawa as a bacterial model. This comparison evaluates whether a less oxygen-sensitive polymerization route can produce zwitterionic terpolymer brush nanocoatings with physicochemical properties and antifouling performance comparable to coatings prepared by conventional SI-ATRP.

By linking polymerization strategy, nanoscale coating structure, chemical composition, and resistance to complex media fouling, this work supports SI-ARGET ATRP as a practical route for scalable fabrication of antifouling nanomaterials.

KEYWORDS: Polymer brush, Antifouling surfaces, Zwitterionic nanomaterials, SI-ARGET ATRP, Surface functionalization

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T5-35 POSTER

Refractory multicomponent protective thin films for bioactive environments

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Refractory multicomponent thin films are of growing interest as protective surface materials for demanding environments where mechanical stability, corrosion resistance, and biological surface interactions may be simultaneously required. In this work, thin films based on WNbTa, WMoRe, and TiWV(Mo,Zr,Nb) systems were considered as potential multifunctional coatings for bioactive environments.

The films were produced by magnetron sputtering under vacuum conditions, using high-power deposition at a low deposition rate. Coatings with thicknesses of approximately 200-300 nm were deposited on different substrates, including Si single crystal, glass, and TiVAl titanium alloy, and analysed using complementary structural, compositional, morphological, mechanical, tribological, corrosion-related, and microbiological characterization methods. These included SEM/EDS, RBS/PIXE elemental depth profiling, AFM surface morphology analysis, XRD phase and microstructure analysis, nanohardness and elastic modulus measurements, ball-on-disk wear testing, corrosion assessment, and antimicrobial evaluation. Particular attention was given to the relationship between coating composition, surface state, and possible functional response under conditions relevant to protective and bioactive applications.

The study provides a comparative basis for assessing refractory-metal-based multicomponent thin films as candidates for advanced protective coatings. Among the investigated systems, the WNbTa film exhibited the highest hardness, reaching about 13 GPa, while the WMoRe film showed the lowest hardness but demonstrated the most promising antibacterial properties. This contrast suggests that mechanical durability and biological surface response may be composition-dependent and should be considered together when designing multifunctional refractory coatings. The obtained results are discussed in terms of their potential for surface durability and control of microbial interactions, supporting further development of such coatings for bioactive and corrosive environments.

KEYWORDS: Refractory multicomponent thin films, Magnetron sputtering, Protective coatings, Antimicrobial activity

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T5-36 POSTER

Laser-fabricated nanostructured titanium grids and their chemical modification for photocatalytic and SERS applications

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Safeguarding environmental quality is a prerequisite for sustainable development, driving the need for efficient systems that remove organic pollutants from water and enable trace-level molecular detection. Therefore, systems for cleaning pollutants and methods for detecting and identifying trace molecular quantities of substances are of justified interest. In this regard, the potential of catalysis and Surface-enhanced Raman Scattering (SERS) is undeniable. We present laser-fabricated titanium grids that are subsequently modified by silver nanoparticle deposition and controlled surface oxidation to operate simultaneously as photocatalysts and SERS-active substrates. We demonstrate that oxidation of laser-perforated grids, which substantially enriches the surface with oxygen, yields the highest degradation rate of methylene blue, whereas grids modified with plasmonic silver nanostructures exhibit strong SERS activity due to their well-controlled nanoparticle architecture. Morphological and compositional analyses reveal that distinct modification protocols produce different silver nanoparticle arrangements and oxide layers, which directly govern photocatalytic efficiency and electromagnetic-field enhancement. The porous three-dimensional microarchitecture of the grids provides a large specific surface area and facilitates efficient analyte adsorption, further amplifying SERS sensitivity. By integrating scalable laser processing with simple wet-chemical treatments, this work establishes a versatile route to multifunctional titanium grids for water purification and molecular sensing and proposes design principles that can be extended to other pollutants and probe molecules.

KEYWORDS: Laser-fabricated titanium grids, Photocatalysis, Surface-enhanced Raman scattering, Silver nanoparticles

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T5-37 POSTER

Protective properties of Cr_3C_2-NiCr coatings on boiler heating surfaces in aggressive corrosive environments

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The operational reliability of coal-fired boiler heating surfaces is critically dependent on the resistance of materials to aggressive working environments under extreme thermal loads. Conventional heat-resistant steels, such as 12Kh1MF, suffer from accelerated degradation at temperatures exceeding 550 °C due to coupled oxidative and sulfidizing processes triggered by combustion products containing sulfur, chlorine, and alkali metals. Despite a wide variety of protection methods, the development of effective barrier layers specifically adapted to the combustion of non-design fuels remains a significant engineering challenge. This study addresses the enhancement of boiler tube durability through the scientific justification and development of gradient detonation coatings within the Cr_3C_2-NiCr system. Here we show that controlled variation of the detonation barrel gas filling between 57% and 73% allows for the formation of a gradient structure with a phase transition from a ductile nichrome matrix at the substrate to a hard carbide phase at the surface using a single powder type. Electrochemical studies in 3.5% Na_2SO_4 solution confirmed a significant shift in the corrosion potential E_{corr} to the passivation region, yielding a corrosion rate of 0.287×10^{-4} mm/year, four times lower than that of unprotected steel. Unlike standard homogeneous coatings, this gradient structure eliminates scale exfoliation during thermal cycling (50 cycles at 650 °C) and prevents the formation of corrosion centers throughout 1000 hours of salt spray testing. Analytical data from 4320 hours of exposure in an operating high-pressure boiler at 970 °C confirm that the dense gradient layer effectively blocks the diffusion of oxygen and aggressive agents, maintaining the steel's mechanical strength 1.9-2.1% higher than unprotected specimens. This developed technology establishes a robust framework for significantly extending the service life of thermal power plant equipment, enabling a 60% reduction in tube failure intensity without compromising the thermal efficiency of the heating surfaces.

KEYWORDS: Corrosion, Boiler heating surfaces, High-temperature oxidation, Thermal stations, Cr3C2-NiCr, Detonation spraying

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T5-38 POSTER

Decomposition of calcium borohydride nanoconfined inside ZIF-67

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Among complex solid metal hydrides, metal borohydrides show the most promising both gravimetric and volumetric hydrogen density due to their unique crystal structure, in which H atom is connected to B atom through a covalent bond in $[BH_4]$ structural unit. Crystal structure with orthorhombic symmetry for $Ca(BH_4)_2$ does not have polymorphous crystallographic complexity as for $Mg(BH_4)_2$, where the decrease in the hydrogen coordination number from twelve (for Ca^{2+}) to eight (for Mg^{2+}) suggests that cation size is one of the reasons why $Ca(BH_4)_2$ does adopt simpler structure than that for $Mg(BH_4)_2$. Among all known borohydrides, $Ca(BH_4)_2$ [1-4] is compound that can demonstrate real potential on reversible hydride decomposition to produce 9.6 wt% H_2:

$$Ca(BH_4)_2 \leftrightarrow 1/3\ CaB_6 + 2/3\ CaH_2 + 10/3\ H_2$$

However, only molten $Ca(BH_4)_2$ at 370 °C demonstrated reversibility in practice. Because of the decomposition products (e.g. calcium polyborates or pure boron) that are thermodynamically and/or kinetically stable, rehydrogenation of bulk and unmodified $Ca(BH_4)_2$ is limited. The main reason is the polar covalent bonding in $Ca(BH_4)_2$ that leads to very slow kinetics for hydrogen exchange.

Here we show that reaction kinetics and reversibility of solid metal hydrides can be improved using a confinement approach to keep the hydride material at the nanoscale, e.g. in the form of nanoparticles embedded in a nanoscaffold. We found that the use of an appropriate scaffold can be considered as effective catalysts for the hydride decomposition and size effect of hydride material add additional contribution to higher kinetics. Furthermore, we found that applied nanoconfinement protect active material from disruptive conditions that could cause its agglomeration and hence decrease reaction reversibility. Our experimental results show higher kinetics and reversibility of the decomposition of $Ca(BH_4)_2$ nanoconfined inside zeolitic imidazolate frameworks of ZIF-67 [5]. Obtained results demonstrate how nanoconfinement approach can be a driving force to improve reaction kinetics and reversibility.

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T5-39 E-POSTER

Kinetic phenomena in high-entropy alloys: Quasi self-diffusion

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In previous works (see, for example, [1-3]), methods were proposed to investigate the physical properties and characteristics of high-entropy alloys (HEAs), in either thin-film or bulk form, based on Fe, Co, Ni, Cr, Cu, or Al. These studies are based on applying the principle of additivity [4] to so-called intrinsic rather than collective atomic parameters. It is important to note that the properties of thin-film HEAs remain underexplored (research was initiated in [1]), whereas bulk high-entropy alloys have been primarily studied for their mechanical and tribological properties.

A key premise in this case is the thesis that the kinetic process in 5-6 component HEAs can be considered as the self-diffusion of individual atoms with a diffusion coefficient $D_{\text{s.s.}}$ close to the corresponding value in single-component i metals (D_i). This approach is justified by the fact that in HEAs, the atomic sizes of the individual components are very similar (deviations r_i from the average atomic radius $\bar{r}$ do not exceed 5%). The main feature of quasi-self-diffusion is the sluggish diffusion effect, which arises due to fluctuations in the internal potential of the crystal lattice of HEAs. In the present work, we considered the effect of this size factor on the process of self-diffusion. The working relation for high-entropy alloy with n components can be written as follows:

$$D_i^{s.s.} = D_i \frac{1-x}{n-1}\left(1 - \frac{r_i}{\bar{r}}\right) \alpha_i, \quad (1)$$

where x is the atomic fraction of the doping element, which alternates among all n metals; the factor (1 − x)/(n − 1) indicates the equiatomic nature of the phase-forming group of atoms; a is a factor that accounts for the atomic size effect. From (1) follow:

$$\frac{D_i^{s.s.}}{D_i} = \frac{1-x}{n-1}\left(1 - \frac{r_i}{\bar{r}}\right) \alpha_i, \quad (2)$$

where α_i is the average value of an empirical coefficient that characterizes the degree to which self-diffusion is hindered by the atomic size factor.

KEYWORDS: High-entropy alloys, Quasi self-diffusion, Additivity principle, Size factor

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T5-40 E-POSTER

Paramagnetic magnetization of high-entropy alloys

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The authors [1, 2] proposed a method for calculating the physical properties of bulk HEAs based on the additivity principle, which is applied to the so-called intrinsic characteristics. Such characteristics include the lattice parameter, Debye temperature, atomic magnetic moment, self-diffusion coefficient, etc. The experimental values of the FCC lattice parameter for film HEAs based on Co, Fe, Ni, Cr, and Al agree well with the calculated values, which may confirm the authors' application of the additivity principle [1, 2].

The method of calculating paramagnetic magnetization was applied by us [2] to 5-6-component HEAs based on Co, Ni, Fe, Cr, Cu, or Al atoms with an equiatomic composition of the main phase-forming elements and an atomic fraction of x = (0 - 0.3) of the doping element, which was alternately represented by all HEA components. The paramagnetic magnetization (M) of the HEA was calculated using the modernized relation of the Langevin theory of paramagnetism for single-component metals:

$$M = N_A\left[\frac{\rho_1}{A_1}c_1\mu_1(\overline{\cos\theta})_1 + \frac{\rho_2}{A_2}c_2\mu_2(\overline{\cos\theta})_2 + \cdots + \frac{\rho_{n-1}}{A_{n-1}}c_{n-1}\mu_{n-1}(\overline{\cos\theta})_{n-1}\right] + \\ + N_A\frac{\rho_n}{A_n}x\mu_n\overline{\cos\theta_n}\,, \quad (1)$$

where N_A is Avogadro's number, ρ – is density, A is atomic mass of elements; c and x are atomic fractions (concentration of the main and auxiliary element); μ - magnetic moment of atoms; $\overline{(\cos\theta)_l}$ – average value $(\cos\theta)_l$ (θ – angle between the direction of the external magnetic field and the magnetic moments of atoms of individual components); $\overline{\cos\Theta} = ctga - \frac{1}{a} = L(a)$ - Langevin function; $a = \frac{B\bar{\mu}\mu_B}{kT}$, μ_B – Bohr magneton; *L(a)* is approximately equal to 0.33 *a* at *a* <<1.

The value of $\bar{\mu}$ for the HEA in the equiatomic approximation was calculated by the formula:

$$\bar{\mu} = \frac{1-x}{n-1}\sum_{i=1}^{n-1}\mu_i + x\mu_n, \quad (2)$$

Using literature data on atomic magnetic moments, calculations of the average magnetic moment of the HEA atoms were performed. Extrapolating M to x = 1 allowed us to compare M values for HEA and individual components, which is important for the analysis of low-temperature paramagnetism in ferromagnetic metals. In the framework of the modernized classical theory of Langevin paramagnetism, the paramagnetic magnetization of the HEA was calculated under magnetic fields B = 1 and 5 T. It was established that M and M_s (saturation magnetization) have values on the order of 10^{-3} emu/cm^3 (emu is the electromagnetic unit), which is consistent with experimental and calculated data [3]. The maximum value of M = $3.80\cdot10^{-3}$ emu/cm^3 is observed for doping with Cr or Cu at B = 5T, and at B = 1T, the largest value of M = $0.76\cdot10^{-3}$ emu/cm^3.

KEYWORDS: High-entropy alloys, Paramagnetic magnetization, Additivity principle, Lattice parameter, Debye temperature, Atomic magnetic moment, Self-diffusion coefficient

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T5-41 E-POSTER

Thermoresistive properties of metal germanides as modern materials for sensor electronics

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The development of sensor electronics requires the development and implementation of new functional materials based on metals and semiconductors, in which, unlike magnetic semiconductor structures formed by introducing magnetic impurities into a semiconductor, it is possible to implement the mechanism of spin-dependent electron scattering, the formation of granular solid solutions, and binary phases [1, 2].

The work presents the results of studies of the thermoresistive properties of iron germanide films. A characteristic feature of the temperature dependences of the resistivity ρ(T) and the thermal coefficient of resistance (TCR) β(T) for Ge and Fe-based systems formed on the basis of two-layer films Ge(30-40 nm)/ Fe(30-70 nm)/S (S is the substrate) is the relatively small value of TCR, which can be explained by the formation of solid solutions of Ge atoms in the Fe layer - s.s. Fe(Ge). In the film materials Fe(10 - 20 nm)/Ge(10 - 20 nm)/Fe(10 - 20 nm)/S (in the initial state), annealed to T_{an} = 800 K, the first heating cycle is characterized by a slight change in the resistivity in the temperature range 300 - 600 K, which is explained by the absence of defects that were already healed during the previous annealing to 600 K. At a temperature of 600 to 800 K, a sharp decrease in the resistivity occurs, which indicates the continuation of the phase formation processes. The following heating - cooling cycles are the same, which indicates the stabilization of the electrophysical properties.

The transition temperature of the film from the amorphous state to the crystalline state occurs at a temperature $T_{a\rightarrow c}$ = 560 - 590 K depending on the thickness of the sample. For Fe_2Ge, FeGe and $FeGe_2$ $\beta = (3\text{-}12)\cdot 10^{-4}$ K^{-1}, which indicates the high thermal stability of these film materials and the possibility of their application in sensor electronics for operation in the region of elevated temperatures.

The phase diagram for the binary Fe-Ge system [3] indicates that, depending on the concentration of Ge atoms, it is possible to form a solid solution of Ge atoms in Fe and six phases of Fe germanides: Fe_3Ge, $Fe_{3,2}Ge_2$, FeGe, $FeGe_2$, $Fe_{13}Ge_8$, and Fe_6Ge_5. Since thin films of metal germanides have found wide application in integrated microelectronic devices, the stability of the operating characteristics of which is affected by the phase composition of the materials at the metal/semiconductor interface, the conditions for their formation are constantly being studied. Iron germanide films FeGe and $FeGe_2$, which are widely used as diode and contact structures of integrated microelectronic devices, are formed in a wide temperature range at a total concentration of Ge atoms from 50 to 70 at. % and are characterized by close to ideal stoichiometry and the absence of a homogeneity region.

KEYWORDS: Germanides, Thermoresistive properties, Sensor electronics, Thermal coefficient of resistance, Transition temperature

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T5-42 E-POSTER

Modeling of coaxial field-effect transistor structures with nanowire and nanotube channels

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Scaling of electronic devices is achieved through the improvement of complementary transistor structures, which is primarily associated with the development of their fabrication technologies [1]. Technology Computer-Aided Design (TCAD) systems form the basis for the development of very-large-scale integrated circuits and sensors, and provide not only the design of individual integrated-circuit elements but also facilitate the visualization of physical and electronic processes occurring within them. The operation of the basic functional element of an integrated circuit, the field-effect transistor (FET), is based on the drift of electrons and holes in the channel.

The aim of this work was to numerically simulate the structure and electrical parameters of coaxial n-type FETs with channels in the form of single-walled carbon nanotubes and silicon nanowires to increase the speed and efficiency of sensor devices.

TCAD software consists of two main components. The first enables the description and simulation of the technological process used to form the device structure, while the second is used to simulate its electrophysical properties. Coaxial FET structures with silicon nanowire channels were designed, and their operating characteristics were investigated. Within the drift-diffusion transport model, taking into account the Bohm quantum potential, distinctive characteristics were demonstrated for three-dimensional models. The thermal stability of the FET was evaluated using temperature coefficients of current and voltage. Their values ranged from $3{,}2\cdot10^{-4}$ to $6{,}2\cdot10^{-5}$ K^{-1}.

Carbon nanotubes (CNTs) are promising materials for forming FET channels due to their unique properties. High performance, low power consumption, and reduced influence of short-channel effects are the main factors determining the considerable practical interest in coaxial CNTFETs. The geometry of carbon nanotubes has a significant influence on charge-carrier transport [1, 2]. The device structure was designed by defining the basic regions, functional materials, doping profiles, and other parameters. The gate of the GAA CNTFET was separated from the channel by HfO_2 and SiO_2 insulating layers. Pd was used as the source and drain electrode material, with the electrodes positioned at the ends of the channel. The channel was formed by a single-walled carbon nanotube. The effective work function of the Pd gate was 5.22 eV. HfO_2 with a dielectric constant of ($k = 25$) and a thickness of 3 nm was used as the high-k dielectric, while a 2-nm-thick SiO_2 barrier layer ($k = 3.9$) was introduced beneath the high-k dielectric. A carbon nanotube with a typical chiral structure and a channel diameter of 1.41 nm was selected as the transistor channel. The gate length was 5 nm. The dopant concentration profile in the induced n-type transistor channel was adopted from [2, 3], where a donor dopant concentration of 10^8 cm^{-3} was introduced into the source and drain contact regions.

KEYWORDS: Field-Effect transistor, Nanowire, Nanotube channels, High-k dielectric, Electrical parameters

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Track 6

Ultrawide Bandgap Materials and Nanophotonics

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T6-01 INVITED

Radiation-induced defects in wide-bandgap semiconductors: Formation, evolution, and impact on device performance

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Wide bandgap semiconductors (WBGSs) are of pivotal importance to the development of next generation power electronics, sensors and high frequency devices. However, the performance and long-term reliability of the devices are significantly impacted by radiation-induced defects arising during ion implantation, device processing or operation in harsh environments. It is therefore essential to understand how these defects form, evolve, and degrade material properties if stable device functionality is to be ensured.

From a materials science perspective, ion bombardment introduces a hierarchy of structural defects, ranging from point defects to extended dislocation networks. The formation pathways of these defects depend sensitively on crystal structure, polarity, and composition. Thus, only the combination of different techniques such as Rutherford backscattering spectrometry in channeling mode (RBS/C), X-ray diffraction (XRD), and transmission electron microscopy (TEM) provide complementary insights into the processes of disorder accumulation and strain buildup.

The core issue addressed in this talk pertains to the process by which defects induced by radiation accumulate and transform in WBGSs, thereby constraining device efficiency and operational lifetime. In this study, we demonstrate the efficacy of integrating RBS/C with McChasy modelling in enabling quantitative identification of defect types and their growth mechanisms in GaN, AlGaN, SiC, and Ga_2O_3 subjected to controlled ion irradiation. However, analytical models frequently lack the capacity to differentiate between various defect types, thus necessitating the employment of advanced Monte Carlo simulations such as McChasy [1]. These simulations explicitly model displaced atoms, dislocation loops, and their fluence-dependent evolution.

The results obtained demonstrate that defect formation in GaN is polarity-dependent, with Ga-polar and N-polar orientations exhibiting distinct defect concentrations and annealing behaviour. The initial observation of dislocations and dislocation loops in AlGaN enabled the development of a dedicated dislocation model implemented in the McChasy code [2]. In SiC, self-implantation with Si and C ions is used as a surrogate for neutron irradiation, thereby enabling the controlled modelling of neutron-induced damage pathways [3]. In the monoclinic β-Ga_2O_3, ion bombardment has been shown to induce significant structural transformations, including strain-mediated defect clustering and symmetry-related lattice rearrangements [4].

These effects directly impact the design of radiation-tolerant power devices, high-frequency transistors, and sensors operating in space, nuclear, or high-temperature environments. This work demonstrates more generally how integrating experiments with physics-based simulations advances the ability to predict material degradation pathways. What, in turn, supports the development of robust nanomaterials and reliable electronic technologies.

KEYWORDS: Wide-bandgap semiconductors, Ion-beam-induced defects, Defect modeling, Radiation damage, Device reliability

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T6-02 INVITED

Ultrawide-bandgap Ga_2O_3 - versatile material for power electronics and photonics

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Semiconducting gallium oxide (Ga_2O_3) is an emerging material with ultrawide bandgap of ~4.7-5.1 eV, high predicted critical electric field > 8 MV/cm, and high transmittance in the ultraviolet region [1-3]. These properties make it a suitable candidate for power-electronic applications, where high voltage/current switching and rectifying is of importance. Ga_2O_3-based devices can offer improved power figure-of-merit compared to established wide bandgap materials such as SiC and GaN and providing sufficient technology maturity is reached, they can extend capabilities of these materials and allow for efficient devices for future power conversion applications. While bulk Ga_2O_3 substrates exist and can be melt-grown by standard techniques such as Czochralski and edge-defined film-fed growth, Ga_2O_3 heteroepitaxy is often sought as it allows integration with highly-thermally-conductive substrates such as SiC; moderate thermal conductivity and good scalability potential make Si another interesting substrate material. Ga_2O_3 heteroepitaxy can help to alleviate the excessive device self-heating related to low Ga_2O_3 thermal conductivity (~11-27 W/mK). Unfortunately, Ga_2O_3 heteroepitaxy currently offers growth of limited selection of crystal phases and orientations. In case of monoclinic β-Ga_2O_3, which represents the only thermally-stable polymorph, heteroepitaxial films typically contain high concentration of defects and rotational variants that contribute to generally much lower crystalline quality, than that typically achieved by homoepitaxy on bulk substrates. Furthermore, heteroepitaxial Ga_2O_3 films often suffer from low electron mobility and improvements are needed to achieve efficient power-electronic devices. Finally, due to the ultrawide bandgap, Ga_2O_3 offers applications in the UV optoelectronics and photonics. Solar-blind deep UV photodetectors can find wide range of uses including industrial and home flame detection and UV sanitation for medical facilities. Furthermore, high laser-damage threshold and anisotropic optical properties of Ga_2O_3 makes it an attractive material for high-power photonics operating in the UV-visible range and can enable photonic integrated circuits for e.g. optical communication and nonlinear optics.

KEYWORDS: Gallium oxide, Ga 2 O 3, Heteroepitaxy, Defects, Power electronics

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T6-03 INVITED

Subtle structural and optical properties of β-Ga_2O_3 nanolayers: A new frontier in oxide materials

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Rare-earth (RE)-doped β-Ga_2O_3 nanolayers are promising systems for a new generation of radiation-resistant optoelectronic applications. RE doping extends the optical functionality of this ultrawide-bandgap host material from the ultraviolet into the visible and infrared spectral range, making β-Ga_2O_3:RE systems attractive for applications such as phosphors, displays, high-power LEDs, and advanced photodetectors.

Our recent studies have focused on subtle structural and optical changes induced by RE ion implantation in β-Ga_2O_3 with different crystallographic orientations. Special attention has been given to orientation-dependent defect formation and phase transitions, as well as to the role of rare-earth dopants both as sensitive probes of these processes and as active luminescent centers.

The presentation will address the influence of irradiation-induced defects, structural disorder, and thermal annealing on both the host material and rare-earth emission. To achieve a comprehensive understanding of these processes, we employed a combination of complementary analytical techniques, including positron annihilation spectroscopy (PAS), high-resolution X-ray diffraction (HRXRD), high-resolution transmission electron microscopy (HRTEM), and Rutherford Backscattering Spectrometry in channeling mode (RBS/c), supported by Monte Carlo simulations using the McChasy code [1]. The optical response of RE ions was investigated by photoluminescence (PL). Different rare-earth dopants were investigated to demonstrate how irradiation-induced nanoscale structural transformations, including defect formation [2], phase transitions [3], and their evolution during post-implantation annealing [2-3], affect luminescence efficiency, and excitation mechanisms of RE ions [4]. Our results reveal complex defect accumulation processes in RE-ion-implanted β-Ga_2O_3, leading to the formation of both crystalline γ-Ga_2O_3 and amorphous regions in distinct damage zones. Although these radiation-induced phases disappear after annealing [2-3], complete defect removal is not achieved. Instead, thermal treatment promotes the rearrangement of residual defects into larger defect complexes.

Particular focus has been placed on optimizing implantation and annealing conditions [4-5] to enhance rare-earth luminescence, control defect-related processes, and understand concentration quenching effects. By correlating radiation-induced structural changes with optical functionality through a comprehensive experimental approach, this work highlights RE-doped β-Ga_2O_3 nanolayers as a new frontier in oxide nanomaterials for tunable light-emitting systems, radiation-tolerant photonics, and advanced optoelectronic devices.

KEYWORDS: Rare-earth ions, Ion implantation, Radiation damage, Optical activation, Radiation-hard optoelectronics

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T6-04 ORAL

Analytical model of Raman gain dynamics in singlemode telecommunication fibers with multiwave pumping

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Raman nanophotonics is part of the high technologies that provide record speeds of information exchange [1] in fiber optic telecommunication systems. Modern fiber lasers and optical amplifiers based on nonlinear light amplification by the stimulated Raman effect [2] are widely used in global telecommunications with terabit bandwidth. The widespread use of nonlinear photonics in modern telecommunications is explained by the simplicity of technical implementation of nonlinear light amplification devices [3] to ensure terabit speed information exchange systems [4]. However, device modeling encounters the great complexity of fundamental processes involving the interaction between many optical signal and pump waves under the influence of molecular nanocomplexes in the optical fiber core. A significant number of modeling techniques have been proposed over the past two decades, ranging from direct numerical solutions of systems of hundreds of differential equations [5] to a large number of alternative phenomenological approaches based on metaheuristic algorithms [6]. Regression models such as Linear Regression (LR), Random Forest (RF), Support Vector Regression (SVR), Gradient Boosting (GB), Artificial Neural Networks (ANNs), and/or improved whale algorithms [7] must first be trained and tested on the basis of statistical performance measures. Therefore, the modeling problem of Raman gain dynamics in single mode telecommunication fibers remains a subject of intensive research. Furthermore, if the properties of the Raman effect are taken into account in more detail, device modeling requires innovative approaches free from the limitations imposed by the numerical methods listed above [8]. Our work presents a quantitative criterion for the nominal operating mode of the FRA without self excitation in the form of the critical signal power at the output of the nonlinear amplifier. On this basis, the applicability of the weak signal model for analyzing Raman gain dynamics in single mode telecommunication fibers with multiwavelength pumping has been proven. The suitability of our model is confirmed by test calculations for standard single mode fibers based on silica glass, namely DCF and TrueWave RS types. The Raman gain profiles of these fibers are given in analytical form. The results of a comparative analysis of distributed FRA parameters designed to operate in several telecommunication fiber transparency windows are presented. The advantages of the analytical model over other methods related to the direct solution of complex systems of differential equations are discussed.

KEYWORDS: Raman scattering, Nonlinear photonics, Telecommunication systems, Optical fiber, DCF

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T6-05 ORAL REMOTE

Effect of dopant nature on luminescence and phase stability of rare-earth doped zirconia

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Zirconia (ZrO_2) is a widely used functional oxide due to its high chemical stability, favorable dielectric properties, and tunable defect structure. Its phase stability and functional response are strongly influenced by dopant type and concentration, which govern the formation of oxygen vacancies, grain size evolution, and polymorphic transformations. Understanding dopant-lattice interactions is therefore essential for the design of advanced oxide materials.

In this work, structural and optical properties of ZrO_2 nanopowders and ceramics doped and co-doped with rare-earth ions were investigated as a function of composition and processing conditions using UV-vis diffuse reflectance, synchrotron-based excitation-emission photoluminescence mapping, scanning electron microscopy, X-ray diffraction, Raman scattering, FTIR and energy-dispersive spectroscopy.

It was found that phase stability is highly sensitive to dopant combinations and processing parameters. Single doping (e.g., Yb^{3+} or Eu^{3+}) leads to stabilization of the cubic phase, while in co-doped systems (e.g., Sc-Ce) additional incorporation of Gd is required to suppress the formation of secondary rhombohedral phases. The Ce/Gd ratio was identified as a key factor controlling cubic phase stability. Thermal processing conditions, including heating rate and sintering time, were shown to significantly influence microstructure evolution by reducing porosity and inhibiting undesired phase transformations.

Taking into account the strong sensitivity of rare-earth luminescence to local symmetry, photoluminescence excitation-emission maps enabled identification of different structural environments and contributions from coexisting polymorphs. The obtained results provide insight into excitation pathways and allow discrimination between host-related and dopant-related emission.

The combined structural and optical analysis demonstrates that precise control of dopant chemistry and thermal processing enables tuning of phase composition, defect structure, and luminescent properties of zirconia-based materials, offering promising approaches for the development of functional ceramics for photonic and energy-related applications.

KEYWORDS: ZrO_2 nanopowders, Ceramics, Rare-earth doping, Phase stability, Luminescence

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Posters

T6-06 E-POSTER

Upconversion luminescence from Er-Yb-Bi codoped clinoptilolite

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Zeolites are promising materials for the creation of new materials with optically active centres, as their structure contains Si-O-Al and Si-O-Si groups with low-energy vibrations, and their pores can be used to accommodate cations, in particular rare earth elements. There are luminophores based on synthetic zeolites doped with lanthanides, which operate via an upconversion mechanism in which lower-energy light is converted into higher-energy light through multiphoton absorption and energy transfer processes. Compared to low-conversion luminescent (LM) materials, LM upconversion labels demonstrate intriguing advantages, such as very low background light, high penetration depth, high detection sensitivity and low photodamage to biological samples. The most effective upconversion LM materials are based on the Er_3+ ion in combination with the Yb_3+ ion as a sensibiliser, which exhibits green and red emission. The presence of Bi can enhance the efficiency of the upconversion luminophore, as this metal can act as an excellent material for blocking and sealing zeolite pores, thereby protecting the optically active centres from LM quenching. A natural zeolite-containing mineral from the deposit in the village of Sokirnytsia in the Ukrainian Transcarpathian region was used in the current study. Transcarpathian clinoptilolite (CL) is an effective sorbent for rare earth elements. During the synthesis of upconversion LM materials based on the "CL-Bi(III)-Er(III)-Yb(III)" composition, the results of studies on the sorption properties of CL with respect to Yb(III), Er(III), and Bi(III) were utilised. A Yb laser with a power of 3 W (λ = 980 nm) was used to excite the upconversion LM. In the upconversion LM spectra of samples based on Transcarpathian CL, in addition to the peaks at λ = 633 nm and 539 nm, which correspond to red and green emission, two further peaks are clearly visible at λ = 492 nm and λ = 380 nm. Moreover, the highest LM intensity is observed at λ = 492 nm. The LM intensity at λ = 380 nm is minimal for samples that do not contain Yb. The absolute Yb content is of key importance for LM in this spectral region. At λ = 492 nm, the intensity of samples without Bi is very high; however, with equal Er and Yb contents, the presence of Bi enhances the LM. The Yb content in the samples has virtually no effect on the LM intensity at λ = 539 nm. The efficiency of green emission increases with an increase in the Yb/Er ratio. The intensity of LM at λ = 633 nm is even slightly reduced if the samples contain Bi. An increase in the Er content in the samples leads to a decrease in the intensity of red emission. The upconversion LM materials we have synthesised and investigated can be used as quantum dot-labelled nanoparticles in vitro cell cultures. Upon irradiation of such biomaterials, they degrade much more slowly than their organic counterparts, i.e. they possess high photostability. Furthermore, they exhibit low overall toxicity to living organisms.

KEYWORDS: Clinoptilolite, Er-Yb-Bi codoped clinoptilolite, Upconversion luminescence

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T6-07 E-POSTER

Peculiarities of the growth mechanism in ultrathin amorphous Mo_xSi_{1-x} films

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Amorphous superconducting MoSi thin films are promising materials for applications in superconducting nanoelectronics, especially for single-photon detection (SNSPD) in the infrared spectral range, where conventional photon counters lose efficiency [1]. Their electrical and superconducting properties are strongly governed by growth conditions, structural homogeneity, and level of disorder [2].

However, questions remain regarding how deposition parameters influence structural properties and, consequently, superconducting behavior. Here we present a systematic investigation of the growth of MoSi thin films deposited by DC magnetron sputtering from two separate sources in an argon atmosphere for films with various thicknesses down to 1 nm. The influence of discharge power, stoichiometry, and substrate material on film thickness, density, and composition was analyzed using XRR and XPS.

We show that variation of deposition parameters can lead to changes in film composition, as revealed by XPS analysis, alongside modifications in structural characteristics identified by XRR. Compared to previously assumed homogeneous amorphous behavior, our results reveal that even subtle structural variations significantly affect charge transport [3]. We demonstrate that the sheet resistance Rs systematically varies with deposition parameters, as determined by four-probe measurements. Disorder-induced localization contributes to variations in normal-state sheet resistance Rs of the film down to 1 nm thick and broadening of the superconducting transition as was observed. Additionally, correlations between composition, density, and thickness obtained from XRR/XPS analysis provide deeper insight into growth-driven structural evolution. These findings establish a direct link between deposition conditions, structural characteristics, and superconducting performance. They provide a basis for optimizing the fabrication of MoSi thin films with tailored properties for next-generation superconducting nanoelectronic devices, including single-photon detectors.

KEYWORDS: MoSi thin films, DC magnetron sputtering, XRR, XPS, AFM

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T6-08 E-POSTER

Effect of formation conditions on the self-assembly of thiacarbocyanine J-aggregates in aqueous solutions and thin films

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The optical properties of cyanine dye J-aggregates are governed by their supramolecular organization, making control over the aggregation process essential for the development of excitonic nanomaterials [1]. Understanding how environmental parameters influence aggregate formation is therefore crucial for designing photonic and optoelectronic materials with tailored properties.

In this work, the influence of formation conditions on the morphology and optical properties of TCC aggregates in aqueous solutions and thin films is systematically investigated. TCC J-aggregates were prepared in deionized water ($5\times10^{-}3$ M), in 0.01 M NaCl solution (final dye concentration 5×10^{-4} M), and in an HCl solution adjusted to pH 3 (final dye concentration 1×10^{-4} M). LbL films were fabricated from the corresponding solutions. Aggregate morphology and self-organization were studied using confocal laser scanning microscopy (ZEISS LSM 900 for Materials), while optical properties were characterized by absorption and fluorescence spectroscopy.

The aggregation environment strongly influenced the supramolecular organization and optical properties of TCC J-aggregates in both aqueous solutions and LbL films. Confocal microscopy revealed predominantly filamentous aggregates in aqueous solution, whereas increasing the ionic strength (0.01 M NaCl) promoted the formation of denser aggregate assemblies. Acidification of the solution (pH 3) resulted in compact island-like structures with a markedly different morphology. These structural features were preserved after LbL deposition, demonstrating that the morphology formed in solution determines the architecture of the resulting films. Absorption spectra of the films exhibited a pronounced J-band centered at approximately 650-655 nm under all preparation conditions [2]. While the J-band position remained nearly unchanged, its intensity and fluorescence increased for films prepared from NaCl and acidic solutions compared with the water sample, indicating that the aggregation conditions modify both the structural organization and radiative properties of TCC J-aggregates.

The results demonstrate that pH, ionic strength, and LbL fabrication conditions provide effective tools for directing the self-assembly of TCC J-aggregates and tailoring their morphology. Controlled manipulation of the aggregation pathway offers a versatile strategy for designing excitonic nanostructures with tunable optical properties for photonic and optoelectronic applications.

KEYWORDS: J-aggregate, Monomer, Exciton, Thin film, Thiacarbocyanine dye, Fluorescence

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Track 7

Magnetic Materials, Magnonics and Spin Phenomena

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T7-01 INVITED

Atomic scale structure-function correlations in spintronic nanomaterials and heterostructures

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Spintronics has attracted significant attention over the past two decades due to its potential to revolutionize CMOS-based logic and data devices through the utilisation of electron spin. Spin manipulation via spin current generation, propagation, as well as spin injection and detection, represents key steps toward the realization of fast, non-volatile, and increasingly important low-power computational devices. Achieving these goals remains highly challenging, requiring atomic-level control of interfaces and thin-film structures in multilayered heterostructures composed of ferromagnetic and antiferromagnetic alloys and oxides, semiconductor layers, half-metals, and topological insulators.

In this work, utilising advanced electron microscopy techniques such as Scanning Transmission Electron Microscopy (STEM), Electron Energy Loss Spectroscopy (EELS), Energy Dispersive X-ray Spectroscopy (EDX), as well as Scanning Tunnelling Microscopy and Spectroscopy (STM/STS), we present an overview of the correlation between atomic structure and functionality in nanoparticles, thin films, and heterostructures. Particular emphasis is placed on the role of inhomogeneities, including interfaces, grain boundaries, point defects, and strain, in determining magnetic properties, spin dynamics, and spin-device performance. First, we discuss how atomic chemical ordering influences magnetotransport properties of magnetite nanoparticles and thin films of Fe_3O_4, as well as heterostructures of half-metallic Co-based Heusler alloys with Si and Ge, aiming to achieve near 100% spin polarization in thin films. Control of half-metal/semiconductor interfaces for maximising spin injection is also addressed. The second part focuses on the role of strain in controlling topological states in the Bi_2Se_3 three-dimensional topological insulator, where tensile strain induces a band gap at the topologically protected surface states. Finally, we discuss the recent demonstration of detecting spin-wave excitations (magnons) using low-energy momentum-resolved EELS in ferromagnetic and antiferromagnetic materials [1-3], along with prospects for atomic-scale imaging of spin structures.

KEYWORDS: STEM, EELS, Spintronics, Halfmetals, Magnons

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T7-02 INVITED

The hidden universality in charge/spin current interconversion and magnetoresistance

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The universal features for charge/spin current interconversion involved tensor order parameters and for magnetoresistance controlled by two vectors in magnetic multilayers are predicted [1-4]. The universal featured termed as anomalous spin-Hall effect and anomalous inverse spin-Hall effect exists are confirmed by recent experiments [5-6]. The universal anisotropic magnetoresistance (UAMR) and unidirectional magnetoresistance (UMR) observed in all nanoscale bilayers or multilayers [7-8] can naturally arise from electron transport influenced by the magnetization vector present in the magnetic material and the interfacial potential inherent in heterostructures [6-8]. Specifically, UAMR represents current-independent resistance (resistivity) in bilayers, while UMR is characterized by resistance that is proportional to the current, even though electron transport in the bilayers is a linear response to high current densities and the induced thermal gradients [4]. The predictions of our theory align well with existing experimental results [7] and with observations in layered Van der Waals magnetic films [8] and have also been confirmed by first-principles calculations [9]. Furthermore, this framework offers a universal perspective that not only bridges UMR and UAMR effects, enhancing our understanding of spin-dependent transport phenomena in bilayers, but also provides a unified picture for well-known MR phenomena: the usual AMR in polycrystalline ferromagnets as a consequence of one-vector physics, and AMR in ferromagnetic single crystals as a consequence of four-vector physics [10].

KEYWORDS: Anomalous spin-Hall and inverse spin-Hall effect, Unusal anisotropic magnetoresistance, Unidirection magnetoresistance, Magnetic bilayers, And multilayers

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T7-03 INVITED

Magnetic time-varying metamaterials

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Metamaterials are man-made structured materials exhibiting intriguing optical properties unavailable in natural materials. The most typical examples aremetamaterials for negative refractive indices and for invisible cloaks. These are referred to as space-varying metamaterials because of the spatially modulated refractive indices. Very recently, a new paradigm for light generation and steering using metamaterials has emerged - time-varying metamaterials, in which refractive indices are temporally modulated. Time-varying metamaterials bring about exotic phenomena, for example, time refraction, time reflection, and analogue of a continuous time crystal as well as promising applications to frequency converters and nonreciprocal devices. Furthermore, time-varying metamaterials mimic magnetoelectric interaction in equivalent moving media [1]. However, experimental demonstration of time modulation in magnetic permeability is still lacking [2,3] while time-varying electric permittivity has been achieved. Therefore, time-varying permeability metamaterials are highly desired. In this talk, we demonstrate magnetic time-varying metamaterials using ferromagnetic resonance at GHz frequencies in magnetic permalloy ($Ni_{80}Fe_{20}$) thin films. The experimental results are reproduced via numerical simulation, verifying that frequency conversion observed is caused by time modulation of magnetic permeability [4]. The present study opens a door to magnetoelectric metamaterials with synthetic motion for probing quantum vacuum effects.

KEYWORDS: Metamaterial, Magneti permeability, Ferromagnetic resonance

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T7-04 INVITED

Grain boundary engineering of Sm(Fe-Co)-B hard magnetic thin films

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RFe_{12}(R: rare earth) compounds with the $ThMn_{12}$-type structure are promising candidates for next-generation permanent magnets due to their high saturation magnetization and anisotropy field with reduced rare-earth content. Epitaxial $Sm(Fe_{0.8}Co_{0.2})_{12}$ thin films have demonstrated excellent magnetic properties, including $\mu_0 M_s$ = 1.78 T, $\mu_0 H_a$ = 12 T, and T_C = 859 K [1]. In B-doped Sm(Fe-Co)$_{12}$-B thin films, we previously achieved a coercivity of 1.2 T by forming a columnar structure where $SmFe_{12}$ grains are surrounded by a B-rich amorphous grain boundary phase [2]. Furthermore, micromagnetic studies predicted that coercivity could reach ~6 T if the α-(Fe,Co) phase at the interface between the V underlayer and the magnetic layer is suppressed [3]. In this study, microstructural control was performed to further enhance magnetic properties by introducing a Sm seed layer and applying post-annealing to promote cap layer diffusion. Thin films were fabricated using ultra-high vacuum magnetron sputtering. A V buffer layer and Sm seed layer were deposited on MgO (100) substrates at 400 °C, followed by the Sm(Fe-Co)-B layer. Structural and magnetic properties were characterized by XRD, SEM, AFM, and SQUID. XRD results showed that introducing the Sm seed layer reduced α-(Fe,Co) phase formation and enhanced (002) and (004) peaks of the $ThMn_{12}$ phase. Magnetization curves revealed suppression of low-field soft magnetic contributions. Consequently, Sm/Sm(Fe,Co)$_{12}$-B films exhibited improved remanence while maintaining coercivity above 1.0 T. These results indicate that the Sm seed layer effectively suppresses soft phase formation and improves crystallographic orientation, highlighting the importance of microstructural control in enhancing coercivity.

KEYWORDS: Permanent magnet, ThMn 12 -type structure, Thin film, Coercivity, Grain boundary

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T7-05 INVITED

Demagnetization process and magnetic properties of $CeZrFe_{11}$/FeCo nanocomposite grains

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Permanent magnets with reduced use of critical rare-earth elements are strongly required for sustainable energy technologies. $ThMn_{12}$-type $CeZrFe_{11}$ is a promising hard magnetic material because of its high Curie temperature, large uniaxial magnetocrystalline anisotropy, and the abundance and low cost of Ce [1]. However, its saturation magnetization is relatively low, which limits the maximum energy product. Exchange coupling with a soft magnetic phase having high saturation magnetization is therefore expected to improve the magnetic performance [2, 3]. However, the effects of laminated nanostructure and grain arrangement on the demagnetization process of $CeZrFe_{11}$-based nanocomposite grains have not been sufficiently clarified.

Here, we show the demagnetization process and magnetic properties of exchange-coupled $CeZrFe_{11}$/FeCo laminated nanocomposite grains by micromagnetic simulations using $MuMax_3$ [4]. In STEP I, single-particle models were examined by changing the FeCo layer thickness and the number of FeCo layers. In STEP II, multi-grain models were also investigated to clarify the effect of grain arrangement, including an inclined structure.

The results showed that the magnetic properties strongly depend on both the laminated structure and the grain arrangement. In the single-grain model, the maximum energy product increased from 250 kJ/m^3 for single-phase $CeZrFe_{11}$ to 373 kJ/m^3 for the laminated nanocomposite grains with one FeCo layer, and further reached 742 kJ/m^3 for the optimized structure with four FeCo layers and a layer thickness of 10 nm. In the multi-grain models, the inclined arrangement improved the maximum energy product by about 3% compared with the symmetric arrangement, and the value reached 434 kJ/m^3.

These results indicate that optimization of the FeCo layer thickness, the number of layers, and the grain arrangement is effective for improving the demagnetization behavior and energy product of $CeZrFe_{11}$-based nanocomposite magnets. This study provides a useful design guideline for high-performance permanent magnets with reduced Ce content by controlling nanocomposite and inclined structures, and is also consistent with our previous studies on hard/soft nanocomposite magnet design and layered hard/soft grain models [5].

KEYWORDS: CeZrFe 11, FeCo, Nanocomposite magnets, Demagnetization process, Micromagnetic simulation

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T7-06 INVITED

Nanocrystal alignment impact on static and dynamic magnetic phase transitions

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Non-equilibrium phase transitions occur across a wide range of physical systems. A relevant example is the dynamic phase transition (DPT) in ferromagnets, for which the time-averaged magnetization Q has been identified as the dynamic order parameter. Hereby, it has been observed that Q changes sharply if an oscillating field undergoes changes in its amplitude H_0 or period P. It has also been documented that Q is dependent on the presence of an additional time-independent bias field H_b, which turns out to be the conjugate field of Q [1]. Studies of the DPT have yielded important insights into dynamically ordered systems, their phase-space behavior, criticality and transient properties, finding strong qualitative similarities in between Q as a function of P and H_b and the thermodynamic magnetic order parameter M as a function of T and H [1,2]. One key difference between thermodynamic and non-equilibrium systems are metamagnetic anomalies in the paramagnetic dynamic state that do not exist in thermodynamic equilibrium [3]. Furthermore, it is noteworthy that all existing studies to date have focused on Ising-type systems, restricting our present understanding to a single material class [4].

In our study here, we experimentally investigate the DPT in polycrystalline Co films that exhibit very weak nanocrystalline alignment and magnetic anisotropy. Specifically, we monitor the dynamic magnetic states via real-time magneto-optical Kerr effect measurements across the relevant dynamic phase space as a function of H_0 and H_b. We find that the qualitative features of the dynamic phase diagram closely follow those of uniaxial Ising-type films. However, the metamagnetic anomalies of the paramagnetic dynamic state, ubiquitous in Ising-type films, appear to be significantly weaker in our nearly isotropic films. Accordingly, the presence of metamagnetic anomalies must be intimately connected with the bistable behavior of Ising systems, which we corroborated by means of detailed analyses of the time-evolution of Q in the dynamic paramagnetic regime. Thus, the modification of the magnetization state energy landscape that is being facilitated by the nancrystalline alignment of magnetic grains is crucially important for its dynamic state behavior. In addition, we also investigated the film thickness dependence of the presence or absence of metamagnetic anomalies.

KEYWORDS: Magnetization reversal, Dynamic phase transitions, Thin films, Nanocrystal order, Magneto-optics

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T7-07 INVITED

Nanoscale imaging of spin textures with varying altermagnetic response

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Altermagnetism is a recently identified magnetic state in which time-reversal symmetry is broken despite a collinear, fully compensated spin structure [1,2]. The resulting response is governed not only by the d-, g-, or i-wave character of the non-relativistic spin order, but also by the orientation of the Néel vector L. Spin-orbit-coupling-driven phenomena such as the anomalous Hall effect [3] and X-ray magnetic circular dichroism (XMCD) [4,5] can thus be switched on and off through reorientation of L, establishing a powerful handle for tuning emergent altermagnetic functionalities. Yet, accessing such L-dependent responses at the nanoscale has remained experimentally elusive. Here [6], we employ nano-spectroscopic XMCD combined with X-ray magnetic linear dichroism (XMLD) to investigate spin textures with locally varying altermagnetic responses in α-Fe_2O_3 (hematite), an earth-abundant g-wave altermagnetic candidate [5,7]. By performing spectroscopy across the temperature-driven Morin transition [8], which reorients L between in-plane and out-of-plane configurations, we observe the switching on-and-off of the XMCD signal, in excellent agreement with DFT+DMFT calculations. While the bulk XMCD vanishes below the Morin temperature, polarization-independent X-ray absorption contrast confirms the Néel vector reorientation and resolves the underlying antiferromagnetic domain configuration. Crucially, nanoscale imaging uncovers a finite XMCD signal at 180° domain walls below the Morin transition, arising from the locally modulated in-plane component of L within walls otherwise embedded in domains of zero altermagnetic response. Conversely, at room temperature we identify topological meron spin textures [9,10] whose planar regions exhibit XMCD while their nanoscopic, out-of-plane cores show vanishing contrast. These observations demonstrate that nanoscale spin textures can host altermagnetic responses that are qualitatively distinct from those of the surrounding domains. Our results establish α-Fe_2O_3 as a platform for engineering locally varying altermagnetic functionalities in a light-element, insulating oxide, and open a route toward exploiting complex spin textures-including domain walls and merons-as nanoscale building blocks for altermagnetic spintronics and information processing [11].

KEYWORDS: Altermagnetism, X-ray microscopy, Spin textures

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T7-08 INVITED

Printing permanent magnets via room temperature laser transfer

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An annealing process, such as substrate heating and/or post-annealing, is crucial for attaining diverse magnetic properties through crystallization, stress management, anisotropy control, and order transformations. For example, Nd-Fe-B micromagnets produced via sputtering[1] with substrate heating and/or post-annealing have been employed in small devices, and pulsed laser deposition (PLD)-fabricated Nd-Fe-B micro magnets followed by annealing [2] have been developed to minimize the size of electronic devices, including microelectro mechanical systems (MEMS) applications. In this study, micromagnets were prepared without utilizing an annealing process. The reduction in process temperature suggests that micromagnets can be broadly applied, as they can be deposited on flexible materials with low softening points for device applications. Consequently, we conducted fundamental experiments using the laser-induced forward transfer (LIFT) technique, which facilitates 3D printing. The LIFT is a printing technique that employs a pulsed laser beam as the driving force to transfer material from a donor film to a receiving substrate. It has been reported that LIFT can be performed in air and/or at room temperature. Since several researchers reported LIFT-fabricated Cu and Ag films, it has been actively studied due to its high potential for application in fine-electronic devices. The preparation of metals, oxides, and semiconductors has been demonstrated using nanosecond lasers, such as Nd:YAG lasers and excimer lasers. However, as far as we know, there has been limited investigation into LIFT-fabricated permanent magnets. Recently, we reported LIFT-fabricated Nd-Fe-B films in a high vacuum atmosphere and confirmed the transfer of the $Nd_2Fe_{14}B$ crystalline phase from a donor film to the obtained samples on several substrates [3]. This contribution mainly reports the magnetic properties and microstructure of LIFT-made Nd-Fe-B micromagnets.

KEYWORDS: LIFT technique, Nd-Fe-B micromagnets, Low temperature process

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T7-09 INVITED

Ultra-low iron loss in soft magnetic ribbons by controlling magnetic domain structure and magnetization process

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Power electronics has been a key technology for high-efficiency energy conversion in renewable energy, electric mobility, robotics, data centers, power grids, and related applications. Soft magnetic passive devices, such as transformers and inductors, have been crucial elements in power electronics and have become increasingly important in recent years. In particular, reducing iron loss in the high-frequency region is a very important issue. Classically, iron loss has been classified into three components of hysteresis loss, classical eddy-current loss, and excess loss. However, recent studies on high-frequency iron loss have revealed new insights different from the conventional understanding of iron loss. Magnetostriction is a well-known degradation factor of soft magnetic property, and it has been understood to affect static iron loss. However, it is clearly revealed that magnetostriction significantly affects high-frequency iron loss [1]. Since the magnetization process changes with increasing frequency, classification based on magnetization processes is more suitable than the classical iron loss classification method [2].

Very recently, we have successfully demonstrated the ultra-low iron loss in the high-frequency region in both powder core [3] and ribbon sample [4]. Especially, the ultra-low iron loss in the high-frequency region in the ribbon sample is attributed to the realization of a narrow stripe magnetic domain structure with several micrometers in width, which promotes the change in magnetization process from magnetic domain wall displacement to magnetization rotation. Afterward, we found that there are different types of fine magnetic domain structures in soft magnetic amorphous and nanocrystalline ribbons, enabling ultra-low iron loss in the high-frequency region. In this talk, we will present these magnetic domain structures and magnetization process controls in amorphous and nanocrystalline ribbons, and these physical mechanisms.

KEYWORDS: Soft magnetic material, High-frequency iron loss, Magnetic domain, Magnetization process

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T7-10 INVITED

Ultralong-living magnons in YIG for quantum magnonics

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Quantum magnonics (QM) investigates magnons - the quanta of spin waves - as information carriers and interconnects in hybrid quantum systems. Yttrium iron garnet (YIG) is the material of choice due to its exceptionally low magnetic damping. Recent experiments have demonstrated single-magnon detection and quantum control in bulk YIG using superconducting qubits [1, 2]. However, these studies rely on standing ferromagnetic-resonance magnons, whose lifetimes are typically limited to several hundred nanoseconds, restricting scalability and spatial separation of quantum elements. Realization of propagating magnons for QM requires YIG films with long lifetimes at millikelvin temperatures (mK). Most high-quality films are grown on paramagnetic gadolinium gallium garnet (GGG) substrates. At mK, GGG increases damping in the YIG layer and severely degrades YIG/GGG performance [3]. A viable solution is provided by the recently developed diamagnetic garnet substrate, yttrium scandium gallium aluminum garnet (YSGAG), which is lattice-matched to YIG while remaining magnetically inert down to mK. YIG films grown on YSGAG by liquid-phase epitaxy preserve low damping from room temperature down to 30 mK and outperform YIG/GGG films, as well as YIG on other diamagnetic substrates [4]. Additionally, progress has been achieved in bulk systems, where ultra-pure YIG crystals exhibit dipolar-exchange magnons with lifetimes exceeding 18 μs at mK [5]. These record values, extracted from nonlinear threshold measurements of three-magnon splitting, demonstrate that magnon dissipation can be suppressed far beyond previously assumed limits. Together, these advances enable ultralong-lived magnons in both YIG films and bulk crystals, and support a materials roadmap toward scalable QM circuits integrating propagating magnons with superconducting qubits, photons, and phonons, including access to nonlinear and nonreciprocal magnon dynamics [4-5].

KEYWORDS: Quantum magnonics, Yttrium iron garnet, Magnon lifetime, Spin waves, Hybrid quantum systems

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T7-11 INVITED

From ensembles to individuals: probing spin dynamics in nanomagnets via ferromagnetic resonance

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Patterned magnetic nanostructures are advanced materials whose unique nanoscale magnetic properties arise from tailored geometry and composition. As nanotechnology rapidly advances, these systems are becoming a key focus for both industry and academia. This talk traces the development of ferromagnetic resonance (FMR) studies along two main directions: (i) downscaling from ensembles to individual magnetic nanoelements and (ii) extending planar nanomagnets into three dimensions. It covers earlier cavity-based FMR investigations of arrays of magnetic nanodisks, as well as more recent broadband FMR studies of individual nanodisks and three-dimensional "nanovolcanoes" using a coplanar waveguide [1].

Transitioning into the third dimension enables spintronic nanodevices with substantially enhanced functionality compared to conventional planar structures. Recently, well-known two-dimensional magnetic vortex configurations, which exhibit an efficient dynamical response to external stimuli without a bias magnetic field, were extended into 3D [2]. This leads to a marked increase in vortex frequencies, up to 5 GHz, compared with the typical sub-GHz range in planar vortex oscillators. A systematic study revealed a complex spectrum of vortex excitation modes, accounting for the reduction of the lowest gyrotropic mode frequency, the inversion of vortex mode intensities, and the nontrivial spatial distribution of the vortex dynamical magnetization.

KEYWORDS: Ferromagnetic resonance, Spin waves, Magnetic nanoelements

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T7-12 INVITED

Nanoscale YIG-based 2D magnonic crystals

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Two-dimensional (2D) magnonic crystals (MCs) - magnetic media with periodic geometric modulation in two in-plane directions - provide a platform for engineering spin-wave (SW) dynamics beyond one-dimensional geometries. The 2D periodicity introduces multiple Bragg conditions simultaneously, enabling direction-dependent band gaps and SW scattering between propagation directions [1]. One-dimensional MCs in YIG have already demonstrated well-defined band gaps and frequency-selective SW filtering [2,3], motivating the extension to 2D antidot lattices for richer band structure control and multi-directional transport engineering.

Here, 2D MCs are realised in 100 nm-thick liquid-phase-epitaxy-grown yttrium iron garnet (YIG) films via electron-beam lithography and ion-beam etching of antidot lattices with varying hole diameters and inter-antenna spacings. Defect-free and defect-modulated MCs are studied. In defect-free antidot lattices, propagating spin-wave spectroscopy (PSWS) reveals multiple partially overlapping rejection bands, consistent with Bragg scattering from distinct reciprocal lattice vectors of the 2D structure. Complementary micro-focused Brillouin light scattering (μ-BLS) provides spatially resolved SW intensity maps and mode profiles within the unit cell.

In defect-modulated lattices (missing row/column/complex shape between the antennas), local modifications of the periodic potential enable SW transport within the band gap. Line defects form waveguides supporting localised gap modes with partially restored transmission. More complex geometries realise functional SW devices: Y-shaped defects act as stub resonators or notch filters; Mach-Zehnder-type layouts are designed to split the SW beam along two paths of controlled length and recombine it at the output port, where path-length difference can achieve frequency-selective constructive or destructive interference, potentially realising a SW analogue of an optical interferometric switch; and S-shaped channels support guided propagation with bend-induced partial reflections and mode profile modifications.

These results demonstrate nanoscale SW transport governed by lattice symmetry and defect engineering, establishing antidot-lattice MCs as a versatile platform for studying more complex phenomena, like non-trivial edge modes in topological 2D magnonic crystals [4].

KEYWORDS: 2D magnonic crystals (MCs), Yttrium iron garnet (YIG) films, Antidot lattice, Nanoscale, Spin-wave routing

ACKNOWLEDGEMENTS: This work was supported by the Austrian Science Fund (FWF) [10.55776/ESP526].

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T7-13 INVITED

Microscale spin-wave devices for next-generation 6G radio-frequency signal processing

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Wireless communication continues to push toward higher frequencies and smaller form factors, demanding radio-frequency (RF) components that handle ever-broader spectra without growing in size or power consumption. As 5G and 6G networks expand from sub-6 GHz bands into Frequency Range 2 (FR_2, 24-71 GHz) and the proposed Frequency Range 3 (FR_3, 7-24 GHz), conventional electronic and acoustic technologies are reaching fundamental performance ceilings.

Spin waves - collective magnetic excitations in ferromagnets - operate naturally in the GHz-to-THz range, can be miniaturized to the micro- and nanoscale, and offer a single magnonic platform on which filters, delay lines, frequency-selective limiters, and reconfigurable signal-processing functions coexist [1]. Yttrium iron garnet (YIG), whose low magnetic damping (~3×10^{-4}) supports spin-wave propagation over hundreds of micrometers to several millimeters, is the material of choice. Yet their deployment has been constrained by significant insertion losses, dominated by inefficient electromagnetic-to-spin-wave conversion at the transducers [2,3].

In this talk I will overview our recent progress on microscale spin-wave RF devices - including a nanoscale frequency-selective limiter [2] and high-frequency delay lines [3] - and then show that the insertion loss of YIG-based U-shaped transducers can be systematically minimized at every operating frequency across 5-30 GHz by tuning the transducer geometry, reaching 6.25 dB at 12 GHz.

The optimum shifts continuously with frequency because the ohmic-inductive transducer impedance and the spin-wave radiation impedance evolve oppositely with frequency. Mapping this matching landscape across more than one hundred device geometries, and benchmarking the data against micromagnetic simulations [4], yields explicit design rules linking any target frequency to a specific transducer geometry. These guidelines - transferable to limiters, filters, and delay lines on the same chip - bring spin-wave RF components close to the performance required for 5G FR_3 signal processing and open a path toward compact, energy-efficient magnonic RF front-ends.

KEYWORDS: Magnonics, Spin-wave devices, RF applications

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T7-14 INVITED

Spatial and temporal coherence of magnon Bose-Einstein condensates

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Magnons are the quanta of spin waves, i.e., delocalized excitations in a lattice of spins. As bosons, they adhere to the Bose-Einstein distribution, which leads to the formation of a condensate at the fundamental energy state whenever the number of (quasi-)particles exceeds the capacity of the gas state. As the condensate's order parameter, the condensate phase is expected to transition to a coherent state in the process of condensation. However, since the first observation of a magnon condensate [1], experimental access to this property has remained elusive.

Since the coherence of a condensate is reflected in a well-defined phase state both in time and space, the challenge of accessing the condensate phase breaks down into two complementary aspects. Temporal coherence becomes apparent through phase-sensitive, time-resolved measurements that reveal the spontaneous emergence of a stable oscillation frequency and a randomly chosen initial phase. Using such a phase-referenced, electrical measurement technique, we provide experimental evidence for strong temporal correlations of the condensate signal and randomized initial phase selection during condensation [2].

In contrast, spatial coherence manifests in the condensate's response to potential landscapes imprinted onto the condensate. Here, spatially modulated magnetization profiles [3] impose phase gradients that drive magnon currents within the condensate. Using Brillouin light scattering spectroscopy with both spatial and temporal resolution, we demonstrate that a redistribution of magnons can be observed within an artificially created magnetization landscape acting as a potential profile [4-5].

Together, these results provide evidence for both temporal and spatial coherence in magnon Bose-Einstein condensates, opening new pathways for controlling phase-driven dynamics in magnonic systems.

KEYWORDS: Magnonics, Bose-Einstein-Condensation, Phase, Coherence

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T7-15 INVITED

Inter-particle interactions in magnetic hyperthermia: Clustering, agglomeration and calorimetric SAR estimation

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Magnetic hyperthermia is an emerging magnetothermal strategy in which magnetic nanoparticles are delivered to a target region and exposed to an alternating magnetic field, generating local heat. Although developed mainly for cancer treatment, magnetic nanoparticle-mediated heating is increasingly explored for thermally triggered drug release, magnetogenetic control of cellular activity, and cryopreserved tissue/organ rewarming. Heating efficiency is commonly quantified by the specific absorption rate (SAR) or specific loss power (SLP). However, SAR/SLP depends not only on particle size, anisotropy and magnetisation, but also on inter-particle interactions, clustering, agglomeration and field-induced reorganisation.

In this talk, I will focus on three connected aspects: experimental evidence of nanoparticle agglomeration in cellular environments, simulations of clustering-dependent SLP, and theoretical-experimental approaches for improved SLP estimation.

Recent experiments have shown that magnetic nanoparticles do not always remain uniformly dispersed under alternating magnetic fields [1]. Vesicles containing magnetic nanoparticles, appear relatively evenly distributed before field exposure, but reorganise into field-aligned chains when the field is applied. Once the field is removed, this organisation relaxes, indicating dynamic and reversible clustering. This suggests that particle arrangement can evolve during hyperthermia. We simulated nanoparticle clustering and examined how prescribed aggregate morphologies influence heating[1]. Our results show that chain formation and local concentration strongly affect SAR/SLP [2], highlighting the importance of inter-particle interactions.

This requires robust SLP estimation and, where possible, the ability to monitor time-dependent changes in SLP during field exposure. Our work has shown that conventional Newton-law-based approaches can introduce large uncertainty when temperature gradients and multiple heat-loss pathways are present. To address this, the Peak Analysis Method [3] estimates SLP from the field on/off temperature peak using a heat-diffusion framework, making it suitable when Newton's law of cooling is invalid. The protocol was validated using heat-diffusion simulations of the liquid sample, holder and surrounding air, and tested experimentally on three devices in different laboratories, improving SLP determination compared with initial-slope, Box-Lucas and Corrected Slope methods. Implemented in a zigzag heating-cooling protocol, it enables repeated SLP estimation and monitoring of heating changes over time or temperature. More recently, the method has been extended into freely accessible online software [4], combining Peak Analysis with statistically guided fitting to reduce subjectivity and support wider use.

KEYWORDS: Magnetic nanoparticles, Magnetic hyperthermia, SLP, SAR, Agglomeration

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T7-16 INVITED

Magnetic tunnel junction assemblies for logic devices

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Artificial spin ice (ASI) has potential for application as low power logic and computing devices, and there have been numerous demonstrations using external magnetic fields. When the magnetostatically coupled nanomagnets are the free layers of magnetic tunnel junctions (MTJs), there are multiple options for electrical control of inputs, including spin torque and voltage-control of magnetic anisotropy as well as a simple Oersted field, and magnetoresistance can be used to detect the outputs. However, it is challenging to control the propagation of injected excitations without an external magnetic field. Here we describe the design of MTJ ASI in order to promote field-free propagation.

Square lattice ASI made from 60 nm circular MTJs shows field-free fluctuations at H = 0 [1]. Here there is no shape anisotropy and symmetry is broken by a small coupling field from the fixed layer. Tunnel magnetoresistance (TMR) is able to distinguish eleven different magnetization angles of the free layer moments, which are explained by a model of near and next nearest neighbor magnetostatic interactions. While high energy "emergent magnetic monopole" configurations are frequently detected, there is only a small driving force for propagation across the array, which comes from the coupling field.

Two promote propagation, a small amount of shape anisotropy in the MTJ free layers is introduced and the angle between their easy axes and the magnetization of the pinned fixed layer is varied. An elliptical nanomagnet with an easy axis at an angle relative to the applied field reverses through a combination of rotation and switching, as seen in micromagnetic simulations. However, when the fixed layer moment is along the field direction, the switching of the free layer is nearly symmetric, leading to nearly zero change in TMR. For measurable changes in TMR while switching the coupling field must be at an angle to the applied field. An additional benefit of changing the angle of the coupling field is the reduction of the energy barrier, which was found to be a minimum at 45° for 60 nm x 90 nm half-patterned MTJs [2]. For external field-free propagation, only the magnetostatic field from the near neighbors plus the coupling field of the fixed layer can be used to propagate injected excitations. Micromagnetic simulations are used to predict the magnetostatic fields due to near neighbors and compared with the angle-dependent coercivities to design optimal ASI. Propagation is tested using hard-wired inputs switched by spin transfer torque to inject excitations, which are detected at different locations in the ASI using TMR measured by conductive atomic force microscopy.

KEYWORDS: Magnetic tunnel junctions, Artificial spin ice, Spintronic logic, Magnetoresistance, Spin-torque

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T7-17 INVITED

Magnetism in metastable actinide compounds: thin films as a gateway to inaccessible ground states

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Actinide materials host some of the most complex magnetic phenomena in condensed matter physics, arising from the competition between relativistic, correlation, and hybridization effects on the 5*f* states. In uranium compounds, multiple electronic and magnetic configurations frequently lie close in energy, rendering the ground state highly sensitive to structural perturbations and chemical environment. Thin-film growth offers a fundamentally distinct regime from bulk synthesis by enabling non-equilibrium stabilization [1,2], interface coupling, and controlled strain engineering [3] - effects that can drive uranium systems toward magnetic and electronic states inaccessible in equilibrium bulk compounds. We demonstrate this behavior in uranium hydrides [1] and chalcogenides [4] prepared by reactive sputtering. A representative example is metastable UH_2, stabilized exclusively in thin-film form [1], in which magnetometry and element-specific spectroscopy reveal robust ferromagnetism accompanied by strong orbital contributions to the uranium 5*f* moment. These findings establish thin-film actinide materials as an independent experimental platform for exploring hidden crystallographic and magnetic phases and emergent 5*f* ground states beyond the reach of conventional bulk thermodynamics.

KEYWORDS: Thin films synthesis, Uranium compounds, Magnetism, Metastable states

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T7-18 INVITED

Magnetic properties and detection of the electronic states for half-metallic ferromagnets in Heusler alloys

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Since half-metallic electronic structures were theoretically predicted in some half-Heusler and full-Heusler alloys [1,2], the half-metallic ferromagnets have been intensively investigated in a field of spintronics. Soft X-ray resonant inelastic X-ray scattering (RIXS) and the magnetic circular dichroism (MCD) were performed in order to detect the half-metallic electronic states in Heusler alloys [3-5]. Because the RIXS is a photon-in/photon-out spectroscopy technique using a high-brilliance synchrotron light source, it allows us to probe the electronic structures in an elemental specific way by tuning the incoming photon energy.

The RIXS-MCD measurements were performed at SPring-8 BL_{07}LSU and NanoTerasu BL_{07}U using left and right circularly polarized light. It has been clarified important information related to the electronic states around the Fermi level can be obtained by systematic studies in some Heusler alloys.

Single crystals of some Heusler alloys were grown by the Bridgeman method. The crystal orientation was checked using Laue's back reflection method and the specimen was cut into stripes in the direction parallel to the <100>.

It was found that the Zeeman energy, width of the gap formed at the Fermi level, and which spin band opens the half-metallic gap can be revealed from comparison between experimental and theoretical spectra of RIXS-MCD. Furthermore, the RIXS-MCD experiments at the new synchrotron facility in Japan, NanoTerasu, were performed for Co_2MnGa alloy, which has been known as a Weyl ferromagnet. Because of the brilliant light at NanoTerasu and the higher resolution of spectra, clearer structures could be observed especially in Co-*L* edge. Interestingly, it was found that the Mn-3*d* orbitals behave half-metallic character around the Fermi level, on the contrary, the Co-3*d* ones exhibit metallic band character at both spin states. These findings suggest that the Weyl crossing would be caused by the Co-3*d* electrons.

KEYWORDS: Half-metallic ferromagnet, Heusler alloy, RIXS-MCD, NanoTerasu

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T7-19 INVITED

GPU-accelerated inverse micromagnetics: from billion-cell simulations to magnonic device optimization

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We present a unified GPU-accelerated framework for inverse micromagnetics, built on auto-differentiable solvers in JAX and PyTorch, and demonstrate its application across three distinct inverse-design challenges: magnetization reconstruction from stray-field data, topology optimization of magnonic devices, and loss optimization in spin-wave transducer systems.

The computational foundation is provided by our micromagnetic solvers magnum.np [1], and NeuralMag [2], jaxFD (finite-difference) and jaxFE (finite-element, based on the Fast Multipole Method) [3]. On 8 NVIDIA B_{200}-192GB GPUs, we demonstrate stray-field evaluation of a 15043 cube (3.4 billion cells) in 492 ms, and transient dynamics of a billion-cell Permalloy cube at roughly one minute of computation per nanosecond of physical time.

Building on these differentiable solvers, we show that micromagnetic energy can serve as a physics-informed regularizer for inverse magnetostatic problems. Applied to nitrogen-vacancy magnetometry data of Fe_3-xGaTe2, our framework jointly reconstructs the magnetization texture and the unknown sensor-sample distance through gradient-based optimization on the unit-sphere manifold [4].

For dynamic inverse-design problems, we combine a level-set parameterization with the adjoint-state method to perform topology optimization of magnonic devices with constant memory footprint. This is demonstrated by the design of a 300 nm-wide YIG demultiplexer achieving frequency-selective spin-wave separation [5].

Finally, applying the inverse framework to spin-wave transducer systems, we decompose the total insertion loss into reflection, ohmic, propagation, and directional contributions. This systematic loss separation, validated against experimental S-parameter data from YIG-based devices, identifies ohmic losses as the dominant mechanism and guides transducer geometry optimization. Together, these results establish GPU-accelerated inverse micromagnetics as a versatile toolchain bridging static reconstruction, dynamic optimization, and device engineering at scales previously inaccessible to micromagnetic simulation.

KEYWORDS: Inverse micromagnetics, Magnonics, GPU-accelerated simulation, Topology optimization, Spin waves

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T7-20 INVITED

Electric excitation of magnetic resonance in altermagnets

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Magnetic resonance is conventionally excited by the radio-frequency oscillating magnetic fields. Electric fields do not couple to the magnetic moment and have no direct influence on it. However, in altermagnets the exchange splitting depends on electron's momentum, and thus electron's acceleration, induced by the electric field, leads to the emergence of an effective magnetic field acting on the spin. In this talk we will present a simple model of an altermagnet where such electrically induced spin resonance is possible and discuss the prospects of its observation.

KEYWORDS: Altermagnets, Spin resonance, Electric-field control, Spintronics

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T7-21 INVITED

Spin-polarised surface plasmon polaritons generated at an oxide/metal interface

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Surface plasmon polaritons (SPPs) have attracted significant attention as a platform for coupling spintronic and opto-spintronic devices [1]. SPPs enable a strong interaction at a metal/insulator interface and allow electromagnetic fields to be confined beyond the diffraction limit. SPPs are generated in a PHz regime in a non-magnetic metal, which can generate a magnetisation gradient and a resulting spin current. In this study, SPP-induced spin currents were measured via the inverse spin Hall effect (ISHE). A thin Ag-layer was deposited on a oxide substrate, including SiO_2, Υ-Fe_2O_3 and MgO, using ultra-high vacuum sputtering. Here Ag exhibited the largest SPP signals among the investigated series of metals. By placing a half-cylindrical prism at the center of the sample, a laser beam was introduced at an elevating incident angle between 20 and 70 degrees from the film plane. The laser incidence was linearly-polarised to generate both *s*- and *p*-polarisations. The spot size of the incident beam was then controlled using an objective lens. For the inverse spin Hall measurement, a source meter (Keithley, 2400) was used to detect the spin Hall voltage by connecting electrical contacts at the diagonal corners of the continuous films. The measurements were carried out with up to 150 repetitions with 2 s interval to eliminate the Joule heating by laser introduction at each angle. For a Ag/SiO_2 sample, we detected a clear Hall voltage signal showing a pronounced dependence on the incident angle. A well defined maximum was measured to appear at approximately 52 degrees, which agrees with the theoretical prediction [1].

KEYWORDS: Surface plasmon polaritons, Inverse spin Hall effect, Oxides

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T7-22 INVITED

Evolution of Mn-derived states in alloyed (III,Mn)V semiconductors

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Ferromagnetic semiconductors (FMSs) based on (III,Mn)V alloys have long served as model systems for exploring spin-charge interactions and engineered magnetic functionalities. In ternary III-Mn-V alloys, Mn provides both the magnetic moments and the charge carriers that enable itinerant hole-mediated magnetic order. As a result, modifying the electronic structure without simultaneously changing the concentration of magnetic species remains challenging.

Alloying the (Ga,Mn)As matrix with elements such as In, P, or Bi provides an additional route for engineering the electronic structure through modifications of lattice parameters and band alignment [1-4]. A central issue in (III,Mn)V systems concerns the nature of the Mn-derived electronic states. In particular, it remains unclear whether Mn forms weakly coupled impurity-like states or states that are strongly hybridized with the host valence band. The degree of hybridization between Mn 3d states and anion p states of the host lattice governs this behavior. In turn, it determines both the character of the Mn-derived states and the mechanism of exchange interactions, ranging from impurity-like exchange in the weak-hybridization limit to valence-band-mediated interactions in the strong-hybridization regime.

In the present study, we combine spectroscopic ellipsometry (SE) and hard X-ray angle-resolved photoemission spectroscopy (HARPES) to investigate the impact of In, Bi, and P incorporation, as well as post-growth annealing, on the electronic structure of (In,Ga,Mn)As, (Ga,Mn)(As,Bi), and (Ga,Mn)(As,P), respectively.

The combined optical and photoemission results provide a coherent picture of how phosphorus incorporation modifies the character of Mn levels in (Ga,Mn)(As,P). The nature of the Mn-induced acceptor state evolves as a function of its energetic separation from the valence-band maximum. The evolution of this energy separation with increasing P concentration can be directly visualized using HARPES. When the acceptor level lies close to the valence-band edge, the Mn states retain a predominantly hybridized, valence-band-like character and remain partially delocalized over neighboring anion sites. As the valence-band edge shifts further away from the Mn levels with increasing P content, the Mn states become progressively more Mn-centered. This results in stronger localization on the Mn 3d orbitals and ultimately leads to the formation of a distinct impurity band.

KEYWORDS: Ferromagnetic semiconductors, P-d hybridization, P) alloys, Hard X-ray angle-resolved photoemission spectroscopy (HARPES), Spectroscopic ellipsometry (SE)

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T7-23 ORAL

Fabrication of the artificial magnetic system and controlling its magnetization states

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The development of technology has made it possible to fabricate artificial structures at sub-micrometer scales with high precision. In applied magnetism, there is significant research into structurally periodic arrays of magnetic elements. The domain structure is influenced by nearest-neighbor interactions, which are dictated by the sample geometry[1]. There are numerous reasons for difficulties in achieving magnetic order. The main obstacle is the presence of many local minima and large energy barriers among them. The energy barriers are usually much higher than the achievable thermal energy.

In this research, we investigate a square lattice with a ferrotoroidal ground state, characterized by closed magnetization loops within each unit cell. Our goal is to create an array of thin, sub-micron ferromagnetic squares, each divided into four isosceles triangles separated by 30 nm gaps, using precise electron-beam lithography and a lift-off process for permalloy. Before, unidirectional edge states were predicted to exist in such crystals [2]. The magnetic states of the prepared structures are investigated by using a magnetic force microscope.

We can manipulate the magnetization within these elements by applying a local external magnetic field using an MFM probe with a specific magnetic moment in lithography mode. By applying a perpendicular external magnetic field, these changes in magnetic states can be reversed to the ferrotoroidal state. This possibility makes such structures promising for future data processing applications, potentially advancing information storage and manipulation.

KEYWORDS: MFM, EBL, Micromagnetism, Magnonics, Spin ice

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T7-24 ORAL

Spike-timing-dependent plasticity in artificial "neurons" based on antiferromagnetic spin Hall oscillator for pattern recognition

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The development of next-generation computing systems is increasingly drawing on the principles of biological information processing. Unlike conventional computers, which rely on sequential execution of commands and centralized memory, biological neural networks operate in an ultra-fast and energy-efficient manner, utilizing local learning rules such as Spike-Timing-Dependent Plasticity (STDP). Replicating these biological properties requires physical devices that can mimic the dynamic behavior of real neurons. Artificial "neurons" based on magnetic materials, particularly those that utilize antiferromagnetic (AFM) spin Hall oscillators (SHOs) [1], have recently emerged as promising candidates for neuromorphic computing. These AFM-based "neurons" are capable of generating ultrafast spikes lasting a few picoseconds, exhibit intrinsic plasticity, and can reproduce key neural functions, including spiking activity and response latency [1]. In this work, we build upon a previously proposed programmable AFM-"neuron" ("P-neuron"), which is a simple two-layer neural network consisting of several single-input AFM-"neurons" [2, 3]. Unlike supervised learning approaches, which dominate conventional machine learning [4], our system employs a biologically plausible unsupervised learning scheme based on STDP, allowing the network to self-organize and perform pattern recognition without external labels [2, 4].

We consider the task of unsupervised learning for pattern recognition of binary images using the extended proposed "P-neuron" architecture [2]. In the system, the input symbol is represented as a 5×5 binary image, where each pixel corresponds to a separate AFM-based "neuron". Each such "neuron" is implemented as a Pt/NiO/Pt spin Hall oscillator driven by direct and alternating current applied to a single Pt contact of the spintronic system [1, 5]. This dynamic generates an output spin current spike that propagates through the second Pt layer, where it is converted into an electrical signal.

The coding of input symbols is performed by converting a binary image into a sequence of time-encoded spikes generated by the first input layer of the "P-neuron". For unsupervised learning, we employ the Spike-Timing-Dependent Plasticity rule, a biological mechanism that modulates synaptic weights according to the relative timing of pre-synaptic and post-synaptic spikes. Simulation results confirm the effectiveness of the proposed approach. Symbols with simple geometric structures (L, T, U, etc.) are recognized with the highest accuracy, reaching up to 90%. More complex symbols containing closed loops and curved features (B, G, R, etc.) are recognized with an accuracy of 75-80%.

We believe that the "P-neuron" with unsupervised learning is effective at rapidly recognizing small-scale images. Although scaling to larger inputs requires further investigation, results highlight the approach's potential for energy-efficient neuromorphic computing.

KEYWORDS: Spin Hall oscillator, Unsupervised learning, Spike-timing-dependent plasticity, Pattern recognition, Neural network

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T7-25 ORAL REMOTE

Microwave absorbing properties of nickel-zinc ferrite and carbonyl iron nanoparticles composites

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With the drastically increasing number of devices with wireless internet access, such as cell phones, IoT systems, etc, the problem of electromagnetic pollution of the environment is only growing. Absorbing materials that decrease the magnitude of electromagnetic radiation can be the principal solution for this problem [1, 2]. Many sensitive to electromagnetic radiation systems require either shielding or coating with absorbing materials that convert external microwave electromagnetic radiation into heat, which is conceptually more rational than shielding. Among the variety of materials tested for microwave absorption, a special place belongs to magnetic dielectrics (ferrites) with high internal dielectric and/or magnetic losses [3, 4]. Here we have synthesized the nanoparticles of nickel-zinc ferrite (NZFO), prepared the polymer-based composite material with variable proportions of NZFO and carbonyl iron (Fe) nanoparticles, and investigated its absorption properties in the 7-18 GHz frequency band. We found that Fe-rich compositions have larger dielectric permittivity (both real ε′ and imaginary ε″ parts) than NZFO-rich samples; however, samples with a large NZFO content exhibit higher values of imaginary permeability μ″ in the lower part of the investigated band (≈7-11 GHz). The absorption properties of composite materials (described by attenuation constant α) show that for Fe-rich composition, α strongly increases with frequency. For NZFO-rich composite α noticeably decreases and magnetic losses dominate over dielectric. Our results demonstrate that such parameters as ε′, ε″, and μ″ can be tuned within a certain range by varying the proportion between NZFO, Fe, and polymer. Moreover, the frequency dispersion of the attenuation constant can also be adjusted according to the specific demands (e.g., growing, descending or frequency independent). This research could serve as the starting point in the search for absorbent composite materials to reduce electromagnetic pollution in the microwave frequency range, in view of the forthcoming global deployment of 5G networks.

KEYWORDS: Nickel-zinc ferrite nanoparticles, Carbonyl iron, Attenuation constant, X-band, Ku-band

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T7-26 ORAL

Thermal performance analysis of Fe_3O_4 nanoparticles under combined AC and DC magnetic fields

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Magnetic hyperthermia has emerged as an innovative modality for cancer therapy, aiming at selectively destroying tumor cells by generating localized heat under an alternating magnetic field (AMF). Consequently, the use of magnetic nanoparticles (MNPs) in biomedical applications has become more common. Researchers have studied various parameters ranging from particle geometry and chemical composition to magnetic anisotropy and colloidal stability are extensively investigated to optimize heating efficiency and to characterize the performance of MNPs [1,2,3]. In these experiments, an alternating current (AC) magnetic field is mainly employed because it can generate heat; however, the frequency and amplitude must be optimized to avoid affecting healthy tissues. Although studies exist regarding the formation of nanoparticle chain structures under direct current (DC) magnetic fields, there is still limited research on how static external fields interact with an AC field [4,5]. Analyzing the impact of magnetic moment orientation changes under combined AC and DC fields is a fundamental requirement for optimizing magnetic hyperthermia methods.

In this study, measurements were conducted using a specialized magnetic hyperthermia system operating at approximately 88 kHz. A static DC magnetic field, ranging from 0 to 50.8 mT, was applied perpendicular to the AC field. The commercial EFH-1 magnetic fluid, containing Fe_3O_4 nanoparticles with an average size of 11.6 nm dispersed in a light hydrocarbon, served as the test medium. At an AC field intensity of 0.9 kA/m, the Specific Loss Power (SLP) values decreased from 0.32 W/g to 0.12 W/g as the external DC field strength increased. This reduction is attributed to nanoparticle clustering and chain structure formation induced by the external field, which negatively impacts thermal efficiency.

KEYWORDS: Magnetic hyperthermia, Magnetic nanoparticles, Fe 3 O 4, Specific loss power

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T7-27 ORAL

Suprising role of Au in crystal growth and physical properties of FeRh single crystals

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FeRh alloy has captivated researchers for more than 80 years due to its peculiar first-order antiferromagnetic (AFM) to ferromagnetic (FM) transition near room temperature, whose origin is still debated. Additionally, FeRh is regarded as one of the most efficient magnetocaloric materials [1,2]. Despite its interest for both fundamental physics and practical applications, growing high-quality single crystals has been difficult due to the complicated FeRh phase diagram.

In this talk, we present recent results on the single-crystal growth of FeRh using an AuPb flux [3]. We found that Au plays a dominant role in the crystal growth, while Pb reduces the melting temperature. During growth, Au-doped, Rh-doped, near-stoichiometric, and Fe-doped FeRh single crystals were obtained. A first-order AFM-FM transition was observed in the Au-doped and Rh-doped samples. In contrast, different phase transitions occurred in the Fe-doped and near-stoichiometric single crystals. Based on these findings, we propose an origin for the first-order AFM-FM transition.

KEYWORDS: FeRh single crystals, First order AFM-FM transition, AuPb flux

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T7-28 ORAL

Ga+ focused ion beam impact on Permalloy/Ti/Si heterostructure

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This work reports on the quantitative characterisation of the Permalloy/Ti/Si heterostructure after a focused-ion-beam (FIB) milling process used to fabricate magnetically insulated nanostructures. Such structures are needed for high-frequency and magnonic devices [1].

FIB milling has become a standard route for direct-write nanoscale fabrication and local material modification, especially when rapid prototyping or shape flexibility is required. The results show that Ga+-FIB can degrade magnetism not only by removing material but also by altering its composition [2,3]. However, a detailed study of the processes involved in FIB processing of magnetic nanostructures remains lacking.

The interaction of the beam with the sample is a complex process due to the high-energy Ga+ ions (30 keV). The complex interaction includes multiple scattering, electromagnetic interactions, element ionisation, thermal heating, vacancy creation, element diffusion, milling, redeposition, recrystallisation, channelling, etc. The processes are strongly dependent on the Ga+ dose and sample composition.

To simplify the picture, the processes result in **surface changes** (increased surface roughness, redeposition, and recrystallisation) and **bulk changes** expressed by element redistribution in the heterostructure. In our work, we study surface roughness and redeposition by atomic force microscopy (AFM) and element distribution by X-ray photoelectron spectroscopy (XPS). We compare the results with those from FIB modelling using TRIM and SDTrimSP calculations. A steady-state macroscopic model is used to estimate the evolution of the sample temperature. We explain several features of the XPS and AFM data and show the strong impact of surface damage on bulk element distribution. We discuss in detail some discrepancies that remain between the experiment and the model data.

KEYWORDS: Magnetic structures, Focused ion beam, XPS

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T7-29 ORAL

Shape-dependent hybrid acoustic modes in $Ni_{80}Fe_{20}$ nanodot phononic crystals

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In recent years, the surface acoustic waves [1] (i.e., acoustic phonons) have emerged as one of the promising candidates for developing next-generation wave-based information and computation technology. For designing practical devices, it is essential to tailor the frequency versus wavevector characters (i.e., band structures) of acoustic phonons. This can be achieved by patterning artificial crystals on thin films, known as phononic crystals, consisting of periodic arrays of nanoelements or nanodots. On one hand, the dispersion characters of propagating acoustic waves can be controlled by varying the periodicity of the nanodot arrays [2, 3]. On the other hand, the dispersion characters of the localized phonons confined within the nanodots can be tuned through the dot geometry. This offers a unique route to tailor the phononic band structure and enable the coupling between localized and propagating phonon modes. Such phonon-phonon coupling is crucial for realizing novel device functionalities, including intermode energy transfer.

In this work, we study femtosecond pulsed laser-induced acoustic phonons in phononic crystals by employing an all-optical pump-probe technique [4]. The phononic crystals are made of 50-nm-thick Py ($Ni_{80}Fe_{20}$) elements with three different shapes: rectangular, diamond, and elliptical. The nanodots, each having lateral dimensions of 200 nm × 250 nm, are periodically arranged in a square lattices on a Si/SiO_2 substrate with varying lattice constant from 275 to 600 nm. The experimental results are corroborated with finite element method-based numerical simulations. Several propagating phononic modes, namely Rayleigh-type surface acoustic waves, are observed in all the phononic crystals. Their frequencies are found to increase linearly with the inverse of the lattice constant. We also identify phononic modes localized within the nanodots, whose frequencies variy with the dot shape. Interestingly, strong coupling between propagating and localized phononic modes are observed in arrays of diamond-shaped nanodots, resulting in the emergence of a high-intensity hybrid phononic mode. The coupling becomes weaker for arrays of elliptical dots. In contrast, no mode coupling is observed in arrays of rectangular nanodots, where the propagating and localized phonons modes remain well separated in frequency. We believe that the ability to control propagating phonons with lattice periodicity and to optimize their coupling with localized phonons via nanodot shape engineering opens exciting opportunities for the realization of advanced phononic devices for wave-based signal processing, energy transfer, and on-chip information technologies.

KEYWORDS: Metallic nanodot arrays, Time-resolved magneto-optical Kerr effect (TR-MOKE) microscopy, Acoustic phonons, Mode coupling, Numerical simulations

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T7-30 ORAL

When Curie-weiss theory breaks down: unified description of size- and shape-dependent Curie-weiss behaviour in nanomagnets

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The classical Curie-Weiss law successfully describes magnetic susceptibility in bulk materials; however, its assumptions of homogeneity and infinite size become invalid at the nanoscale, where surface disorder, reduced atomic coordination, and shape anisotropy strongly influence magnetic behaviour. In this work, we present a geometry-dependent modification of the Curie-Weiss equation that incorporates finite-size effects through explicit separation of surface and core magnetic contributions. A surface fraction parameter, η, is introduced to quantify morphology-dependent magnetic inhomogeneity in nanoscale systems. Analytical formulations are derived for spherical and cubic nanostructures, demonstrating how particle size and geometry renormalise both the Curie constant and Weiss temperature. The model predicts a systematic crossover from surface-dominated magnetic disorder in ultrasmall particles to bulk-like Curie-Weiss behaviour with increasing particle dimensions, while naturally recovering the classical thermodynamic limit. The proposed framework provides a physically transparent and generalised mean-field description of magnetic susceptibility in finite systems, establishing particle size and morphology as key control parameters for nanoscale magnetic order. These results offer new insight into the design and optimisation of functional magnetic nanomaterials for advanced technological applications.

KEYWORDS: Finite-size effects, Magnetic nanomaterials, Modified Curie-Weiss law, Surface-to-volume ratio, And shape anisotropy

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T7-31 ORAL

Structure formation and magnetic properties of Gd-doped yttrium iron ferrites

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Ultra-high frequency (UHF) ferrites are essential materials for modern communication and radiolocation systems, particularly in emerging technologies such as 5G networks, where high signal stability, low losses, and miniaturization are required. Yttrium iron garnet ($Y_3Fe_5O_{12}$, hereinafter it is marked as YIG) is of particular interest due to its low magnetic and dielectric losses, high electrical resistivity, and stable magnetization [1]. Tailoring its properties via cation substitution, especially with rare-earth elements such as gadolinium, provides an effective strategy for tuning magnetic behaviour and enhancing performance under varying conditions. However, the properties of Gd-doped YIG ferrites strongly depend on both dopant concentration and synthesis route. In this context, developing reliable synthesis approaches that ensure high chemical homogeneity and controlled phase formation is critical for obtaining materials with optimized microwave characteristics.

Yttrium-gadolinium iron garnets ($Y_{3-x}Gd_xFe_5O_{12}$, x = 0-1.0) were investigated to clarify the mechanisms of garnet phase formation and the influence of gadolinium doping on structural and magnetic properties. The powder materials were synthesized by co-precipitation in aqueous solution followed by thermal treatment up to 1200°C and sintering for ceramic samples at 1400°C.

X-ray diffraction (XRD) and FTIR analysis showed that garnet structure forms via a two-stage mechanism involving an intermediate orthorhombic perovskite phase. At 700-800 °C, yttrium-iron and gadolinium-iron perovskites form, followed by the formation of $(Y,Gd)FeO_3$, which reacts with Fe_2O_3 to yield the garnet phase. Single-phase cubic garnet was obtained at 1200 °C for all compositions [2].

It was found that gadolinium substitution reduces the temperature of garnet formation by ~100 °C, reaching up to 200 °C for selected compositions (x = 0.4 and 1.0). This effect is non-monotonous, indicating a complex role of dopant concentration. In particular, garnet formation occurs at 800 °C for x = 0.4 and already at 700 °C for x = 1.0 [2].

The structural evolution significantly affects ceramic properties. Increasing Gd content leads to reduced porosity, with values below 5% for $x \geq 0.6$ at relatively low sintering temperatures. Magnetic measurements revealed a non-monotonous variation of saturation magnetization, coercivity, and ferromagnetic resonance linewidth, with an optimum at x = 0.6 [2]. These results demonstrate that Gd doping enables effective control of phase formation, microstructure, and magnetic properties, providing a pathway for designing low-porosity ferrites with the garnet structure with enhanced microwave performance.

KEYWORDS: YIG garnets, Phase transformation processes, Ceramics, Magnetization saturation, Ferromagnetic resonance linewidth

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T7-44 ORAL

Synchronization dynamics in a dual-antiferromagnetic-layer spin Hall oscillator

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Antiferromagnetic (AFM) materials are promising for ultrafast spintronics due to their intrinsic terahertz-frequency dynamics, robustness against external magnetic-field perturbations, and nearly vanishing stray fields, which support stable high-density integration [1]. These properties can be exploited in an antiferromagnetic spin Hall oscillator (AFM SHO), typically realized as a Pt/AFM bilayer, where a DC charge current induces a spin current via the spin Hall effect and generates spin-transfer torque that drives self-sustained oscillations of the AFM sublattice magnetizations. However, conventional single-layer AFM SHOs remain limited by a narrow frequency-tuning range (0.1-2.0 THz) and output power below the ~1 μW technological benchmark [2,3]. Mutual synchronization of phase-locked oscillators can overcome these limitations by producing a stronger coherent collective output. This paper investigates the synchronization dynamics of a dual-antiferromagnetic-layer spin Hall oscillator (DAL SHO) within a vertical Pt/AFM/S/AFM/Pt heterostructure. Unlike spatially distributed arrays, this single device internally couples two identical, current-driven canted AFM layers via spacer-mediated magnetodipolar interaction. We model this system using coupled Landau-Lifshitz-Gilbert-Slonczewski equations to track the four sublattice magnetization vectors. The comprehensive effective field accounts for exchange, magnetic anisotropies, the Dzyaloshinskii-Moriya interaction, spin-pumping-enhanced damping, spin-transfer torque, and cross-demagnetization coupling. By varying the direct current density in one platinum layer, we effectively control the frequency detuning between the two interacting AFM subsystems. Analysis of the time-dependent Néel vectors confirms a stable phase-locked state characterized by zero relative frequency detuning and a constant phase offset of ~0.28 rad. With a fixed bottom-layer current, magnetodipolar coupling merges the initially distinct frequencies, yielding a shared synchronization bandwidth of nearly 100 GHz (spanning 230-330 GHz for top currents of $1.3\text{-}2.7\cdot10^8$ A/cm^2. Notably, expanding the spacer thickness from 6 to 26 nm attenuates this cross-demagnetization coupling, systematically compressing the synchronization window from 110 GHz down to 80 GHz. The obtained results demonstrate that the DAL SHO can support internal synchronization driven by spacer-mediated magnetodipolar coupling. The synchronization dynamics can be controlled dynamically through the applied current and structurally through the spacer thickness. This makes the DAL SHO a promising compact platform for coherent upper-sub-terahertz signal generation, controllable phase locking, and future networks of synchronized antiferromagnetic spintronic oscillators.

KEYWORDS: Antiferromagnet, Spin Hall oscillator, Terahertz frequency, Mutual synchronization

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Posters

T7-32 E-POSTER

Symmetry-dependent resonances in Fe/MgO/ZnO/MgO/Fe sandwiches

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Following the pioneering study on Fe/MgO/Fe sandwiches [1], two decades have been devoted to discover materials that simultaneously enhance spin-transfer torque (STT) and tunnel magnetoresistance (TMR) for faster, energy-efficient switching with improved readability in high-performance magnetic tunnel junctions (MTJs). Even when fabrication challenges are set aside, theoretical efforts have consistently fallen short of delivering the desired outcomes. MgO, owing to the symmetry-dependent tunnelling of the Δ_1 states, has retained its position as the preferred tunnel barrier for foundry-grade MTJs. However, the physics of single-barrier tunnelling in MgO imposes an intrinsic trade-off between the TMR and the RA product in conventional MTJs. To address this issue of regular tunnelling, we explore the physics of symmetry-driven resonances of the Δ_1 states [2] in a magnetic tunnel junction (MTJ) comprising an Fe(001)/MgO(001)$_{2\text{-layers(l)}}$/ZnO(001)$_{3l}$/ MgO(001)$_{2l}$/Fe(001) heterostructure, premised on the self-consistent coupling of the non-equilibrium Green's function (NEGF) with density functional theory (DFT). The conceived heterostructure-based MTJ, titled Δ_{1R}-MTJ, opens up a new frontier for engineering high-performance MTJs, providing a sizable tunnel magnetoresistance (TMR) of $\approx 6 \times 10^3$ % and a nominal resistance-area (RA) product of 0.14 fi·µmZ, with a high (≈ 99%) spin polarisation. The TMR% observed here is ≈ 3.2 times higher, and the RA product is ≈ 6.5 times lower than that of a 4L-MgO-based MTJ at zero bias. These attributes indicate a significant enhancement in STT, thereby enabling swift and energy-efficient switching dynamics in the Δ_{1R}-MTJ. The quantum well in this system is designed with an insulator, instead of metals, to primarily capitalize on the absence of non-Δ_1 symmetry bands near the Fermi window, and avoid scattering at room temperature that disrupts the resonance. Furthermore, the Fe/MgO/ZnO/MgO/Fe stack in the Δ_{1R}-MTJ is compatible with foundry-grade CMOS processing.

KEYWORDS: Tunnelmagnetoresistance, Symmetry-dependent resonant tunneling, Spin transfer torque (STT)

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T7-33 POSTER

Role of amino acids in tailoring the magnetism of $CoFe_2O_4$ nanoparticles

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Magnetic nanoparticles exhibit tunable size-dependent physicochemical and magnetic properties, making them attractive for applications in data storage, magneto-optical devices, photocatalysis, and biomedicine [1,2]. Cobalt ferrite ($CoFe_2O_4$) is a technologically important ferrite due to its high magneto crystalline anisotropy, chemical stability, and mechanical hardness. However, its structural and magnetic properties are strongly governed by particle size, morphology, and surface chemistry, which are highly sensitive to synthesis conditions. Established synthesis routes such as hydrothermal, sol-gel, and co-precipitation methods enable modulation of nucleation and growth kinetics through parameters including temperature, pH, and stirring rate [3,4]. Despite these advantages, $CoFe_2O_4$ nanoparticles typically exhibit strong agglomeration arising from high surface energy and magnetic dipole interactions, which limits their functional performance. Surface modification using surfactants or capping molecules has been shown to mitigate aggregation through electrostatic and steric stabilization while enabling controlled particle growth and surface functionalization [5].

Herein, $CoFe_2O_4$ nanoparticles were synthesized via a hydrothermal co-precipitation route in the presence and absence of amino acids acting as capping agents [1]. The role of amino acid functionalization on crystallographic structure, morphology, and magnetic behaviour was systematically examined. The results demonstrate that amino acid capping significantly enhances nanoparticle dispersion and customize magnetic properties, thereby improving functional performance. These findings suggest that amino acid-modified $CoFe_2O_4$ nanoparticles are promising candidates for magnetically recoverable adsorbents and catalytic systems in wastewater treatment.

KEYWORDS: Magnetic nanoparticles, Cobaltferrites ($CoFe_2O_4$) nanoparticles, Tuning magnetism, Amino acid surfactants, Environmental remediation

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T7-34 E-POSTER

Hall effect in [Fe/I]n discontinuous multilayers (I = SiO_2, MgO, HfO_2)

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The practical interest in nanocomposites stems from their potential for use as magnetosensitive elements in nanoelectronics, spintronics, computing, and other fields [1-3]. The use of such materials enables improved device reliability and significantly reduced size, weight, power consumption, and cost [3-6]. One of the effects utilized in such structures, on which highly sensitive magnetic field sensors, microelectronic compasses, displacement sensors, and rotational speed sensors can be developed, is the Hall effect [7, 8]. Hall sensors are widely used across many areas of modern industry, including mechanical engineering, automotive electronics, aviation technology, welding equipment, medical equipment, household appliances, and computer technology. The transport sector utilizes a wide range of sensors for safety, engine performance monitoring, and vehicle positioning systems [9].

The aim of this work was to conduct an experimental study of the Hall effect in as-deposited and annealed at 700 K [Fe(d)/I(3)]$_{10}$/S discontinuous multilayers (I = SiO_2, MgO, HfO_2) obtained by the method of sequential layer magnetron sputtering in a vacuum. The Hall effect was measured at room temperature using a four-point configuration. When measuring the Hall voltage in the case where the vectors of the electric current density and the magnetic field induction are mutually perpendicular, account was taken of the contributions of additional (parasitic) draw arising in the circuit due to secondary thermal and galvanomagnetic effects. To minimize the impact of these negative factors and the asymmetry in contact placement, four measurements were taken with the electric current flowing in different directions in the presence of a magnetic field.

For [Fe(2)/I(3)]$_{10}$/S discontinious multilayes (after annealing at 700 K) and [Fe(7)/I(3)]$_{10}$/S discontinious multilayers (after deposition and annealing at 700 K), regardless of the insulator material, both the anomalous and normal Hall effects are observed. For all structures with d_{Fe}= 7 nm, the anomalous Hall effect is observed over a wide range of magnetic fields (-2 - +2 T). This makes it possible to use them as sensitive elements in magnetic field sensors that are stable in the presence of various physical fields. For as-deposited and annealed at 700 K [Fe(7)/MgO(3)]$_{10}$/S and [Fe(7)/HfO_2(3)]$_{10}$/S discontinuous multilayers, the value of the anomalous Hall effect is (1.8-4.2)·10^{-9} m3/C and is only slightly dependent on the type of dielectric layers and heat treatment. A decrease in the Fe layer thickness to 2 nm results in a 6- to 7-fold increase in the intrinsic Hall coefficient, primarily due to structural changes in the system (the transition to island films).

KEYWORDS: Discontinious multilayers, Magnetron sputtering, Magnetic metal, Insulator, Hall effect

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T7-35 E-POSTER

Correlation between ferromagnetic resonance and giant magnetoresistance in granular Co-Ag alloy thin films

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The development of magnetic nanomaterials is a key direction for advancing spintronics and nanoelectronics. Of particular interest are granular Co-Ag thin films, in which ferromagnetic nanograins are dispersed in a non-magnetic metallic matrix, giving rise to giant magnetoresistance (GMR) due to spin-dependent scattering of charge carriers at ferromagnetic granule/non-magnetic matrix interfaces and within the ferromagnetic granules themselves [1]. Ferromagnetic resonance (FMR) is an informative technique for probing magnetic nanostructure, effective magnetic fields, and spin dynamics. However, the correlation between GMR and FMR in such systems remains insufficiently understood.

In this work, an experimental study was carried out to establish a correlation between magnetoresistive behavior, dynamic magnetic properties, and structural state of granular Co_xAg_{100-x} thin films in the as-deposited state. Films with 15 at.% ≤ x ≤ 75 at.% and a thickness of 85 nm were prepared by electron-beam co-evaporation. The nanostructure was analyzed by TEM, including HRTEM. Transverse and longitudinal magnetoresistance were measured at 140-440 K in magnetic fields up to 1.6 kOe. GMR exhibits pronounced maxima at x = 26-32 at.%, correlating with the structural percolation threshold. With increasing temperature, the GMR peak shifts from 26 to 32 at.%, indicating a stronger superparamagnetic contribution at lower Co content. A maximum GMR of 1.26% at 1.6 kOe was obtained for x = 26 at.% at 140 K, decreasing by a factor of 1.3 at 290 K. High-field measurements (up to 90 kOe) for the predominantly superparamagnetic x = 26 at.% sample revealed a GMR of 33% at 5 K, attributed to suppression of thermal fluctuations and alignment of magnetic moments. FMR spectra show nearly isotropic resonance fields (~2 kOe) for x ≤ 26 at.%, indicating weak intergranular interactions, whereas for x = 75 at.% the perpendicular resonance field reaches ~15 kOe due to strong anisotropy. This evolution correlates with an increase in effective magnetization from ~48 to ~1000 emu/cm3, evidencing a transition from a superparamagnetic granular ensemble to an exchange-coupled ferromagnetic system.

A clear correlation between GMR and FMR characteristics is established, governed by concentration-driven changes in magnetic nanostructure and intergranular interactions.

KEYWORDS: Ferromagnetic resonance, Giant magnetoresistance, Co-Ag alloy thin films, Percolation threshold, Superparamagnetism

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T7-36 E-POSTER

Mutual synchronization in a three-element antiferromagnetic spin Hall array

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The unique properties of antiferromagnetic (AFM) materials facilitate breakthroughs in modern fields, notably ultrafast spintronics and terahertz-frequency (TF) systems. A spin Hall oscillator (SHO) consisting of adjacent AFM and heavy-metal (typically Pt) layers could be a useful platform for promising applications utilizing TF magnetization dynamics [1, 2]. While a single AFM SHO can be frequency-tuned via a DC current, its practical implementation is severely limited by a low output power that usually does not exceed 1 μW. A widely recognized strategy to overcome this limitation is to synchronize multiple oscillators. While dual-oscillator systems are well documented, the complex nonlinear dynamics of larger AFM arrays remains mostly unexplored.

In this paper, we propose and investigate a planar array consisting of three mutually coupled AFM Josephson-like SHOs [3], which could be convenient system for achieving larger output powers than in a single SHO.

We consider a geometry in which three distinct AFM Josephson-like oscillators are situated on top of a common Pt layer. Local DC drive currents in the Pt layer excite TF rotation of magnetization in each AFM region via the spin-orbit torque. The common Pt layer acts as a coupling channel for pure spin currents, providing a symmetric mutual coupling mechanism between the adjacent precessing magnetizations of SHOs.

We numerically solve a system of coupled non-isochronous phase equations governing the AFM Néel vectors and investigate the collective behavior of the three AFM SHOs array for various DC drive currents. To rigorously manage the extreme computational stiffness caused by the intrinsic terahertz-frequency nutations, the numerical integration was executed utilizing adaptive stiffness-switching algorithms. Furthermore, the reliable extraction of the true locking thresholds from the massive parametric sweep necessitated a customized contiguous-block algorithm to explicitly filter out chaotic numerical artifacts generated by transient chimera states. Transient dynamical analysis confirms robust phase-locking between the three elements. The obtained synchronization bandwidth was approximately 0.024×10^8 A/cmZ, spanning a drive current window from 1.988×10^8 A/cmZ to 2.012×10^8 A/cmZ. In addition, by performing an inverse parametric sweep and constructing a high-resolution 2D phase coherence map, we successfully extracted the global synchronization boundaries (Arnold tongue) of the system [4]. Our calculations reveal that the investigated array exhibits unique topological transitions, including a sudden expansion of the synchronization bandwidth at critical coupling strengths of approximately 0.1 due to the overcoming of non-isochronous frequency shifts.

We believe that understanding the observed complex multi-oscillator locking regimes is a crucial step toward the development and optimization of high-power, highly coherent AFM THz signal sources.

KEYWORDS: Antiferromagnet, Spin Hall oscillator, Terahertz frequency, Mutual synchronization

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T7-37 POSTER

Time-resolved linear dichroism in magnetic fluids: concentration-dependent optical response

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Magnetic fluids (ferrofluids) have attracted significant attention due to their unique field-responsive optical properties, enabling applications in photonics, biomedical devices, sensing, and tunable optical components. In particular, linear dichroism, arising from field-induced nanoparticle alignment, offers a promising mechanism for optical switches, sensors, and modulators. However, time-resolved and concentration-dependent studies of dichroic behavior in commercially available ferrofluids remain limited in the literature, especially within the visible spectral range [1, 2]. In this study, we investigate the linear dichroism of a commercial magnetic fluid (EFH_1) by performing transmission measurements under two orthogonal polarization states in the 500-800 nm wavelength range. The experiments were conducted using a spectrometer (OceanView - USB_{4000}) while the ferrofluid sample was placed in a cuvette with a 2-mm optical path between the poles of an electromagnet. Measurements were carried out under applied magnetic fields ranging from 0.19 T to 0.75 T. Measurements were acquired with a temporal resolution of 600 ms, and the ferrofluid concentration varied between 1% and 5%. The results reveal a pronounced polarization-dependent transmission behavior under an applied magnetic field. At 600 nm, a maximum transmission decrease of approximately 20% was observed when the polarization was aligned parallel to the magnetic field, while a reduction of about 10% was measured for the perpendicular polarization. Time-dependent analysis shows that the system reaches equilibrium faster at lower concentrations: the response time was determined to be approximately 3 s for 1% concentration, 4.2 s for %5 concentration with polarization parallel to the applied field. These findings provide new insights into the dynamic optical response of magnetic fluids and highlight their potential for use in fast and tunable magneto-optical devices, such as optical modulators.

KEYWORDS: Magnetic fluids, Ferrofluids, Linear dichroism, Magneto-optical effects, Time-resolved measurement

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T7-38 POSTER

Spin-wave implementation within the VAMPIRE software package

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Spin waves, also known as magnons, are collective excitations of the spins in a magnetic material. Spin waves play an important role in the behaviour of magnetic materials, determining the system response in the GHz and THz regimes. The spin-wave dispersion relation, i.e. the spin wave frequencies as a function of the wavevector can be calculated theoretically using both atomistic spin dynamics (ASD) and linear spin wave theory (LSWT). The LSWT is a first-order approximation for the spin-wave dispersion relation and can be computed using the SpinW [1] implementation.

The LSWT is limited by its linear approximation, which restricts it to small oscillations and long-wavelength excitations, and it cannot account for nonlinear effects or finite-temperature spin fluctuations. The ASD overcomes these limitations, simulating individual spins at the atomic level to capture nonlinear behaviour, thermal effects, and localized phenomena in complex magnetic systems. The temperature dependence of spin waves is important for understanding the dynamic properties of a wide range of magnetic materials. In spintronics, THz emission and the spin Seebeck effect are directly related to the SW and magnon-magnon [2] and magnon-phonon [3] interactions.

In this work we will present the implementation of spin-wave calculations into the VAMPIRE software package [4,5]. The ASD model implemented in the current VAMPIRE software is able to describe a large range of temperature-dependent magnetic properties and the dynamics of complex magnetic systems. This allows simulation of spin waves for complex magnetic materials (ferromagnetic, ferrimagnetic, antiferromagnetic and frustrated spin configurations) and various geometries (core-shell particles, multilayers, system with defects/ impurities) and 2D materials.

KEYWORDS: Magnetisation dynamics, Spin wave, Magnons, VAMPIRE

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T7-39 E-POSTER

Rectification of pulse signals in a ferromagnetic spin-torque microwave detector

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Spin-torque microwave detectors (STMDs), which are based on ferromagnetic magnetic tunnel junctions (MTJs), are now considered as promising microwave signal detectors for a wide range of modern scientific and technological applications [1-4]. These detectors can have ultra-high volt-watt sensitivity, which greatly exceeds that of state-of-the-art Schottky diodes; they can also provide a very low minimum detectable microwave power and a high signal-to-noise ratio [1-3]. However, these positive features of STMDs have only been observed experimentally and explained theoretically and numerically for a single input harmonic microwave signal [1-3] or a small set of harmonic signals [4]. Conversely, the response of STMDs to non-harmonic signals, such as pulse signals, has been poorly analyzed, even though these pulse signals can naturally carry information and energy for conventional and unconventional digital computing and telecommunications devices, particularly neuromorphic spintronic devices. Therefore, the aim of this study is to analyze the response of an STMD to input microwave pulse signals, specifically the detector's output DC voltage U_{DC}.

We developed a numerical model of the magnetization dynamics, in an STMD under the action of an arbitrary, non-harmonic input microwave signal, which is characterized by the signal current $I(t)$. This model is based on the Landau-Lifshitz-Gilbert-Slonczewski equation for the unit magnetization vector, $\mathbf{m}(t)$, which includes the Berger-Slonczewski term that depends on $I(t)$. Using the numerically calculated $\mathbf{m}(t)$ for a given $I(t)$, we calculate the magnetoresistance of the device $R(t)$. Next, we estimate the time-dependent output voltage of the detector, $U(t) = I(t)R(t)$, and finally calculate the time-averaged output DC voltage of the STMD U_{DC}.

We consider positive and symmetric rectangular pulses described by the signal current $I(t)$, with different pulse amplitudes ($I_0 > 0$), durations (τ) and repetition periods (T). As expected, the detector's response to pulse signals depends on the pulse type (positive or symmetric); however, the detector's behavior for both considered types of pulses is generally similar. At rather small pulse amplitudes, $I_0 < I_{th}$, the rectified voltage generated by an STMD depends linearly on I_0 and the τ/T ratio, $U_{DC} \sim I_0(\tau/T)$, corresponding to the linear regime of detector operation (I_{th} is the critical pulse amplitude). In this regime, some pulse characteristics (e.g., pulse amplitude I_0 or the τ/T ratio) can be unambiguously determined from the measured U_{DC} if the other pulse characteristics are known. In the other regime, which is observed when $I_0 > I_{th}$, the dependence of U_{DC} on I_0 and τ/T is nonlinear and nonmonotonic due to the strongly nonlinear magnetization dynamics, which prevent the unambiguous detection of the input pulse characteristics.

The obtained results can be important for the development of spintronic devices that detect and process pulse signals.

KEYWORDS: Spin-torque microwave detector, Pulse signal, Magnetization dynamics, Rectified voltage

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T7-40 E-POSTER

Spin-torque microwave detector with uniaxial magnetic anisotropy of the free magnetic layer

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Spin-torque microwave detectors (STMDs) are nanoscale spintronic devices based on magnetic tunnel junctions that generate an output DC (or low-frequency) voltage UDC when an input harmonic microwave signal current $I(t)$ is applied [1-3]. In an STMD, the input signal current, $I(t) = I_{AC} \sin(2\pi ft)$, excites magnetization dynamics in the free magnetic layer (FL) of the detector, giving rise to AC variations of the device magnetoresistance R(t). The mixing between the current $I(t)$ and the magnetoresistance $R(t)$ oscillations produces an output DC voltage U_{DC} if the frequency of magnetoresistance oscillations coincides with the input signal frequency f [1].

STMDs can have substantially better working characteristics than semiconductor detectors (e.g., Schottky diodes), however, these advantages are only available for certain operational regimes of STMDs that depend on the bias DC magnetic field, the magnetic anisotropy of the FL, the magnitude I_{AC} of the AC signal current [1, 3]. In particular, recently has been a growing interest in studying and applying STMDs with FLs made of anisotropic ferromagnetic materials [1, 3], such as L_{10} materials, which are characterized by uniaxial magnetic anisotropy (UMA). The aim of this paper is to theoretically and numerically analyze the performance of an STMD with a FL that exhibits UMA.

Our analytic model is based on the Landau-Lifshitz-Gilbert-Slonczewski equation, which is written in the macrospin approximation for the unit magnetization vector $\mathbf{m}(t)$. The effective magnetic field in the equation includes contributions from the bias DC magnetic field, the demagnetization field, and the UMA field. Using spherical coordinates for $\mathbf{m}(t)$, we derive equations for the polar (θ) and azimuthal (φ) angles of the vector $\mathbf{m}(t)$. By averaging these equations over the period of input signal oscillations, $1/f$, we can estimate the threshold current I_{th} required to excite sustainable magnetization dynamics, as well as the detector's output DC voltage U_{DC}.

Using the obtained analytical expressions, we calculate the dependence of the U_{DC} on the amplitude (I_{AC}) and frequency (f) of the input harmonic signal $I(t)$ for different values of the UMA fields. We also estimate the power conversion ratio, P_{DC}/P_{AC}, as a function of these parameters. This ratio is defined as the output DC power of the detector (P_{DC}) divided by the input AC power (P_{AC}), and it characterizes the device's energy harvesting capability.

We found that in the out-of-plane magnetization precession regime, the UMA field defines the stable magnetization precession trajectory. The detector's output DC voltage U_{DC} and the P_{DC}/P_{AC} ratio moderately depend on the FL's UMA field. Additionally, using higher UMA fields can expand the detector's operating frequency band, and its power conversion ratio can reach ~ 10%. We believe these results are important for the development and optimization of STMDs and STMD-based energy harvesters.

KEYWORDS: Spin-torque microwave detector, Uniaxial magnetic anisotropy, Magnetization dynamics, Rectified voltage, Energy harvesting

ACKNOWLEDGEMENTS: This work was supported in part by grant No. 2025.07/0237 from the National Research Foundation of Ukraine. The authors thank all brave defenders of Ukraine who made it possible to finalize this publication.

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T7-41 E-POSTER

Possible microwave power redistribution due to the formation of magnon-plasmon-polaritons

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Surface electromagnetic waves (SEWs), which are often considered plasmon-polaritons (PPs), are coupled electromagnetic and electron density excitations [1, 2]. SEWs and PPs propagate along this interface between two media and their energy is localized near this interface, making them highly suitable for applications in modern surface physics and advanced electronics. These waves (quasiparticles) have been widely studied in the terahertz, infrared, and optical bands due to their strong field confinement, high sensitivity to material properties, and significant potential for developing various devices [1, 2]. However, the properties of SEWs and PPs in the microwave range, especially at the interface of magnetic conductors where magnon-plasmon-polaritons (MPPs) can be excited under certain conditions, are still poorly understood. Therefore, this paper aims to experimentally study the MPP formation process, which we believe is accompanied by microwave power redistribution.

We carried out our experiment in the Ka-band using a ferromagnetic surface electromagnetic wave resonator (FSEWR), which was a rectangular metal conducting film situated in a below-cutoff waveguide [3]. The incident electromagnetic wave excites PPs in the FSEWR. When a certain in-plane DC bias field is then applied to the resonator, the electromagnetic field of the incident wave also excites magnetization oscillations (magnons) in the FSEWR, which can force the formation of MPPs. This process requires additional energy, the binding energy of magnons and PPs, which can be measured experimentally.

In our experiment, we precisely measured the microwave power incident on, reflected from, and transmitted through the FSEWR, and calculated the power losses in the FSEWR. Our experimental results demonstrate that losses increase up to four times when the bias DC magnetic field of ~500 mT required for magnon excitation is applied. At the same time, the resonator frequency changes by ~0.5% (0.13 GHz), and the reflection coefficient at resonance changes by approximately three times. We believe these results can be explained by the redistribution of microwave power due to MPP formation.

The obtained results are important for the physics and applications of microwave MPPs and for the development of magnetic film-based microwave plasmonic devices that can be tuned by DC magnetic fields.

KEYWORDS: Surface plasmon, Plasmon polariton, Microwave resonator, Ferromagnet, Film

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T7-42 POSTER

Visualizing local phonons and edge state magnetism on 7-atom wide armchair graphene nanoribbons

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Graphene nanoribbons (GNRs) offer a suitable platform for carbon-based spintronics due to their negligible spin-orbit coupling, yet practical spin devices require precise control over magnetic moments, contacts, decoherence, and edge-state engineering. Here, we present a combined STM/STS/IETS study of 7-AGNRs on Au(111) addressing fundamental spin phenomena in such nanoscale systems. We demonstrate that controlled hydrogen abstraction at zigzag termini induces delocalized Kondo resonances extending ~2.5 nm along the edges. Temperature-dependent spectroscopy reveals a Kondo temperature of ~68 K [1], with DFT confirming weak inter-state coupling despite substrate screening, highlighting robust intrinsic edge magnetism. To optimize charge transport, we engineer C-Au covalent bonds that lift GNRs into suspended configurations, eliminating substrate quenching and revealing a pristine bandgap of 2.78 eV [2]. These suspended GNRs has been utilized as functionalized STM tips which enabling high-resolution imaging of edge-state quantum interference. This way we obtain enhanced inelastic tunneling spectroscopy maps of longitudinal and shear-like phonon modes localized at the armchair edges [3], which remain protected from substrate scattering. These edge-protected vibrations are critical for understanding spin-phonon coupling and coherence limits.

KEYWORDS: Graphene nanoribbons, Spin phenomena, Kondo effect, Spintronics, Inelastic tunneling spectroscopy

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T7-43 POSTER

Spectroscopic ellipsometry evidence of Mn level hybridization in (Ga,Mn)(As,P)

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The dilute ferromagnetic semiconductors (DFSs) based on III-Mn-V alloys are prototypical systems for studying the interplay between spin and charge degrees of freedom in solids and have played a central role in the development of spin-based electronic concepts. In these materials, Mn simultaneously supplies localized magnetic moments and itinerant holes, leading to carrier-mediated ferromagnetism. As a consequence, tuning the electronic structure is intrinsically coupled to the magnetic dopant concentration, limiting independent control of exchange and band structure.

A key route to overcome this limitation is chemical alloying of the host lattice, which modifies band structure and impurity levels without directly altering Mn content. In particular, (Ga,Mn)(As,P) offers a unique platform in which the electronic structure can be tuned via the As/P ratio, in addition to Mn concentration and thermal processing. In this system, substitutional Mn at Ga sites acts as an acceptor, with its binding energy increasing significantly from ~0.11 eV in (Ga,Mn)As to ~0.4 eV in (Ga,Mn)P, suggesting a continuous tuning of the degree of p-d hybridization with increasing P content.

Despite extensive studies, the fundamental nature of Mn-derived electronic states in III-Mn-V ferromagnetic semiconductors remains unresolved: whether they form valence-band-hybridized states or more localized impurity-like states. This distinction is governed by the strength of hybridization between Mn 3d states and anion p states, which ultimately controls the character of the exchange interaction.

Here, we employ spectroscopic ellipsometry (SE) to probe the evolution of Mn-derived electronic states in (Ga,Mn)(As,P) as a function of phosphorus concentration and post-growth annealing.

The SE results provide a coherent picture of how phosphorus incorporation modifies the character of Mn levels in (Ga,Mn)(As,P). The nature of the Mn-induced acceptor state evolves as a function of its energetic separation from the valence-band maximum. When the acceptor level lies close to the valence-band edge, the Mn states retain a predominantly hybridized, valence-band-like character and remain partially delocalized over neighboring anion sites. As the valence-band edge shifts further away from the Mn levels with increasing P concentration, the Mn states acquire a progressively more Mn-centered character. This results in stronger localization on the Mn 3d orbitals and eventually leads to the formation of a separated impurity band. These strongly localized states give rise to pronounced atomic-like d-d transitions, which are clearly resolved in the SE spectra. Our SE measurements also demonstrate pinning of the Fermi level, making E_0 virtually independent of P content. Nevertheless, we have clearly shown here that (Ga,Mn)(As,P) offers a versatile platform on which the fundamental aspects of impurity physics can be reliably tuned using chemical controls.

KEYWORDS: Dilute ferromagnetic semiconductors (DFSs), P-d hybridization, (Ga, P) alloys, Spectroscopic ellipsometry (SE)

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Track 8

Superconductivity in Nanoscale and Mesoscopic Systems

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T8-01 INVITED

Magnetic landscape of superconducting resonators under radio-frequency excitation

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Superconducting resonators are essential components in quantum circuits and highly sensitive sensors. However, their performance is often compromised by magnetic flux penetration, as the interaction of flux quanta and the induced radio-frequency (RF) currents in the superconducting thin film leads to significant energy dissipation. At low operating temperatures, this issue is aggravated as thermomagnetic instabilities can trigger the sudden propagation of magnetic flux avalanches. An important open question is whether the RF excitation itself stimulates the nucleation and propagation of magnetic flux avalanches in the superconducting thin film. The literature remains inconclusive on this point, partly due to the lack of compelling evidence for this phenomenon. In this presentation, we address this challenge by directly visualizing magnetic flux penetration through Faraday rotation imaging under simultaneous RF excitation [1]. We demonstrate that the avalanche activity exhibits a weak dependence on the RF intensity. However, magnetic flux bursts clearly influence the RF transmission properties of the device. Furthermore, we can unambiguously associate a particular avalanche event with a jump in resonance frequency. This enables us to identify the loci of most deleterious events and understand the distinct origins of upward and downward frequency shifts. These observations are supported by electromagnetic simulations in which local changes of the kinetic inductance mimic flux avalanches and confirm the invasive character of the MOI technique. The insights gained from this study aim to contribute to the broader understanding of the magnetic resilience of superconducting resonators and to improve their efficiency and stability.

KEYWORDS: Superconducting resonators, Magneto-optical imaging, Magnetic flux avalanches, Vortex dynamics

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T8-02 INVITED

DC-operated Josephson junction arrays as a cryogenic on-chip microwave measurement platform

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The control and readout of superconducting qubits conventionally relies on signals within the 4-8 GHz frequency range [1]. However, existing systems face challenges, as the high-frequency signal is typically generated at room temperature and transmitted through multiple attenuation stages to the cryogenic environment, inducing noise and lacking scalability [2]. Addressing these issues, it is more beneficial to situate the control circuits near the qubit devices.

As a step towards this goal, we leverage arrays of weak link Josephson junctions as on-chip signal generators capable of converting DC voltage into AC current, emitting voltage-tunable radiation according to the Josephson relations [3]. We successfully fabricated such arrays, utilizing superconducting MoGe and NbTiN islands with dimensions of 500 × 500 nmZ, placed on a 5 nm-thick Au film as the weak link material [4]. The detected RF signal emitted by the arrays when biased with a DC voltage shows high-power regions consistent with the Josephson relation, confirming coherent emission. The emitted radiation can be further tuned using temperature, magnetic fields, applied currents, and device design. Furthermore, a clone of the SNS junction arrays can also serve as a fully DC-operated microwave radiation detector, leading us to propose a high-frequency measurement platform entirely based on DC instrumentation and wiring.

KEYWORDS: Superconducting devices, Josephson junctions, Cryogenic microwave sources

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T8-03 INVITED

Spin mixing in Ising superconductors

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The immunity of Ising superconductors to external magnetic fields originates from a spin locking of the paired electrons to an intrinsic Zeeman-like field [1]. In non-centrosymmetric crystals, spin-momentum locking generates type-I Ising pairing, where the direction of the intrinsic field can be inferred directly from the spin expectation values. In contrast, centrosymmetric materials host type-II Ising pairing: here, electron spins locked to orbital degrees of freedom form Cooper pairs from spin-orbit-split doublets [2]. Time-reversal symmetry enforces spin degeneracy within each doublet, obscuring the spin polarization of the bands and complicating the determination of the spin-orbit field direction.

We introduce an efficient framework for identifying Ising pairing based on the spin-mixing parameter b^2 [6]. To validate this approach, we perform first-principles calculations for monolayer transition-metal dichalcogenide superconductors $PdTe_2$, $NbTe_2$, and $TiSe_2$. We compute b^2 for individual Fermi pockets and construct a comprehensive picture of possible type-II Ising pairing throughout the Brillouin zone. Complementing these results, we use group-theoretical analysis to elucidate the structure of spin-orbit coupling and the microscopic origin of spin mixing in the bands forming the Fermi surfaces.

Our analysis shows that, contrary to expectations based solely on spin-orbit locking, not every spin-orbit-split doublet contributes to Ising pairing. Finally, by relating the spin-mixing parameter b^2 to the intrinsic out-of-plane Zeeman field, we estimate the corresponding upper critical in-plane magnetic field. The proposed framework can be readily implemented in commonly used density-functional-theory packages and tight-binding approaches, providing an efficient tool for screening candidate type-II Ising superconductors.

KEYWORDS: Ising superconductivity, First principles calculations, Spin mixing

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T8-04 INVITED

Recent progress of NbN-based superconducting quantum bits

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Development of superconducting quantum computers has been actively pursued worldwide in recent years. In this talk, we will present our recent progress of various types of high-coherence superconducting quantum bits (qubits) with niobium nitride (NbN)-based Josephson junctions.

First one is NbN-based transmon with the sidewall spacer (SWS) structure. We fabricated NbN/AlN/NbN junctions with this structure in which the lossy insulating layer (SiO_2) exists only near the junction sidewalls. In the sidewall spacer structure, the volume of SiO_2 is much less than that in the conventional structure, making it easier to remove SiO_2 using buffered hydrogen fluoride at the end of the process. We developed sidewall spacer-passivated junctions with varying the AlN thicknesses and measured their current-voltage characteristics at 10 mK and 2.2 K. As a result, we observed that the high subgap resistance and the low critical current density (J_c) of 15.8 A/cmZ, which were suitable for the qubits. Furthermore, we achieved reliable control of J_c with excellent characteristics over a wide range of the AlN thickness. By using this technique, we developed transmons with SWS structure and achieved the excellent lifetime over 100 μs which is significant improvement as non-Al-based qubits.

Second topic is self-shunted flux qubits (SSFQs) [1]. Among the various types of superconducting qubits, a flux qubit with three Josephson junctions which shows the high anharmonicity is a promising candidate for the large-scale superconducting quantum computer. However, the shunt capacitor in the flux qubits drastically increases the device footprint and becomes a bottleneck for large-scale integration. To achieve both the large anharmonicity and small footprint, we propose and demonstrate a ultracompact SSFQs in which the shunt capacitance is provided by the large-area Josephson junctions [1]. We observed the large anharmonicity of 790 MHz as well as the long lifetime of 24.7 μs, which is the longest value reported for flux qubits without the shunt capacitors.

Another issue of the scalability of the flux qubit was the need of the half-flux-quantum bias to achieve the flux-insensitive point (longest coherence time). Theoretically, it has been presented that the flux-bias-free operation could be achieved by incorporating the ferromagnetic Josephson junction (π-junction) in the qubits [2]. In this work, as a novel Josephson junction technique to realize the flux-bias-free flux qubits, we developed the NbN-based ferromagnetic π-junctions with a diluted ferromagnetic interlayer of CuNi or PdNi and their π-shift [3-5]. In recent years, we have successfully confirmed the flux-bias-free operation of the flux qubits with the NbN-based π-junction in the microwave cavity [5]. The demonstrated flux-bias-free qubit showed the reasonable coherence time of 1.5 μs, which was three orders of magnitude higher than that of the previously reported phase qubit with the π-junction.

KEYWORDS: Superconducting qubit, Josephson junction, π-junction, Nitride

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T8-05 INVITED

Engineering electronic phase transitions in cuprate superconductors: from nanoscale oxygen control to cryogenic memory

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High-temperature cuprate superconductors exhibit an exceptionally rich phase diagram in which superconductivity, correlated metallic states, and insulating phases are significantly affected by oxygen stoichiometry and carrier density. Effectively controlling this sensitivity in a scalable and precise manner is crucial for both fundamental research and the development of superconducting devices. In this study, we present an integrated experimental approach to engineer and exploit electronic phase transitions in epitaxial $YBa_2Cu_3O_{7-x}$ (YBCO) thin films through local direct laser writing and electric-field modulation of oxygen content and hole concentration. Initially, we demonstrate nanoscale spatial tuning of superconductivity via maskless direct laser writing under ambient conditions. By locally inducing controlled oxygen depletion, sub-micrometer grayscale patterns are created over large areas, enabling continuous and reversible modulation of the superconducting critical temperature, carrier density, and critical current density. Cryogenic magneto-optical imaging directly visualizes the spatial redistribution of superconductivity and magnetic flux penetration, while transport measurements confirm systematic tuning of both normal-state and superconducting properties. Correlated Raman spectroscopy and optical reflectometry identify laser-power-dependent oxygen depletion without structural damage, establishing direct laser writing as a non-destructive, scalable method to navigate the cuprate phase diagram and engineer superconducting nanostructures with locally programmed functionality [1]. Building on controlled oxygen landscapes, we further explore electric-field-induced metal-insulator transitions in YBCO-based heterostructures for cryogenic memory applications. These devices exhibit non-volatile, multilevel resistive switching that persists well below the superconducting transition temperature. Two competing mechanisms are identified: electrochemical oxygen vacancy migration dominant at high temperatures, and a low-temperature electrostatic transition driven by hole redistribution within an oxygen-depleted interfacial layer. The latter enables low-voltage, highly stable analog resistance states and reproducible potentiation-depression cycles. A physics-based compact model accurately reproduces the experimental behavior and supports circuit-level simulations for cryogenic in-memory and neuromorphic computing architectures [2]. Finally, complementary magnetotransport measurements reveal anomalous in-plane magnetoresistance and planar Hall effects near the superconducting transition, indicating unconventional quasiparticle transport and a previously underappreciated spin-orbit landscape in cuprate superconductors.

KEYWORDS: High-temperature cuprate superconductors, Field-induced carrier doping, Direct laser writing, Metal-insulator transition, Cryogenic memory applications

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T8-06 ORAL

Reactive sputtering optimization of ultrathin NbTiN films for superconducting nanowire single photon detector applications

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Ultrathin niobium titanium nitride (NbTiN) films are widely used in superconducting nanowire single-photon detectors (SNSPDs) due to their high critical temperature, fast response, and compatibility with nanofabrication processes [1-3]. In this work, NbTiN thin films with thicknesses ranging from 3 to 12 nm were deposited on sapphire substrates by reactive magnetron sputtering using dual-target Nb (DC) and Ti (RF) sources. The influence of substrate temperature and nitrogen content in the sputtering atmosphere on the structural, electrical, and superconducting properties of the films was systematically investigated. The films were deposited at substrate temperatures ranging from room temperature to 600 °C under varying Ar/N_2 gas ratios, while maintaining a working pressure of 3 mTorr. Sheet resistance measurements, superconducting transition characterization, and X-ray photoelectron spectroscopy were used to evaluate transport properties, stoichiometry, and disorder effects. Additional thickness-dependent measurements were performed to assess the evolution of superconductivity in ultrathin films. A clear correlation between deposition temperature and superconducting performance was observed. Increasing substrate temperature reduced sheet resistance and enhanced the critical temperature, indicating improved crystallinity, reduced disorder, and optimized nitrogen incorporation. Notably, NbTiN films deposited under nitrogen-rich conditions demonstrated robust superconductivity despite operation in a strongly poisoned sputtering regime. For a 7 nm film deposited at 600°C under an Ar/N_2 flow ratio of 50/50 sccm, a sheet resistance of approximately 300 fi/sq was obtained, corresponding to a resistivity of about 210 µfi·cm, suggesting a dense and moderately disordered superconducting state. All films with thicknesses greater than 5 nm, deposited at 600°C, showed critical temperatures above 10 K. The obtained results indicate that optimized NbTiN films for SNSPD applications require a balance between superconducting strength and controlled disorder. The combination of moderate sheet resistance and elevated critical temperature suggests that high-temperature reactive sputtering can stabilize high-quality NbTiN even under high nitrogen fractions. These findings provide insight into process-structure-property relationships in ultrathin superconducting nitrides and support the development of reproducible SNSPD-grade NbTiN thin films.

KEYWORDS: NbTiN thin films, Reactive sputtering, Superconducting nanowire single-photon detectors, Ultrathin films, Disorder engineering

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T8-07 ORAL

Features of phonon spectrum degeneracies at the R point of A_{15}-type crystals

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Phonon spectra play a central role in understanding the dynamical stability and lattice properties of intermetallic compounds. In particular, A_{15}-type materials exhibit unusual structural and vibrational characteristics, for example, superconductivity, that make them a long-standing subject of condensed matter research.

A_{15} compounds such as Mo_3X and Cr_3X (X = Ge, Si) are characterized by a complex cubic structure (space group Pm-3n) with strong symmetry constraints. These features lead to highly structured phonon dispersions and enable symmetry-driven degeneracies at high-symmetry points of the Brillouin zone. However, the origin and robustness of phonon degeneracies in A_{15} systems, particularly at the R point, remain not fully clarified.

In this work, a symmetry-consistent lattice-dynamical framework is developed using a superlattice representation of the A_{15} structure. The crystal is described within a (4a × 4a × 4a) simple cubic metric, resulting in a complete model with 64 effective lattice positions. A dual description in terms of lattice nodes and modulation vectors is introduced, allowing the dynamical problem to be formulated in a modal basis.

Here we show that the phonon spectrum at the R point exhibits a characteristic set of symmetry-protected degeneracies that remain robust under variation of model parameters. The obtained structure arises from symmetry constraints of lattice dynamics rather than from accidental parameter tuning. Compared to simplified approaches, the results reveal a stable degeneracy pattern with high-multiplicity states, indicating that such features are intrinsic to the A_{15} family as shown in [1-5].

These findings provide additional insight into the role of symmetry in determining vibrational properties of complex intermetallic systems and may be relevant for materials with strong lattice-coupling effects. Overall, symmetry-protected phonon degeneracies can be regarded as a characteristic fingerprint of the A_{15} structural class.

KEYWORDS: Superlattice, Phonon spectra, Modulation vector, Superconductors, Phonon degeneracy

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Track 9

Nanosensors, Nanodevices and Functional Systems

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T9-01 INVITED

Tellurene electronics and beyond

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The development of wearable sensors for continuous monitoring of biomarkers is a promising alternative to the costly tools currently used in healthcare. Two-dimensional (2D) materials exhibit high sensitivity to physiology-relevant signals. However, few studies report 2D materials-based wearable sensors, primarily due to the intrinsic limitations of related materials that render them poor performance for sensing. Ongoing efforts in 2D materials also face difficulty scaling up due to restrictions on the synthesis conditions and stability. I will discuss our recent progress in developing tellurene-based wearable sensors with multiple modalities for continuously monitoring physiological and mental states. We show that wearable sensors based on tellurene, an emerging 2D semiconductor with intriguing properties, hold substantial promise for addressing the challenges of implementing 2D materials wearable sensors with high sensitivity and specificity. We aim to leverage our platform to fill the gaps in developing clinically applicable 2D materials-based wearable sensors.

KEYWORDS: Tellurene, 2D semiconductors, Nanoelectronics, Wearable sensors, Digital health

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T9-02 INVITED

The development of multi-pixel field emission x-ray devices

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The first concept of multi-source Computed Tomography (CT) systems originated in the 1980s, and opened the way to innovative system concepts in X-ray and computed tomography. Multi-source CT systems offer promising opportunities in system performance. In addition, multi-source X-ray radiographic systems are widely studied, namely for X-ray stereographic imaging, X-ray tomosynthesis imaging, and inverse-geometry imaging. One significant benefit of the multi-source X-ray technology is the ability to fabricate the source array in various two-dimensional configurations. The more complicated distributive source topologies are designed to improve the sampling of projection data, to further improve both in-plane and depth imaging resolution within the constraints of the limited-angle acquisition of projection data. In multi-source systems, the X-ray sources are arranged in an array format, and each source is launched individually. However, current X-ray generators are not suited for these systems because of their large size, huge power requirement, and slow response. This talk will focus on the field emission X-ray technology that enables to the realization of multi-source CT systems.

KEYWORDS: Field emission, X-ray, Carbon nanotubes

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T9-03 INVITED

Advanced electrochemical immunosensors for SARS-CoV-2 detection based on gold nanostructures and MXenes

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Electrochemical immunosensors have emerged as critical analytical platforms across diverse applications, particularly in biomedical diagnostics. These bioanalytical systems offer remarkable sensitivity and efficiency, rapid response, and ease of miniaturization. The principal operation of an electrochemical immunosensor is the conversion of specific antigen-antibody interaction into a measurable electrical signal, proportional to analyte concentration in the sample. In recent years, nanomaterials have emerged as powerful tools to enhance the sensitivity of immunosensors by modulating the electroactive surface area, improving electron transfer kinetics, and ensuring better spatial orientation and activity of biomolecules at the nano-bio interface [1-4].

In this presentation, two label-free electrochemical immunosensors will be presented. The first immunosensor, based on a graphite rod electrode electrochemically modified with gold nanostructures and covalently immobilized SARS-CoV-2 spike (S) protein, was developed for the detection of specific anti-S antibodies. The impact of gold nanostructures on the performance of the immunosensor was evaluated. Additionally, the influence of non-specific interactions on the analytical signal was investigated, along with methods used to reduce such effects. The second immunosensor, based on a screen printed graphite electrode modified with MXenes and polydopamine, was developed for the detection of the SARS-CoV-2 S protein. MXenes have attracted significant attention as two-dimensional materials with unique chemical, electrical, and morphological characteristics that can improve the performance of electrochemical biosensors. Although MXenes and their composites show considerable promise in biosensor development, further systematic investigation is required to elucidate their specific advantages and optimize their performance in sensing applications. This research provides valuable insights into the application of various nanomaterials in electrochemical immunosensors for biomedical applications.

KEYWORDS: Electrochemical immunosensor, Gold nanostructures, MXenes, SARS-CoV-2 spike protein, Specific antibody

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T9-04 INVITED

Programmable DNA origami micro-nano assemblies for optomechanics and Raman sensing

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DNA nanotechnology has revolutionized nanoscale fabrication by enabling the precise and programmable assembly of structures with nanometric precision [1]. Its unparalleled structural versatility makes it an ideal platform for organizing objects into complex hybrid architectures. Extending this concept toward microscale offers an exciting opportunity to bridge nanoscale precision with microscale functionality without relying on top-down methods. However, the controlled bottom-up fabrication of such hybrid micron-sized assemblies remains a major challenge. Here, we present the fabrication of well-defined hybrid micro-nano assemblies with controlled geometry and functionality were the DNA origami serves simultaneously as a rigid mechanical bridge between distinct microparticles and as a multifunctional nano-breadboard for the site-specific placement of fluorophores, quantum dots, and metallic nanoparticles [2]. Leveraging this programmability, we fabricate heterodimer microparticle assemblies (Janus-type) by using chemically modified specific sequences at the termini of the 24-helix bundle (24HB) to enable selective conjugation via biotin-streptavidin interactions and click chemistry [3]. The resulting heterodimers exhibit structural integrity, and selective DNA-mediated coupling is confirmed through fluorescence and transmission electron microscopy, reveling precise localization of the 24HB interlinks bridging the components. Moreover, these assemblies demonstrate robust mechanical stability under optical trapping, showing stable 2D and 3D confinement and orientation-dependent behavior arising from their intrinsic asymmetry. We further demonstrate hybrid micro-nano systems combining a polystyrene microsphere with a 50 nm gold nanoparticle linked by DNA origami, forming well-defined plasmonic nanogaps that enhance localized electromagnetic fields for surface-enhanced Raman spectroscopy (SERS). Beyond Raman or optical trapping applications, the modularity of this platform establishes DNA origami as a structural interface for coupling microscale manipulation with nanoscale plasmonic functionality [4]. This approach opens new opportunities for reconfigurable nanoplasmonic assemblies, optomechanical probes, and programmable photonic systems for sensing and spectroscopy.

KEYWORDS: DNA origami, Optical tweezers, RAMAN

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T9-05 INVITED

Advanced nanocomposite materials for high-performance hybrid sensors: tuning selectivity for environmental and biomedical applications

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The demand for high-precision sensing in environmental monitoring and biomedical diagnostics has accelerated the development of multifunctional sensors fabricated using diverse approaches, composite nanomaterials, and advanced tuning processes. Considering the vast array of possibilities, a primary point of interest lies in nanocomposite materials and their integration into hybrid sensors designed to address specific challenges within environmental and biomedical niches and various biomarkers [1].

Previous studies have demonstrated significant potential for metal-oxide based gas sensors and tuning them by either functionalizing with various nanoparticles, and/or by coating them with polymers [2] and metal-organic frameworks [3] to enhance their sensitivity and selectivity for target analytes. Notably, the potential of TiO_2 coated with PV_4D_4 polymer has been established, where samples were tuned via AgAu nanoparticles functionalization [4]. Furthermore, thermal annealing of the polymer transitioned the coating into a ring-to-cage structure, significantly increasing selectivity towards targeted analytes. Thus, a two-in-one sensor with a dual-response was obtained which responded as n-type for hydrogen and p-type for carbon dioxide with responses of up to 230% and 130 % respectively, [4] showcasing its versatility for multi-gas detection. In addition, research has focused on ZIF-71-coated, Al-doped CuO-based hybrid gas sensors [5]. These studies showed that this specific combination responded to n-butanol by up to 11% at 200 °C and to hydrogen gas by up to 61% at 250 °C, exhibiting excellent repeatability and durability. Furthermore, tests under various relative humidity levels showed that MOF-ZIF-71-coated CuO:Al possesses enormous potential for stable detection of targeted gases, [5] indicating the possibility of developing humidity-tolerant devices that remain stable over extended periods of operation.

Thus, in this paper, several sensors are presented to substantiate the potential of composite materials in detecting various biomarkers and target analytes for different industries, with emphasis on various tuning processes and the thermal annealing of various architectures. This paper explores the strategic design and fabrication of composite-based gas sensors, focusing on the synergistic effects achieved through advanced tuning processes and the resulting enhancements in molecular selectivity and sensitivity. Ultimately, our findings underscore the transformative role of hybrid nanocomposites in establishing a new generation of robust, multifunctional sensing platforms capable of meeting the rigorous environmental and clinical monitoring.

KEYWORDS: Hybrid sensors, Biomedical, Polymer

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T9-06 INVITED

Concepts and prospects of hybrid memristive-chemiresistive hydrogen gas sensors

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Hydrogen is a promising energy carrier widely utilized in energy storage applications, chemical synthesis and other areas of industry. However, due to its high flammability, reliable and fast detection is crucial to ensure safety. Conventional H_2 gas sensors face challenges in sensitivity, selectivity, and integration with intelligent systems [1]. Recently, hybrid devices combining gas sensing and memristive memory, gasistors, have been proposed and explored [2,3]. The gasistor integrates a metal-oxide semiconductor gas sensor and a resistive-switching element (memristor) into a single crossbar cell, e.g. Pt/TiO_2/Pt. Such devices simultaneously detect the presence of hydrogen gas and store the detection event in their resistive state. Thanks to their structure, they can be easily integrated into crossbar arrays for in-sensor computing and other neuromorphic applications. Here we explore gasistor design improvements enabling higher sensitivity, stability, reproducibility, as well as new functionality of these hybrid devices.

The originally proposed single cell gasistor [3] suffers from high limit of detection (> 1000 ppm H_2), caused by the extremely high baseline resistance of the sensing part, and limited resistive switching performance. It has been shown that incorporation of large-scale nanoporous top Pt electrodes in this type of sensors decreases the baseline resistance and allows detection of very low (down to 3 ppm) H_2 concentrations [4]. However, this approach is not directly applicable to single cell gasistors since large electrode cross-section area leads to much higher resistive switching currents, deteriorates the switching repeatability and can even lead to transition from bipolar to unipolar resistive switching. To address this problem, a modular gasistor with separate gas sensing and resistive switching cells is proposed. Such configuration allows for independent optimization of the two cells to maximize their gas sensing and resistive switching performance, respectively. Moreover, the two cells can be connected in both parallel and series configuration, detecting either decreasing or increasing H_2 concentration events, respectively. Preliminary results further indicate that a memristor cell exhibiting analogue (continuous) resistive switching, when integrated into a gasistor, can function as an analogue memory element. In this configuration, the gasistor is able to encode in its resistive state not only the occurrence of increasing or decreasing H_2 concentration events, but also the corresponding maximum or minimum H_2 concentration reached during its operation.

KEYWORDS: Gas sensors, Hydrogen, Gasistor, Memristor

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T9-07 INVITED

Challenges during the formation and application of molecularly imprinted polymers dedicated for the determination of large molecular weight analytes

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Early and accurate diagnosis of cancer is important biomedical issue. However, sometimes the duration and costs of diagnosis are rather high, require sophisticated bioanalytical equipment and should be performed by well-trained personnel. The application of sensors based on cheap artificial biological recognition elements could solve some recent technological problems in this research/technology direction [1-3]. Recently, molecularly imprinted polymers (MIPs) are gaining significant attention, because MIPs can replace antibodies and natural receptors, which most frequently are used for the determination of cancer biomarkers. In this presentation the ways in which MIPs can be formed directly on sensor electrochemical and/or surface plasmon resonance (SPR)-chip surface will be discussed. Proper and efficient polymerization is still challenging, therefore, before the polymerization is reasonable to apply mathematical and computational modelling to select suitable polymeric structure, which will properly interact with imprinted template/analyte. Ther selection of polymerization methods is also very important technological issue, which will be discussed during the presentation. For the deposition of MIP-based layers chemical and electrochemical methods could be applied. After polymer layer formation the next significant obstacle is 'mild' extraction of the template and formation of cavities complementary to selected biomarker. However, this technological step is not always easy and requires selection of proper eluent and extraction conditions suitable for this purpose. This task is especially complicated when we are trying to design MIP for large molecular weight cancer biomarkers. The next step, after the formation is the choice of the conditions for selective interaction of MIP with the biomarker, and the adaptation of sensitive analytical signal detection method. In our recent research the most frequently we are using electrochemical and surface plasmon resonance based analytical protocols. The advantage of electrochemical methods is that they can be used in optically nontransparent solutions, however the sensitivity of electrochemical methods is not always very high. This disadvantage could be eliminated or at least reduced by simultaneous application of surface plasmon resonance based analytical signal determination methods.

KEYWORDS: Molecularly imprinted polymers (MIPs), Surface plasmon resonance (SPR), Electrochemistry, Biomarker

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T9-08 INVITED

Quantum sensing with NV centers in diamond: from nanoscale magnetometry to spin-wave imaging

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NV centers in diamond are a leading platform for quantum sensing, offering atomic-scale spatial resolution and nanotesla-per-root-hertz magnetic field sensitivity under ambient conditions. Their spin-dependent photoluminescence, read out via ODMR, enables precise nanoscale magnetometry through Zeeman shifts of the ground-state spin sublevels.

In this contribution, I will present an overview of scanning NV magnetometry applied to complex magnetic materials. We first review the operating principles of NV-based quantum sensing and discuss recent technical advances in tip fabrication and stand-off distance minimization that have pushed spatial resolution below 50 nm. We then demonstrate scanning magnetometry results on archetypal multiferroic and ferrimagnetic materials. In $BiFeO_3$, NV imaging reveals the sub 50 nm spin cycloid structure and its electrically controlled switching, providing quantitative stray-field maps of the antiferromagnetic order. In Bi:YIG, we image ferrimagnetic domain patterns with high contrast, exploiting the material's large magneto-optical response and low spin-wave damping.

Beyond static field imaging, we discuss NV-based magnetic noise spectroscopy, where spin relaxation measurements (T_1 relaxometry) probe GHz-frequency magnetic fluctuations. This approach enables the localization of domain walls and structural defects through their characteristic local enhancement of magnetic noise, offering a non-invasive probe of dynamic magnetism at the nanoscale.

Finally, we present NV-based spin-wave imaging. By detecting the evanescent microwave stray fields of propagating magnons, NV magnetometry resolves spin-wave wavefronts, dispersion relations, and mode selectivity via controlled sensor-sample distance tuning. Together, these capabilities position NV-center quantum sensing as a uniquely comprehensive tool for the nanoscale investigation of magnetic materials and spintronic devices.

KEYWORDS: BiFeO, Quantum sensing, Nanoscale magnetism, NV centers, Diamond

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T9-09 INVITED

MTJ-based artificial neuron suitable for fully analog machine learning

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Magnetic tunnel junctions (MTJs) are nanoscale spintronic devices composed of two ferromagnetic layers separated by an insulating barrier. MTJs are CMOS-compatible and widely used commercially in magnetic memory and sensor technologies, with over 10^8 devices manufactured annually. In this work, we demonstrate a practical analog artificial neuron by pairing a spin-valve/magnetic tunnel junction (SV/MTJ) device with an NMOS transistor. This SV/MTJ-nMOS neuron supports fully analog machine learning and is compatible with conventional electronic systems and neural network architectures.

In a recent theoretical study [1], it was shown that an SV/MTJ device can function as an artificial neuromorphic device replicating fundamental behaviors observed in biological neurons, such as short spike generation, response latency, synaptic integration, refraction, inhibition, adaptation, and spike-train generation. By integrating this SV/MTJ device with an NMOS transistor, both input and output signals become voltage-based. This configuration allows straightforward implementation of synaptic weights through voltage-controlled amplifiers, thus enabling seamless integration into fully analog neural networks.

To validate system-level performance, we constructed a three-neuron SV/MTJ-nMOS neural network in LTspice program, complete with supporting circuitry [2]. A feedforward backpropagation algorithm was employed, performing all learning and synaptic weight adjustments entirely in the analog domain using spike timing (time-encoded signals). An example of realization of an XOR logic gate, a standard neural network benchmark, was used to assess learning effectiveness. After approximately 30 training epochs, the network reliably converged, performing XOR classification successfully. The complete training cycle required less than 2 μs of simulation time. These results confirm the potential of the SV/MTJ-nMOS artificial neuron circuit for fast, low-power, fully analog machine learning, compatible with standard electronic design and established neural network frameworks.

KEYWORDS: Magnetic tunnel junction (MTJ), Artificial neuron, Analog machine learning

ACKNOWLEDGEMENTS: This work was supported in part by the Oakland University Foundation.

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T9-10 INVITED

Synthetic molecular recognition architectures for intelligent electrochemical sensing

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Selective molecular recognition remains one of the central challenges in the development of next-generation chemical and biosensing technologies, particularly for applications requiring operation in complex biological, pharmaceutical, and environmental matrices. Molecularly imprinted polymers (MIPs) have emerged as robust synthetic recognition materials capable of mimicking biological affinity systems while offering superior physicochemical stability, lower production costs, and compatibility with scalable sensor fabrication technologies.

This work discusses recent advances in electropolymerized MIP-based electrochemical sensing systems utilizing conducting polymer interfaces for selective analyte recognition. Particular emphasis is placed on polypyrrole-based molecular imprinting strategies and electrochemical transduction architectures enabling enhanced selectivity, sensitivity, and operational stability [1]. Previous studies demonstrated the successful application of molecularly imprinted polypyrrole layers for selective electrochemical detection of melamine, urine, and other biologically relevant compounds, highlighting the importance of polymer morphology, imprinting efficiency, and nanostructured modifications in sensor performance [2-5].

The work further examines how electrochemical deposition methods, conducting polymer engineering, and interfacial modification strategies contribute to the development of miniaturized and low-power analytical systems. Electrochemical and quartz crystal microbalance-based characterization approaches are discussed as effective tools for evaluating adsorption behavior, binding affinity, and recognition-layer dynamics in MIP architectures [3, 4].

Recent developments indicate that intelligently engineered MIP interfaces can support highly selective detection in complex matrices while remaining compatible with portable, wearable, and distributed sensing technologies. Emerging opportunities involving hybrid electrochemical platforms, intelligent signal processing, and autonomous sensing frameworks are also considered, particularly in relation to healthcare diagnostics, food safety assessment, and environmental monitoring applications [5].

These advances position molecular imprinting technologies as a promising platform for future intelligent sensing infrastructures integrating synthetic molecular recognition with scalable electrochemical analytical systems.

KEYWORDS: Molecularly imprinted polymers, Electrochemical sensors, Conducting polymers, Selective molecular recognition

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T9-11 INVITED

Atomic and molecular layer deposition strategies for gas separation: applications in membranes and sensing

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Atomic Layer Deposition (ALD) and Molecular Layer Deposition (MLD) are two highly controlled thin-film deposition methods that have gained significant attention for the functional modification of porous materials used in gas separation processes. Their unique capability to build highly conformal coatings with angstrom-level precision enables precise engineering of membrane surfaces, pore architectures, and hybrid organic-inorganic interfaces. Through the controlled adjustment of surface chemistry, mechanical response, and effective pore size, ALD and MLD open new routes for tuning gas transport behavior and improving selectivity in both dense and porous separation systems.

In this presentation, we will highlight recent progress in the application of ALD and MLD across different classes of gas separation membranes, including inorganic, polymer-based, and mixed-matrix systems. Representative examples from our research will illustrate how modifications achieved via ALD/MLD can enhance membrane performance by improving selectivity, operational stability, and interfacial integration. Particular emphasis will be placed on the rational design of pore structures and hybrid coatings, which provide deeper insight into gas transport phenomena at the nanoscale.

Finally, we will address the current limitations and future opportunities associated with scaling up ALD and MLD technologies for membrane and sensor fabrication. The presentation will emphasize their growing potential in advancing next-generation gas separation solutions for clean energy production, carbon capture, and industrial gas purification.

KEYWORDS: Atomic layer deposition, Molecular layer deposition, Gas-separation membranes, Conformal coatings, Gas sensing

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T9-12 INVITED

From batch to continuous: scalable microwave polyol synthesis of metallic nanoparticles

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Metallic nanoparticles based on copper, iron, and nickel are compelling candidates for next-generation conductive inks, printed electronics, and magnetically functional materials, offering high performance at significantly lower cost than noble metals. However, their synthesis is typically hindered by oxidation susceptibility, reliance on hazardous reducing agents, and limited scalability.

We present a microwave-assisted polyol platform in which ethylene glycol acts as both solvent and reducing agent, eliminating external reductants and enabling reactions in air within minutes. Lignin, sourced from lignocellulosic biomass as a circular-economy byproduct, is incorporated as a bio-derived capping agent that simultaneously controls particle size and protects against oxidation across all three metal systems.

For copper, the platform delivers tunable particle sizes from ~47 to 800 nm, with the process transferring to a continuous-flow microwave reactor at production rates of ~5 g h^{-1} and >95% reaction efficiency. Lignin-stabilized Cu nanoparticles show no detectable oxidation after nine months in air, and after sintering at 150 °C reach conductivities of 10^5-10^6 S m^{-1}, compatible with flexible substrates. For iron, zero-valent Fe nanoparticles (~ 70 nm) are obtained with saturation magnetization of 158 A·m^2/kg, demonstrating robust room-temperature ferromagnetism. For nickel, introducing lignin together with preformed seeds reduces particle size from 730 to 239 nm while preserving a saturation magnetization consistent with metallic *fcc* Ni.

Together, these results establish microwave-polyol chemistry as a versatile, sustainable, and scalable route to Cu, Fe, and Ni nanomaterials for emerging applications in printed electronics and magnetic functional devices.

KEYWORDS: Microwave-assisted synthesis, Polyol process, Metallic nanoparticles, Conductive inks, Continuous-flow synthesis

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T9-13 ORAL REMOTE

Core-shell Au@PEtOx-PBuOx colloids with tunable LCST transition for thermally switchable optical applications

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Hybrid nanostructures containing a noble metal core with polymer shell are the basis for the creation of "smart" materials with controllable properties. Such systems allow the adjustment of optical properties by external influence, which is of great importance for nanotechnology. Among such materials, polymers with lower critical solution temperature (LCST), capable of reversible phase transition upon heating, attract special attention. Poly(2-oxazolines) are promising polymers for such systems due to their high biocompatibility and the possibility of precise control of the phase transition temperature. However, the synthesis of stable hybrid nanosystems with sharp swithing optical response in specific temperature ranges, in particular physiological ones, remains a difficult task. Here we show that our synthesized nanoparticles with a gold core and a shell of PEtOx-stat-PBuOx statistical copolymers act as thermosensitive optical absorbtive switches with a tunable phase transition temperature. We found that increasing the proportion of the hydrophobic component PBuOx from 0 to 0.3 allows lowering the LCST point from 81°C to 17°C, reaching a biologically relevant 37°C at x=0.19. The phase transition is accompanied by compression of the polymer shell and subsequent aggregation of particles, which leads to a pronounced red shift and increase in the intensity of the localized surface plasmon resonance (LSPR) peak. The sensitivity of this hybrid nanosystem to structural changes is confirmed by SERS experiments, which demonstrate an enhancement of the Raman scattering intensity due to plasmon interaction during thermal cycling. The above-mentioned nanosystems are the basis for the creation of thermo-optical devices and sensors. The ability of the system to accurately respond to temperature variation near human body temperature makes these nanoparticles extremely promising for biomedical applications, in particular for in vivo diagnostics.

KEYWORDS: Gold nanoparticles, Nanobiosensors, Poly(2-oxazolines), LCST, LSPR

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T9-14 ORAL

MoS_2/PANI composite-based photoluminescence sensor for selective sensing of dimethoate pesticide

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This study explores the development of a sensitive and selective sensing nanocomposite for detecting a widely used organophosphate pesticide called dimethoate. It poses significant environmental and health risks due to its high toxicity and persistence in agricultural products. To address these concerns, we developed a novel MoS_2 QDs/PANI nanocomposite and employed a photoluminescence technique to detect dimethoate. The MoS_2 QDs/PANI nanocomposite was synthesized in a single-step process and characterized using XRD, UV-visible, photoluminescence (PL), TEM, and FTIR techniques. The nanocomposite demonstrated selective detection of dimethoate which is one among other pesticides. Utilizing the PL approach, the sensing nanocomposite achieved a detection limit (LOD) of 1 nM and a linear range (LR) of 1-30 nM. The relative standard deviation (RSD) for metal ion interference was 3 % and 5 % for actual raw samples, indicating that, the nanocomposite has high specificity and stability. Additionally, the sensing nanocomposite exhibited a 5 % RSD for repeatability, confirming its reliability. The sensing parameters of the MoS_2/PANI nanocomposite were compared with existing literature, highlighting its superior performance. This novel nanocomposite offers a promising solution for effective and reliable dimethoate detection, contributing to improved food safety and environmental protection.

KEYWORDS: Pesticide, Nanocomposite, MoS 2, QDs, Photoluminescence

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T9-15 ORAL

Pesticides detection through fluorescent aminosilane-coated ZnO nanoparticles

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Triazole fungicides are widely employed in agriculture to protect crops, herbs, and fruits; however, their extensive use raises concerns regarding environmental persistence and potential risks to human health [1]. Conventional analytical methods for pesticide detection, such as high-performance liquid chromatography, provide high sensitivity but often require expensive instrumentation, complex sample preparation, and long analysis times. In this work, we propose a rapid and sustainable fluorescence-based sensing strategy for the detection of penconazole, selected as a model triazole fungicide.

The sensing platform is based on ZnO nanoparticles, chosen for their low toxicity, biocompatibility, optical properties, and low production cost [2]. To improve colloidal stability and promote interaction with the analyte, the nanoparticles were functionalized with N-(2-aminoethyl)-3-aminopropyltrimethoxysilane (AEAPTMS). The methoxy groups of the silane undergo hydrolysis and condensation reactions with hydroxyl groups naturally present on the ZnO surface, forming stable Zn-O-Si bonds and generating a thin organosilane coating around the nanoparticles [3]. The exposed terminal amino groups reduce aggregation in aqueous media and provide active sites for interaction with penconazole molecules.

Surface modification was confirmed by IR spectroscopy, while UV-Vis measurements were employed to evaluate the stability and dispersibility of ZnO@AEAPTMS suspensions in hydrophilic solvents over time. Fluorescence measurements were then carried out by progressively adding penconazole to stable aqueous dispersions of the functionalized nanoparticles. Emission spectra were recorded upon excitation at 365 nm over a concentration range between 0 and 10 ppm.

The fluorescence intensity increased with increasing penconazole concentration up to approximately 3 ppm, after which a plateau was observed. The obtained trend suggests a concentration-dependent interaction between the analyte and the functionalized ZnO surface, supporting the potential use of ZnO@AEAPTMS nanocomposites as fluorescent nanosensors for pesticide detection.

Overall, this approach represents a promising alternative to conventional analytical techniques, combining sensitivity, simplicity, and sustainability for the monitoring of triazole pesticide residues in aqueous environments. L. Casoli (1), C.Ricci (1), G.A. Bracchini (1), A. Conti (1), I.Fabrizi (1), E.M. Bauer (2), A. Lembo (1), L.Gontrani (1), M.Carbone (1) (1) STARTNETICS, Department of Chemical Science and Technologies, University of Rome Tor Vergata. (2) Institute of Structure of Matter-Italian National Research Council (ISM-CNR)

KEYWORDS: ZnO nanoparticles, Coatings, Nanosensors, Fluorescence, Pesticide detection

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T9-16 ORAL

Sensor performance of hydrogel-based gold/carbon quantum dot nanocouples with metal enhanced fluorescence

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Carbon quantum dots (CQDs) are a rapidly growing class of carbon-based nanomaterials known for their tunable fluorescence, biocompatibility, and rich surface functionality [1].CQDs have been widely used for fluorescence-based detection of biomolecules, ions, and environmental analytes due to their rapid response, high sensitivity, and ease of surface modification [2]. In hydrogel-CQD systems, the hydrogel provides a hydrated three-dimensional network that improves nanoparticle dispersion and facilitates analyte diffusion while maintaining mechanical stability [3].Immobilizing CQDs within hydrogels also enhances signal reproducibility, long-term stability, and localized fluorescence readout compared with colloidal systems [3,4]. By combining CQD fluorescence with the soft and permeable nature of hydrogels,these composites show strong potential for biomedical diagnostics, environmental monitoring, and portable sensing applications [4].Coupling CQDs with gold nanoparticles enhances fluorescence through the metal-enhanced fluorescence (MEF) effect, leading to stronger emission than pristine CQDs. This enhancement arises from plasmonic interactions between gold nanoparticles and CQDs, highlighting the potential of Au/CQD nanostructures for sensitive optical sensing platforms [5].In this study, poly(acrylic acid-co-acrylamide) hydrogels incorporating CQDs synthesized via a solid-state method were prepared at concentrations of 0-2.5% v/v to evaluate their functional properties.In parallel, CQDs synthesized in the presence of chloroauric acid ($HAuCl_4 \cdot 3H_2O$) were incorporated at the same concentrations to investigate the effect of metal-enhanced fluorescence on emission behavior.The hydrogels were characterized in terms of rheological properties and fluorescence response.Rheological analysis showed a concentration-dependent decrease in mechanical strength with increasing nanoparticle content. For CQD-containing samples, increasing the concentration to 2.5% v/v reduced the storage modulus (G′) from approximately 13,000 Pa to 2,000 Pa, corresponding to a 6-7 fold decrease. A more pronounced reduction was observed for Au/CQD hydrogels, where G′ decreased to approximately 270 Pa at the same concentration, indicating a stronger weakening effect in the presence of Au.Fluorescence analysis also revealed a concentration-dependent decrease in emission intensity for both systems.As the concentration increased from 0.1% to 2.5% v/v, fluorescence intensity decreased by approximately 17 fold for CQD and 28-fold for Au/CQD. At 0.1% v/v, Au/CQD samples exhibited approximately 1.25 fold higher fluorescence intensity than CQD-only samples.This comparison highlights the influence of gold nanoparticles on the overall functional performance of the hydrogel system for potential biomedical sensing applications.

KEYWORDS: Fluorescence sensing, Hydrogel composites, Carbon quantum dot, Metal-Enhanced fluorescence

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Posters

T9-17 E-POSTER

Thermal switching of photoluminescence of MoS_2 2D quantum dots hybridized with colloidal Au@PEtOx core-shell nanoparticles

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We study the thermo-induced morphological transformations and optical switching phenomena in colloid solution of nanohybrids, consisting of luminescent MoS_2 monolayer quantum dots (2D QDs) and Au@PEtOx core-shell nanoparticles (NPs) with a gold core and a shell of the thermoresponsive poly(2-ethyl-2-oxazoline) (PEtOx) polymer with a conformational lower critical solution temperature (LCST) phase transition. The binding of MoS_2 QDs to the PEtOx shell was confirmed through a combination of UV-Vis absorption, photoluminescence (PL), and Raman scattering spectroscopies. PEtOx exhibits a characteristic LCST phase transition behavior, undergoing conformational changes from a hydrophilic to a hydrophobic state upon heating. The effect of LCST transition in the PEtOx polymer shell on the MoS_2 QDs PL upon heating and reverse cooling was investigated in detail. Upon heating, the passing through the LCST point is accompanied by a step-like increase in the PL intensity with its subsequent sharp quenching. This sharp dependence of the PL intensity at LCST was attributed to be the result of the action of several physical mechanisms: the shrinking of the polymer shell during the phase transition, the NPs aggregation driven by the increased hydrophobicity of polymer shell, and the plasmonic PL enhancement of MoS_2 QDs in the Au core field.

In comparative studies of the MoS_2 QDs / PEtOx and MoS_2 QDs / Au@PEtOx NPs systems, the LCST point for PEtOx polymer bound to the Au core in Au@PEtOx NPs is noticeably higher (80 °C) compared to bare PEtOx (65 °C). Furthermore, in MoS_2 QDs / Au@PEtOx NPs nanohybrid, the jump-like changes in the PL intensity occur in a much narrower temperature range (ΔT = 6 °C) and have a noticeably larger relative enhancement (20.5 %) compared to MoS_2 QDs / PEtOx with ΔT = 15 °C and a 12.6 % enhancement. Thus, the narrow temperature range and large PL intensity jump are physical characteristics making the MoS_2 QDs / Au@PEtOx NP nanohybrid highly potential for creating high-sensitive luminescent nanothermometers and switches for the application in nanophotonics, biology, and nanomedicine.

The presented hybrid nanosystem represents a promising model and its performance can be further optimized for future applications. In particular, tuning the QD/NP ratio to enhance the amplitude and to make narrower the temperature window of the LCST-related PL switching, as well as modifying the copolymer shell composition to shift the LCST toward physiological conditions.

KEYWORDS: MoS 2, QDs / Au@PEtOx NP nanohybrid colloid, Thermo-responsive polymer, Thermo-induced optical switching, Nanophotonics

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T9-18 E-POSTER

The effect of nanowire formation on the surface of a Si p-i-n structure on their electrical properties

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Silicon nanostructured surfaces in the form of nanoporous layers or arrays of nanowires (NW) are effectively used in the manufacture of various types of detectors, in particular photodetectors based on *p-i-n* structures. Such layers allow for an increase in the effective radiation absorption area at the operating wavelength (which is particularly relevant in the near-IR region, where silicon has low absorption), an increase in the effective path length of radiation within the semiconductor, and a reduction in the surface reflectance.

Here, we have shown that by establishing the optimal depth of the nanostructured layer or the optimal length of the NW located in the doped n^+-region, it is possible to achieve more efficient radiation absorption without significant degradation of the dark current.

The Si *p-i-n* structures with NW were fabricated using diffusion-planar technology according to the process conditions described in [1]. Arrays of NW were formed by metal-assisted etching of silicon substrates in a mixture of hydrofluoric acid and hydrogen peroxide, with prior deposition of silver nanoparticles in aqueous mixtures of $AgNO_3$ and HF. NW with a thickness of 30-40 nm and a length of approximately 200-230 nm were formed in a phosphorus-doped n^+-layer with a thickness of approximately 4.2-4.6 μm. Planar samples were compared with samples containing an array of nanowires.

From the reverse *I-V* characteristics of the structures, it was established that the nanostructured samples nevertheless possessed a slightly higher dark current density: J_d = 78-82 μA/cm^2 for planar structures and J_d = 81-94 μA/cm^2 for nanostructured ones (V_{bias} = −100 V). For both types of samples, the activation energy at low (V_{bias} = −20 V) bias voltages was E_a = 0.56-0.57 eV, indicating the dominance of the generation mechanism of current transport, and at high reverse voltages (V_{bias} = −100 V), the activation energy was E_a= 0.45-0.46 eV, indicating the predominance of the generation mechanism in the space charge region with a contribution from tunneling through localized (trapped) states.

The depth of the donor energy levels (at low voltages) from which thermal generation of charge carriers occurs was $\Delta E \approx 0.14$ eV for the nanostructured sample and $\Delta E \approx 0.18$ eV for the planar sample. The determined energy level depth was $\Delta E \approx 0.2$ eV for the nanostructured sample and $\Delta E \approx 0.18$ eV for the planar sample. A slight change in the dark current without a change in the current transport mechanism indicates only a slight increase in the surface density of traps that induce additional surface generation. The conducted studies indicate the potential effective use of the investigated structures in the production of *p-i-n* photodiodes, which will allow for a significant increase in the detection efficiency and sensitivity of photodetectors with a minimal change in dark current; this is possible provided that NW are formed in the doped front layers.

KEYWORDS: Si p-i-n structures, Nanowires, Mechanism of current transport, Activation energy, Dark current

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T9-19 E-POSTER

Electrical properties of photosensitive heterostructures ITO/n-$ZnFe_2O_4$/n-CdTe

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Thin films of zinc ferrite $ZnFe_2O_4$ obtained by various technological methods are characterized by a band gap $E_g \approx 1.9$ - 2.1 eV [1] and a high transmittance in the spectral region of visible radiation ($T > 60\%$). The E_g values of the films, as well as their optical and electrical properties, determine their use in heterojunctions and heterostructures as front or buffer (when using a front film of transparent conductive oxide) layers.

ITO/*n*-$ZnFe_2O_4$/*n*-CdTe diode structures were fabricated by sequentially depositing $ZnFe_2O_4$ thin films by spray pyrolysis and magnetron sputtering a film of transparent conducting oxide ITO (In_2O_3:Sn) onto the surface of plane-parallel CdTe crystalline plates. *n*-CdTe substrates with a specific electrical conductivity $\sigma = 1.4$ fi^{-1}·cm^{-1}, electron concentration $n = 8.75 \cdot 10^{15}$ cm^{-3}, and Hall mobility $\mu_H = 1000$ cm^2 ·V^{-1}·s^{-1} (at $T = 300$ K) were used. The resistivity of *n*-$ZnFe_2O_4$ films was $\rho \approx 10^6$ fi·cm.

The diode properties of the structures are confirmed by the high current rectification ratio of ~ $2 \cdot 10^5$ at $T = 296$ K and $|V| = 1.0$ V. The analysis of *I-V*-characteristics measured in the temperature range $T = 296$ - 341 K was carried out taking into account the profile of energy bands of the ITO/*n*-$ZnFe_2O_4$/*n*-CdTe heterostructure. It has been established that the energy barrier that determines the electrical properties of the heterostructure is formed in the near-surface region of *n*-CdTe. According to the estimate by extrapolation of the straight branches of the *I-V*-characteristics to the voltage axis, the barrier height $q\varphi_b = 1.1$ eV. A high value of $q\varphi_b$ leads to the formation of an inversion layer in *n*-CdTe, the presence of which significantly affects the current transfer mechanisms in the studied structures.

In the range of forward voltages $3kT/q < V < 0.6$ V in ITO/*n*-$ZnFe_2O_4$/*n*-CdTe heterostructures, the recombination mechanism of current transfer with the participation of deep levels in the middle of the CdTe band gap E_C - 0.63 eV dominates. A decrease in the barrier thickness with a further increase in the forward voltage causes electron tunneling from the CdTe conduction band into the conduction band of the $ZnFe_2O_4$ film. The determined tunneling activation energy is $\Delta E_t \approx 0.3$ eV, and it can be interpreted as the energy of the level in the conduction band of CdTe from which tunneling occurs $\Delta E_t = E_t - E_C \approx 0.3$ eV. At reverse biases - 1.3 V < V < - $3kT/q$, the generation of electrons in the space charge region from deep energy levels E_C - 0.56 eV in the CdTe band gap with their subsequent movement into the base region of the structure is decisive. An increase in the reverse voltage above 1.3 V leads to an avalanche multiplication of charge carriers in the strong electric field of the barrier region of the structure. ITO/*n*-$ZnFe_2O_4$/*n*-CdTe heterostructures are photosensitive and promising for use as visible radiation sensors.

KEYWORDS: Heterostructures, Thin films, ZnFe 2 O 4, Mechanism of current transfer, Photosensitive

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T9-20 POSTER

Geometry-driven temporal signal encoding in TiO_2 gas sensors for neural network integration

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TiO_2-based gas sensors are typically evaluated using scalar electrical parameters, such as resistance-based metrics or steady-state response at a given gas concentration. However, such scalar approaches inherently discard a significant portion of the information encoded in the temporal evolution of the sensor signal [1], [2].

This work introduces a geometry-driven interpretation of TiO_2 gas sensing, in which the sensor output is reinterpreted as a dynamic signal rather than a single measurement value. Nanostructured TiO_2 sensing elements with systematically varied contact and active-area geometries were designed and fabricated using electron-beam lithography. The use of electron-beam lithography enables the formation of submicron-scale structures and provides a pathway for systematic control of geometrical parameters, enabling controlled investigation and optimization [3].

Here, geometry is treated as a dual-function parameter that simultaneously defines the effective sensing area and modulates the kinetics of gas interaction processes, including adsorption, desorption, diffusion, and charge transport [3], [4]. As a result, different geometrical configurations can generate distinct temporal electrical signatures under identical gas exposure conditions.

Experimental measurements were performed for hydrogen in the concentration range of 50-10,000 ppm under controlled temperature conditions. The analysis focused on transient response characteristics, recovery behavior, and overall signal morphology. The results demonstrate that geometrical variations lead to reproducible and systematic differences in dynamic signal profiles, including cases where steady-state metrics fail to distinguish between sensor configurations.

To interpret these observations, a geometry-informed representation of the sensor response is proposed. This approach links structural parameters with steady-state and dynamic signal characteristics and enables the transition from scalar outputs to multidimensional feature vectors derived from temporal signal evolution. Within this framework, a sensor array composed of geometrically diverse elements can be interpreted as a hardware-defined feature extraction layer for subsequent neural network processing. Instead of assigning each sensor to a single input variable, the time-dependent responses themselves form the feature space for subsequent data analysis [2], [5]. The presented concept establishes a direct link between sensor design and data representation, enabling the co-design of sensing structures and machine learning models and opening a pathway toward gas sensing systems where nanostructured geometry directly encodes information for AI-based classification at the sensor level.

KEYWORDS: TiO_2 gas sensors, Hydrogen detection, Dynamic response, Temporal signal encoding, Neural networks

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T9-21 POSTER

Extending the measurement range and accuracy of MagLev density systems through off-center imaging

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Magnetic levitation (MagLev) based applications are utilized across diverse fields, including industrial engineering, materials science, and biochemistry, due to their ability to enable contactless manipulation of organic and inorganic materials. Density measurement is one of the key applications of MagLev, which is based on determining density from the levitation height of diamagnetic or paramagnetic objects within a paramagnetic or diamagnetic fluid. Permanent magnet-based MagLev systems offer several advantages, including the ability to measure the density of one or more samples simultaneously, label-free measurement, and portability.

Rectangular prisms and cylindrical-shaped magnets with the same poles facing each other can be used in MagLev density measurement systems. However, especially in rectangular magnet geometries, magnetic levitation measurements are generally taken around the central symmetry axis of the magnets. On this central axis, aligned magnets generate a magnetic force primarily opposite to gravity, while other magnetic field components cancel due to symmetry. Accordingly, when the measurement axis shifts from the central axis, other components become non-zero, which changes the magnetic field gradient and thus the force. From another perspective, when measurements are taken only on the central axis, the number of samples that can be measured is limited due to the limited range of the imaging system. By considering these issues, it has been shown that shifting the measurement region from the central axis toward the edges increases both the number of measurable samples and the measurement accuracy by accounting for off-axis magnetic field components.

To theoretically analyze off-center measurements, magnetic field components were calculated for Anti-Helmholtz geometry magnets, and a measurement system was developed. A capillary tube placed between two rectangular magnets, an illumination module, a microcontroller with custom-designed Python-based software, an HQ camera with a lens, and a translation stage were utilized to develop the system. The camera system was shifted from the central axis toward the edges of the magnets, and the positions of microparticles with known densities were recorded.

Particles with an average density of 1.09 g/mL within an 82.5 mM Gadovist paramagnetic solution were used to confirm the theoretical calculations. A total of 297 samples were investigated while the system was laterally shifted by 21.5 mm from the central axis. The results indicate that, when only the magnetic forces along the central axis are considered, the maximum observed deviation was found to be in line with the theoretical calculations and was around 1 kg/m3. The maximum theoretical deviation found for different densities was 4.55 kg/m3.

KEYWORDS: Maglev, Magnetic field of rectangular magnet system, Density measurement, Magnetic levitation

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T9-22 E-POSTER

Electrochemical formation and sensory properties of polypyrrole/Ti_2AlC nanocomposite films

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Polypyrrole (PPy) is one of the most widely studied conducting polymers due to its high electrical conductivity, environmental stability, and biocompatibility, enabling a broad range of practical applications, including corrosion protection, energy storage systems, biomedical technologies, and sensing devices [1-3]. Electrochemical deposition is a well-established method for fabricating PPy thin films. This technique enables precise control over the thickness and morphology of the resulting polymer layer by adjusting parameters such as the applied potential and deposition time. MAX phases, particularly Ti_2AlC, are a class of highly conductive layered materials characterized by a unique combination of metallic and ceramic properties. Owing to their structure, which consists of strong Ti-C bonds and relatively weaker Ti-Al bonds, these materials exhibit high electrical conductivity, excellent thermal and mechanical stability, and oxidation resistance. Despite these advantages, the influence of MAX phases on the properties of conducting polymers remains poorly explored. The present work aims to establish the conditions for the electrochemical deposition of PPy/Ti_2AlC nanocomposite films onto optically transparent semiconductor electrodes and to study their sensing properties.

The PPy/Ti_2AlC composite films were fabricated on glass substrates coated with a semiconducting SnO_2 layer using cyclic voltammetry. It was established that monomer electrooxidation occurs at 0.7 V vs. Ag/AgCl and results in the formation of uniform polymeric films. At -0.4 V, a cathodic peak appears, the intensity of which increases with the number of scan cycles, probably due to charge-accumulation processes driven by MXene-like layers, which increase electrical conductivity and the specific surface area of the composite films. The sample morphology was examined by scanning electron microscopy, while surface elemental analysis confirmed the incorporation of Ti_2AlC into the polymer matrix. Compared to pristine PPy films, the PPy/Ti_2AlC nanocomposites exhibited enhanced optical absorption across the entire spectral range, along with a shift of the absorption maximum from 370 to 450 nm, attributed to π-π^* transitions within the conjugated polymer backbone. It was found that the adsorption of organic solvent molecules significantly changes the surface resistance of the composite film, measured by the two-point method. Moreover, the incorporation of Ti_2AlC particles considerably improves the sensitivity of polypyrrole by 5 times to acetone, and by 16 times to acetonitrile vapors.

KEYWORDS: Polypyrrole, MAX phase, Electrochemical deposition, Resistive sensors

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T9-23 POSTER

Steady-state and high-speed switching behavior of dual silicon nanowire gate-all-around field effect transistors

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We investigate the effects of various dielectric materials on the electronic performance of dual silicon-nanowire (SiNW) Gate-All-Around Field-Effect Transistors (GAAFETs). Building upon our previous research, this study evaluates both direct current (DC) characteristics and high-frequency switching dynamics across different dielectric substrates, including titanium dioxide (TiO_2), tantalum pentoxide (Ta_2O_5), cerium oxide (CeO_2), and aluminum oxide (Al_2O_3). FET structures with multiple active nanowire channels within the same device matrix can deliver higher currents than a single-channel device. Such structures are also relatively easy to fabricate compared to GAAFETs, in which the gate surrounds each individual channel [1]. Experimental results have shown the former structures to demonstrate outstanding performance [2]. Our previous work [3] demonstrated that within small GAAFET structures with 2 SiNWs as the active channels, and with gate-lengths of 50 nm, dielectric radius of 25 nm, and the edge-to-edge distance between the nanowires ranging from 5 nm to 10 nm, there is a substantial gain in overall drain current compared to a single SiNW channel. However, the gain is less than twice, and decreases with decreasing distance between the SiNWs. This is because the electronic coupling between the channels shields the gate, thereby reducing gate control.

An ensemble Monte Carlo (EMC) simulation of electron transport [3] serves as the basis for determining the device structure's electronic response. The EMC simulation uses a calculated band structure based on empirical Tight-Binding (TB). The lowest 4 conduction subbands are used within the EMC simulation. Electron-phonon scattering rates, through longitudinal acoustic and optical phonons, are calculated using first-order perturbation theory and Fermi's Golden Rule. These calculations also include inter-subband electron transfer.

The impact of multiple active SiNW channels within a shared dielectric matrix in a GAAFET configuration has been systematically examined. Although the aggregate drain current in this multi-channel architecture exceeds that of a single SiNW channel GAAFET, the channels exhibit substantial electrostatic coupling, resulting in lower current levels than isolated SiNW channels operating within independent GAA structures.

KEYWORDS: Gate-All-Around transistor, Field-Effect-Transistor, Silicon nanowire, Electron-Phonon scattering, Ensemble Monte Carlo

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T9-24 E-POSTER

Luminescent hydrogen peroxide sensor based on oxygen-deficient TbO_2-x nanocrystals

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The development of efficient sensors for the detection of reactive oxygen species, particularly hydrogen peroxide (H_2O_2), represents a critical objective in the fields of analytical chemistry and biomedical monitoring [1]. This research focuses on the unique sensory capabilities of oxygen-deficient terbium oxide (TbO_{2-x}) nanoparticles, which offer a promising alternative to traditional rare-earth oxide platforms.

Stable aqueous solutions of these nanoparticles, characterized by an average size of approximately 20 nm and a cubic fluorite-type crystal structure, were successfully produced via colloidal synthesis methods. A key feature of these nanoparticles is the coexistence of terbium ions in both trivalent (Tb^{3+}) and tetravalent (Tb^{4+}) states, with the Tb^{3+} fraction measuring approximately 33% as confirmed by X-ray photoelectron spectroscopy. Under UV excitation, the TbO_{2-x} nanoparticles exhibit characteristic narrow-band luminescence, corresponding to the 4f−4f electronic transitions of the Tb^{3+} ions. The sensory response is initiated upon the addition of hydrogen peroxide, which triggers a significant luminescence quenching, thereby enabling a "turn-off" detection mode. This quenching is primarily driven by the H_2O_2-induced oxidation of Tb^{3+} to Tb^{4+} occurring at the nanoparticle surface. Beyond simple intensity changes, the ratio between the emission bands at 617 nm ($^5D_4 \rightarrow {}^7F_3$) and 544 nm ($^5D_4 \rightarrow {}^7F_5$) demonstrates a linear correlation with the analyte concentration. Such a ratiometric sensing approach provides a built-in calibration mechanism that enhances measurement precision.

The developed sensor is effective across a wide concentration range from 0.25 mM to 400 mM. The adsorption kinetics of H_2O_2 on the nanoterbia surface are most accurately modeled by the Temkin isotherm, suggesting a heterogeneous surface environment with varying adsorption energies. A distinct characteristic of this system is its irreversibility; the luminescence intensity does not recover after the sensing event due to the high standard redox potential of the Tb^{3+}/Tb^{4+} pair (+3.1 V), which prevents the spontaneous back-reduction of the cations.

The use of TbO_{2-x} nanocrystals opens up new possibilities for the creation of luminescent H_2O_2 sensors. Due to the linear dependence of the spectral line intensity ratio on the H_2O_2 concentration, these nanoparticles ensure high measurement accuracy in ratiometric mode, making them promising for use in precision analytical and biomedical systems.

KEYWORDS: Terbium oxide nanoparticles, Hydrogen peroxide, Luminescent sensor, Luminescence quenching, Reactive oxygen species

ACKNOWLEDGEMENTS: This research was supported by National Research Foundation of Ukraine, Grant № 2025.07/0093.

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T9-25 E-POSTER

Dual-mode luminescent sensing of H_2O_2 using Eu^{3+}-doped colloidal nanoceria

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Reactive oxygen species (ROS) play a fundamental role in cellular physiology, acting as both essential signaling molecules and potential agents of oxidative stress [1]. Among various ROS, hydrogen peroxide (HP) has recommended itself as a key biological agent, being a ubiquitous and highly reactive cell signaling molecule that is essential for regulating numerous physiological processes.

The dual nature of HP makes the precise control and monitoring of its concentration imperative. While controlled levels of HP are necessary for normal cell signaling, fluctuating or excessive HP levels are linked to various pathological conditions, necessitating the development of sensors capable of real-time, in situ monitoring in complex biological systems. While organic fluorescent sensors offer high sensitivity, they often suffer from low photostability and irreversibility, which limits their use for tracking these dynamic fluctuations [2]. To overcome these limitations, this study proposes an inorganic sensor based on Eu^{3+}-doped colloidal ceria nanoparticles (CeO_{2-x}:Eu^{3+}), which combine the unique redox activity of nanoceria with the stable luminescent properties of rare-earth ions.

The developed sensor operates in two distinct modes:

1. Turn-off Sensing. The addition of HP leads to the monotonic quenching of both the Ce^{3+} (430 nm) and Eu^{3+} (591 nm) luminescence bands. The quenching of Ce^{3+} is caused by its oxidation to the non-luminescent Ce^{4+} state by HP molecules adsorbed on the NP surface. In contrast, the quenching of Eu^{3+} luminescence is attributed to hydroxyl groups formed during the catalytic decomposition of HP on the NP surface.

2. Ratiometric Sensing. The sensor allows for ratiometric detection by monitoring the ratio between the $^5D_0 \rightarrow {}^7F_1$ (591 nm, symmetry-insensitive) and $^5D_0 \rightarrow {}^7F_2$ (606 nm, symmetry-sensitive) transitions of Eu^{3+}. The $Ce^{3+} \rightarrow Ce^{4+}$ oxidation process reduces the number of oxygen vacancies, which increases the local symmetry around Eu^{3+} ions and subsequently increases the 591/606 nm intensity ratio. The CeO_{2-x}:Eu^{3+} nanoparticles provide a robust, multi-channel platform for HP sensing. The ability to perform ratiometric measurements enhances data reliability by minimizing the influence of environmental factors and equipment settings. Successful testing in cell media confirms the potential of these NPs for real-time HP monitoring in complex biological environments.

KEYWORDS: Ceria nanoparticles, Hydrogen peroxide, Redox activity, Ratiometric sensor

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Track 10

Nanomaterials for Energy and Environmental Technologies

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T10-01 INVITED

Biomimetic interfaces in strain-driven photocatalysis

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Nowadays, polydopamine (PDA) is a rather well-known biomimetic polymer with a vast range of applications. In this talk, I will explain the development of multifunctional catalysts using a mechanism we have termed interfacial temporal control. The research shows that the thickness of a polydopamine coating on zinc oxide tetrapods (ZnOT) determines the material's flexophotocatalytic selectivity, shifting the preference toward either oxidative or reductive pathways. The presentation will provide experimental evidence of a thickness-dependent efficient charge-transfer interface. We will show how a PDA configuration promotes the generation of hydroxyl radicals, which are highly effective at degrading organic pollutants. Conversely, we show that a different configuration functions as a capacitive electron sink. This physical change temporarily decouples the electron and hole pathways, thereby suppressing recombination and increasing hydrogen evolution rates. The presentation will further show that both processes are driven by the photo-flexoelectric effect in ZnOT structures, offering a reliable method for engineering catalysts with programmable selectivity for specific environmental and energy applications.

KEYWORDS: Flexoelectrics, Photocatalysis, Strain-driven, Water-Splitting

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T10-02 INVITED

Learning exciton transport mechanisms in next generation materials from simulation based inference

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Singlet fission (SF) materials, which convert a single absorbed photon into two triplet excitons, are promising platforms for high-efficiency energy conversion, quantum sensing, and next-generation optoelectronic technologies. However, practical deployment remains limited by inefficient triplet transport and extraction, particularly across heterogeneous interfaces and silicon heterojunctions. Quantitative understanding of the microscopic transport mechanisms and kinetic parameters governing triplet motion in realistic SF materials is therefore essential for device optimization.

Learning these kinetic parameters is challenging because the underlying dynamics are highly nonlinear, particularly in the presence of processes such as singlet-singlet annihilation. Existing approaches often rely on spatially averaged measurements or simplified diffusion models that assume Gaussian exciton distributions at all times, limiting their ability to capture the non-Gaussian, multi-mechanism transport dynamics characteristic of SF materials. As a result, current methods provide limited quantitative insight into the microscopic mechanisms controlling triplet mobility and extraction.

Transient absorption microscopy (TAM) offers a direct route to overcome these limitations by enabling spatially and temporally resolved imaging of exciton populations following photoexcitation. In a typical TAM experiment, a tightly focused pump pulse generates singlet excitons that subsequently undergo transport and singlet-triplet interconversion. The resulting dynamics are probed using a time-delayed, co-focused probe pulse raster-scanned across the excitation region. Repeating these pump-probe measurements over a range of delay times produces quantitative, time-resolved maps of evolving exciton distributions.

To interpret these complex dynamics, we will present recently developed Bayesian inference frameworks to systems whose behavior is accessible only through simulation (in other words, whose likelihood can only be numerically reconstructed through simulation), as is the case for non-linear exciton transport in SF materials. In these systems, coupled nonlinear and spatially heterogeneous processes do not admit analytical likelihoods for purposes of inference. Our approach, relying on an adaptation of simulation-based inference (SBI), leverages simulations of candidate transport models and compares them directly with experimental observations to infer posterior probability distributions over model parameters. By recovering posterior distributions directly from TAM data, this framework enables quantitative identification of transport mechanisms and prediction of how perturbations, such as spatial heterogeneity in transport parameters, influence exciton dynamics and triplet extraction even quantifying anisotopic diffusion in perylenediimide crystals for the first time.

KEYWORDS: Transient absorption microscopy, Singlet fission materials, Bayesian inference, High-efficiency energy conversion, Next-generation optoelectronic technologies

ACKNOWLEDGEMENTS: Tanner Scott Volek, Sean Roberts (UT Austin); Bonfilio Nainggolan (ASU)

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T10-03 ORAL

Application of nickel iron layered double hydroxides/activated carbon (NiFe-LDH@AC) composite for preconcentration and removal of Cr and as from water systems

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A nickel-iron layered double hydroxides/activated carbon (NiFe-LDH@AC) composite was synthesised via hydrothermal assisted ultrasonic exfoliation and its structural properties and morphologies were characterised using various analytical characterization techniques. These include transmission electron microscopy (TEM), scanning electron microscopy coupled with energy dispersive spectroscopy (SEM-EDS), Fourier transform infrared (FT-IR) spectroscopy, Brunauer-Emmett-Teller (BET) and X-ray diffraction (XRD). The material was applied as an adsorbent for preconcentration and removal of As and Cr. The target analytes were quantified using inductively coupled plasma optical emission spectroscopy (ICP-OES). Under the optimal conditions, the preconcentration method was validated with respect to linearity, limits of detection (LOQ), accuracy, limits of quantification (LOQ) and precision. The linear ranges were 0.1-150 µg/L and 0.07-100 µg/L for As and Cr, respectively. The precision was investigated in terms of repeatability and reproducibility. The results were expressed in terms of relative standard deviation (%RSD) and the values were less than 5%. The LOD and LOQ ranged from 0.021-0.031 and 0.1-0.07 µg/L for As and Cr, respectively. Finally, the accuracy was validated by successfully analysing spiked samples and the recoveries ranged from 92.6-99.2%. The adsorbent was then explored for the removal of target analytes and adsorption capacities were 102 mg/g and 92.6 mg/g for As and Cr, respectively. The metal ions adsorption was evaluated using kinetics and isotherm models and the results followed pseudo second-order kinetics and Langmuir isotherms. Finally, the removal efficiency for spiked effluent wastewater samples ranged from 89.7-100%.

KEYWORDS: Adsorption, Layered double hydroxide, Wastewater

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T10-04 ORAL

Synthesis and cyclic performance of Al_2O_3, La_2O_3, and MgO stabilized nano CaO sorbents for CO_2 capture

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Carbon capture technologies are increasingly important for reducing greenhouse gas emissions in energy-intensive industries such as power generation, cement, iron-steel, and chemical production [1]. Among high-temperature CO_2 sorbents, CaO-based materials are considered highly promising due to their low cost, high theoretical CO_2 uptake capacity, and ease of regeneration during carbonation-calcination cycles [2]. However, pure CaO sorbents suffer from severe sintering, pore collapse, and surface area loss during repeated cycles, leading to rapid performance degradation [3,4].

In this study, four different sorbent systems, namely CaO, CaO-Al_2O_3, CaO-Al_2O_3-La_2O_3, and CaO-Al_2O_3-MgO, were synthesized via the sol-gel method in order to improve the cyclic stability and structural durability of CaO-based sorbents. The synthesized materials were characterized using X-ray Diffraction (XRD), Scanning Electron Microscopy coupled with Energy Dispersive Spectroscopy (SEM-EDS), Brunauer-Emmett-Teller (BET) surface area analysis, and Thermogravimetric Analysis (TGA).

XRD analyses confirmed the formation of crystalline CaO phases together with calcium aluminate-related structures that contributed to structural stabilization. SEM observations revealed that the incorporation of Al_2O_3 improved particle dispersion and reduced agglomeration compared to pure CaO. It was demonstrated by BET analysis that the supported sorbents possessed higher surface area and improved pore accessibility, facilitating gas diffusion during carbonation.

It was observed from TGA cycling experiments that the modified sorbents exhibited significantly improved CO_2 capture stability compared to pure CaO. Among the investigated materials, CaO-Al_2O_3-La_2O_3 demonstrated the highest cycle stability, whereas CaO-Al_2O_3-MgO showed enhanced resistance against thermal degradation. The findings indicate that the combined use of support materials and stabilizing additives is an effective strategy for improving the long-term performance of CaO-based sorbents for high-temperature CO_2 capture applications.

KEYWORDS: Carbon capture, Solid oxide sorbents, Sol-Gel, Calcium loop

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T10-05 ORAL

Synthesis and optical properties of $CsPbI_3$ perovskite films enhanced by Au and Ag plasmonic nanoparticles

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Cesium-lead-iodide ($CsPbI_3$) perovskite thin films have emerged as highly promising materials for next-generation photovoltaic technologies due to their excellent optoelectronic properties. However, reducing the thickness of the perovskite absorber layer to mitigate toxicity and improve environmental stability often leads to reduced light absorption, particularly in the near-infrared (NIR) spectral range where these films are optically thin. To address this trade-off, we report on the synthesis of photosensitive $CsPbI_3$ thin films integrated with plasmonic metasurfaces comprising Au or Ag nanoparticles of different size and shape. The integration of such plasmonic metal nanostructures into the device architecture is a well-established and highly effective strategy for dramatically enhancing light absorption and carrier dynamics in perovskite solar cells [1].

The plasmonic nanostructures are designed to confine and scatter light at the subwavelength scale by exciting localized surface plasmon resonances (LSPR). In this work, $CsPbI_3$ films with thicknesses ranging from 100 to 300 nm were synthesized and combined with layers of Au and Ag nanoparticles. The optical constants and structural morphology of the fabricated layers were characterized using multi-angle spectroscopic ellipsometry (SE-2000, Semilab).

Our results demonstrate that placing these plasmonic nanoparticles in close proximity to a metal back-contact supports hybrid "gap modes" [2] which strongly localize the electromagnetic field within the photoactive perovskite layer. While Ag, Au spherical nanoparticles provide substantial absorption enhancement in the visible spectrum, the inclusion of nanorods extends this enhancement into the NIR region. Tuning the inter-particle distance, their size, shape and the composition of the plasmonic layer allows for the precise alignment of the LSPR with the absorption edge of the synthesized $CsPbI_3$ material [3]. This integrated architecture offers a robust pathway for developing stable, high-performance perovskite solar cells with significantly reduced active layer thicknesses.

KEYWORDS: Plasmonic metasurfaces, Perovskite solar cells, CsPbI3, Au and Ag nanoparticles, Gap modes

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T10-06 ORAL

Effect of nucleating agents on subcooling and stability of methyl laurate phase change material nanoemulsions

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Phase change material nanoemulsions (PCMEs) are a novel class of thermal fluids developed to simultaneously enhance heat transfer performance and enable latent energy storage functionality [1]. These systems are designed by dispersing submicron-scale droplets of a phase change material within an aqueous carrier fluid [2]. While the formation of finely emulsified droplets is essential for maintaining long-term stability and fluidity, this strategy may also lead to pronounced subcooling of the dispersed phase, which can compromise their thermal effectiveness. As a result, careful optimization of formulation parameters is required to balance dispersion stability and phase transition performance [3].

In this study, PCMEs were formulated using methyl laurate as the phase change material and an ethylene glycol-water mixture as the base fluid. Different dispersed-phase compositions were systematically investigated, including the incorporation of selected *n*-alkanes, fatty alcohols and fatty acids as nucleating agents to enhance colloidal stability and mitigate subcooling effects. The quality of the dispersions was evaluated through dynamic light scattering and zeta potential analyses, confirming good temporal stability of the optimized systems. Differential scanning calorimetry results evidenced that the inclusion of appropriate nucleating agents led to a marked reduction in subcooling, with the methyl laurate/*n*-nonadecane/1-eicosanol combination showing the most favorable phase change characteristics. Additional rheological measurements showed moderate viscosities and mainly Newtonian behavior, supporting the suitability of these nanoemulsions for latent thermal energy storage applications.

KEYWORDS: Phase change material nanoemulsions, Methyl laurate, Nucleating agents, Subcooling reduction, Transport properties

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T10-07 ORAL

Synthesis of starch-based nanoparticles and anthocyanins extracted from ipomoea batatas (l.) lam as a potential pH sensor in alkaline media

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Anthocyanins are natural pigments extensively utilized in the food industry due to their potent antioxidant properties and high colorimetric sensitivity to pH variations. While their role as bioactive additives and indicators in food science is well established, research on anthocyanin-based nanoparticles specifically designed as environmental biosolutions remains remarkably scarce. This gap limits the development of sustainable, plant-derived tools for monitoring complex ecological and industrial systems.

Here we demonstrate that biodegradable nanostructures based on native and acetylated starch can successfully encapsulate anthocyanins extracted from Ipomoea batatas (L.) Lam, enabling the creation of robust nanostructured environmental sensors. By employing ultrasound-assisted extraction and multi-stage synthesis, we developed formulations that capitalize on the high concentration of stable diacylated peonin and cyanidin derivatives found in this specific sweet potato variety. Our results show that modified starch matrices significantly enhance the stability of these phenolic compounds by reducing aggregation and preserving chromatic intensity. The resulting particulate materials, composed of nanoparticle clusters smaller than 200 nm, exhibit a precise and reproducible colorimetric response across different pH levels. These findings establish that starch-based nanomaterials can successfully overcome the traditional stability barriers of natural pigments while maintaining their functional sensing capabilities.

Spectroscopic analysis using Raman and FTIR techniques allowed the identification of structural and chemical differences among native, gelatinized, and acetylated starch samples, both in the presence and absence of anthocyanins. Acetylation introduced characteristic ester groups, evidenced by the C=O band around 1735 cm^{-1}, together with a decrease in the intensity of the -OH group. These results confirm the chemical substitution of starch and its improved compatibility with anthocyanins, favoring a more stable encapsulation. In turn, gelatinization caused the disruption of starch crystallinity, facilitating the physical encapsulation of the pigment through the formation of hydrogen bonds. The presence of aromatic bands around 1600 cm^{-1} and the displacement of the -OH group corroborate the pigment-matrix interaction.

Consequently, this study provides a foundation for the development of sustainable, multifunctional colorimetric systems. Furthermore, these bio-based nanostructures offer a promising pathway for the creation of smart materials and optical sensors for environmental monitoring and agro-industrial applications.

KEYWORDS: Anthocyanins, Acetylated starch, Nanoencapsulation, Colorimetric response, Environmental pH sensors

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T10-08 ORAL

Unlocking the photocatalytic potential of semiconductor metal oxides using octahedral molybdenum clusters

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Several metal oxide-based materials, such as nanostructured titania (TiO_2) or ceria (CeO_2), have been established as materials potentially suitable for the remediation of contaminated waters.

One of the reasons for their applicability is their properties as photocatalysts, functioning as such due to their unique structural (e.g., abundance of surface hydroxyl groups, structural defects) and physical/electronic (e.g., sufficient band gap width) features. [1,2]

However, real world applications of these materials still face several issues, mainly due to their insufficient ability to absorb visible light, leading to their use primarily under UV light irradiation, making their real world use economically and practically difficult. [3]

This research deals with the modifications of metal oxide photocatalysts using octahedral molybdenum clusters, which are phosphorescent dyes with excellent visible light absorption properties, and the ability to produce reactive oxygen species, mainly singlet oxygen. [4] Composites, using titania and ceria, with a variety of different molybdenum clusters were prepared using simple and cheap synthesis methods, ensuring fast and highly reproducible fabrication process.

The composites were tested on model phenolic compounds (phenol, BPA, BPS), as well as microplastics. They exhibit superior ability to remove and decompose pollutants in water under visible light irradiation, owing to dye sensitization, which promotes efficient energy transfer and prolonged electron-hole separation. Synergistic functionality between several produced reactive oxygen species (hydroxyl radicals and singlet oxygen), is also shown to play a significant role. The results presented demonstrate that cluster-modified metal oxides offer a highly efficient, sustainable pathway for solar-driven wastewater remediation, moving advanced photocatalysis closer to viable large-scale environmental applications.

KEYWORDS: Titania, Nanoceria, Molybdenum clusters, Photocatalysis, Dye sensitization

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Posters

T10-09 **POSTER**

Solar-activated green synthesis of bio-capped silver nanostructures for environmental and antibacterial applications

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This study presents a sustainable solar-activated green synthesis of silver nanostructures using a biomass-derived extract as a dual-function reducing and stabilizing agent. Green synthesis of metal nanoparticles has emerged as a promising alternative to conventional chemical methods due to its environmental compatibility, low cost, and reduced toxicity [1]. Under natural sunlight irradiation, photoactive phytochemicals undergo excitation, generating electrons that facilitate the reduction of Ag^{+} ions into metallic Ag^{0} without the need for external reducing agents or energy-intensive processes [2].

The formation of silver nanostructures was confirmed by a characteristic localized surface plasmon resonance (LSPR) band centered at approximately 450 nm, consistent with previously reported Ag nanoparticle systems [3]. Photoluminescence (PL) analysis revealed significant fluorescence quenching, indicating efficient interfacial electron transfer between excited phytochemicals and the nanoparticle surface [4]. Fourier transform infrared (FTIR) spectroscopy further demonstrated the involvement of oxygen-containing functional groups in both reduction and stabilization processes, confirming the dual role of the biomass extract [5]. Transmission electron microscopy (TEM) analysis showed predominantly spherical nanoparticles with average sizes in the range of 25-35 nm, which is favorable for high surface reactivity and biological interaction [6].

The synthesized nanostructures exhibited strong broad-spectrum antibacterial activity against both Gram-positive and Gram-negative bacteria, in agreement with the well-established antimicrobial properties of silver-based nanomaterials [2],[6]. In contrast, the extract alone showed negligible antibacterial effect, confirming that the activity originates from the formed nanoparticles.

Overall, this work demonstrates an eco-friendly and scalable strategy for the synthesis of functional nanomaterials and provides direct insight into photo-induced reduction mechanisms. The integration of solar energy with waste-derived biomaterials highlights the potential of this approach for environmental remediation and biomedical applications, aligning with emerging sustainable nanotechnology trends [1].

KEYWORDS: Green synthesis, Silver nanoparticles, Solar-driven processes, Biomass-derived extract, Photoluminescence quenching

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T10-10 E-POSTER

Multifunctional composite including inorganic nanoparticles for modifying polymer microporous filtration membrane

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The performance of commercial polymer membranes: for microfiltration and ultrafiltration of the liquids of technical and biological origin is complicated by low permeate flux down to the stop of filtration process, and by long-time regeneration of the membrane systems, which requires a considerable amount of reagents and pure water for rinsing. These problems are caused by low hydrophilicity of commercial membranes made of PVDF, PES, ePTFE, since organic substances and microorganisms adhere to hydrophobic material causing its fouling. Polymer membranes to foul can be overcome by their modifying with inorganic nanoparticles - they perform hydrophilizing function so far as hydration shells around them prevent undesirable adhesion. Main approaches: (i) blending the solution of polymer with preliminarily synthesized inorganic nanoparticles followed by the membrane formation, (ii) attaching preliminarily synthesized nanoparticles to the surface of preliminarily formed membrane or their embedding into pores, (iii) synthesis of nanoparticles on the surface of preliminarily formed membrane or inside its pores (for commercial membranes, the directions (ii) and (iii) are suitable). Modifying asymmetric membranes containing active layer allows one not only to prevent fouling, but also to ensure the separation ability towards one or other species. There is a problem for symmetric macroporous membranes to fill pores as much as possible in order to provide retention of colloidal species. In this work, we modified macroporous ePTFE membranes with a composite containing polymer (filling pores), nanoparticles of zirconium hydrophosphate (hydrophilizing, enhancement of mechanical durability), silver nanoparticles, (bactericidal activity), advanced carbon nanomaterials (hydrophilizing, enhancement of AgNPs activity), the combinations of directions (ii) and (iii) were used. To facilitate modifying, the membranes were preliminarily treated with synthetic (polyethyleneimine, acetylacetonate zirconium complex) and natural agents (collagen, polysaccharides, particularly with those generated by bacteria), as a result, the water contact angle decreased from >90^{o} down to 20^{o}. The membranes demonstrate cut-off against bovine serum albumin, ovalbumine and lactalbumine indicating the pore size of <10 nm. The modified membranes show the flux recovery ratio of 50%, the permeability of ≈100 L $m^{-2}h^{-1}bar^{-1}$. It was found the transformation of microfiltration membranes into ultrafiltration materials as well as their stability against fouling and biofouling. The membranes can be applied to the production of multichannel tubular modules, where more massive and fragile ceramic membranes are usually used. The membranes are recommended for water and wastewater treatment as well as for needs of food industry and nanotechnologies. Further development of the work can be directed to the membrane application for the treatments of various solutions of natural, technogenic and biogenic origin.

KEYWORDS: EPTFE membranes, Zirconium hydrophosphate, Silver nanoparticles, Surface modification, Biofouling resistance

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T10-11 POSTER

Tribological evaluation of dynamic friction and durability of resin nanostructured surfaces

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Nanostructures on cicada wings exhibit bactericidal properties [1]; however, their tribological behavior and durability remain unclear [2]. In this study, resin nanostructured surfaces with nanopillar geometries were fabricated by thermal nanoimprint lithography using anodic aluminum oxide (AAO) templates. The dynamic friction coefficient was evaluated under repeated unidirectional sliding (up to 1000 cycles) with varying normal loads, and structural changes after testing were examined by scanning electron microscopy (SEM).

The friction coefficient increased rapidly in the initial stage (0-50 cycles), followed by a gradual increase, regardless of nanostructure shape and height, indicating that the initial increase is governed by changes in contact conditions. Although some nanostructured surfaces exhibited lower friction coefficient than that on a flat surface under certain conditions, no consistent dependence on geometry was observed [3]. SEM observations revealed tip deformation without significant fracture, indicating sufficient durability.

These results demonstrate that friction behavior is governed more by contact conditions and deformation than by nanostructure geometry.

KEYWORDS: Nanostructured surface, Dynamic friction coefficient, Tribology

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T10-12 E-POSTER

The influence of finishing chemical treatment on the formation of a nanostructured surface of InSb substrates

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Indium antimonide InSb is an important narrow bandgap semiconductor for infrared optoelectronic devices, high sensitivity sensors, and related electronic applications. The performance and reproducibility of InSb based devices depend strongly on the quality of substrate surface preparation. Surface defects, residual damage, crystallographic anisotropy, and insufficient control of the final polishing stage can limit device fabrication and degrade functional properties. Therefore, controlled chemical treatment of InSb substrates remains an important technological problem.

This work investigates the influence of finishing chemical treatment on the formation of ultra smooth InSb surfaces with different crystallographic orientations. Particular attention is given to iodine containing etching compositions based on I_2 and HI. These solutions are considered as an alternative to I_2 based methanol etchants because they provide stable polishing behavior, long storage stability, and improved process controllability. Chemical dynamic polishing and chemical mechanical polishing were compared as finishing treatments for InSb substrates with (111)A, (111)B, (110), (100), and (211) orientations.

It was found that I_2 and HI etching compositions produce a polishing effect on all investigated InSb orientations. Atomic force microscopy showed that chemical dynamic polishing is suitable as the final treatment stage for InSb (111), (110), and (100) substrates, whereas chemical mechanical polishing is more effective for substrates with (211) orientation. The minimum polishing rate was obtained for an etching mixture containing 3 mass.% iodine, which enabled controlled and uniform material removal. Depending on crystallographic orientation, the arithmetic average roughness Ra after finishing treatment was in the range of 0.43 to 1.06 nm.

The results show that optimized I_2 and HI based finishing treatment enables uniform removal of thin damaged surface layers and formation of mirror like InSb surfaces with controlled nanorelief. Such surface preparation is important for the fabrication of next generation InSb optoelectronic and infrared sensor devices.

KEYWORDS: Ultra-smooth surface, Crystallographic orientation, Indium antimonide (InSb), Chemical polishing

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T10-13 E-POSTER

Performance evaluation of TiO_2-water nanofluid in nuclear power plant spent fuel pool heat exchangers

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Ensuring an efficient and stable heat exchange process of nuclear power plant (NPP) systems is a critical aspect of safety during NPP operations. To improve it, it is proposed to use TiO_2 nanofluid as a heat carrier in spent fuel pool heat exchangers TG(11-13)W_{01}. Adding nanoparticles to the base fluid enhances its thermal properties, but increases viscosity, therefore increasing hydraulic resistance and required pumping power. This work investigates the expediency of using TiO_2-water nanofluid in TG(11-13)W_{01} heat exchangers by comparing specific pump power as a function of the heat transfer coefficient (N(α)) for different TiO_2 volume fractions (φ).

The thermophysical properties of nanofluid were calculated for nanoparticle volume fraction ranging from 0.2% to 0.8%, and velocities 1.5 - 2.1 m/s, with maximum heat exchanger operating temperature of 70 °C. The dimensions of the heat exchanger under study were adopted from operating typical prototypes. The properties of base fluid and nanoparticles were calculated using data fitting curves proposed in the following references [1, 2], the nanofluid properties were calculated as proposed [1, 3, 4]. The Nusselt number of nanofluid was calculated using B. S. Petukhov's equation [5].

The results show an increase of the heat transfer coefficient on the whole studied range of volume fraction and velocity, with a peak at φ = 0.6%. However, by comparing N(α) curves, it was found that the most efficient volume fraction considering pressure losses due to increased viscosity, is φ = 0.4%. The results of this theoretical research can be used to intensify heat exchange efficiency in operating NPP spent fuel pool heat exchangers without significant design changes, or decrease required pumping power and electricity usage, while maintaining same heat exchange rate. All the modifications must take the increased price of heat exchange nanofluid into consideration.

KEYWORDS: Heat transfer nanofluids, Nuclear spent fuel pool heat exchanger, TG11W01 heat exchanger, TiO 2, Heat transfer enhancement

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T10-14 E-POSTER

Nanostructured montmorillonite-based sorbents for uranium removal: Role of activation sequence and surface modification

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Nanoscale architecture of layered clay minerals provides a versatile platform for tuning surface properties and functional performance in environmental applications. In montmorillonite-based systems, the sequence of chemical and physicochemical treatments governs the modification of native layer organization, defect density, and interlayer accessibility, which ultimately control sorption behavior toward uranium species.

This study presents a comparative analysis of uranium sorption by montmorillonite subjected to two distinct modification routes: (i) acid activation followed by surfactant modification, and (ii) surfactant-modified montmorillonite subsequently treated by mechanical activation. Although both approaches involve chemical and physicochemical transformations of the clay structure, they generate fundamentally different surface states and sorption environments.

The first approach, involving acid activation followed by surfactant functionalization, produced a material with enhanced surface area and a transition from cation-exchange behavior to effective uptake of anionic and neutral uranium species. This system exhibited stable performance under highly mineralized water conditions (up to 12 g/L), with sorption well described by a Langmuir-type mechanism indicating relatively uniform active sites.

In contrast, the second approach, based on high-energy mechanochemical activation of organo-modified montmorillonite, resulted in pronounced structural disorder, delamination, and defect generation, while preserving surfactant-induced surface functionality. This synergistic combination led to a substantial increase in sorption performance, reaching nearly an order of magnitude higher uranium uptake. This reflects the formation of energetically heterogeneous adsorption sites governed by both surface complexation and electrostatic interactions. Sorption in this case was best described by Freundlich and Temkin models, confirming a multi-site and energetically diverse adsorption system.

The results demonstrate that treatment sequence-controlled nanostructuring of montmorillonite enables targeted tuning of uranium sorption mechanisms. This approach provides a flexible platform for designing clay-based nanomaterials for reactive barriers, water treatment systems, and engineered environmental protection technologies.

KEYWORDS: Layered nanomaterials, Treatment sequence, Sorption mechanisms, Surface defects, Uranium removal

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T10-15 E-POSTER

Carrier recombination in inorganic $CsPbI_3$ perovskite nanocrystals

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All-inorganic $CsPbX_3$ (X=Cl, Br, I) perovskites have emerged as a compelling solution to well-known stability problem. By replacing the organic cation with cesium Cs+, $CsPbI_3$ provides an inorganic lattice framework that is significantly more robust against thermal degradation. Moreover, with a bandgap of ~1.73-1.80 eV, $CsPbI_3$ possesses a near-ideal bandgap for tandem solar cell configurations (as the top layer) and for intermediate-band photovoltaics.

$CsPbI_3$ nanostructures were synthesized using a modified hot-injection method, which is known for producing high-quality and size-monodisperse all-inorganic nanocrystals. Cesium oleate, prepared by dissolving cesium carbonate Cs_2CO_3 in cyclohexanone and oleic acid, and lead iodide PbI_2, dissolved in octadecene with oleic acid and oleylamine under vacuum and heated at 120°C, were the precursors. The PbI_2 precursor was heated to 160°C under argon before the cesium oleate was rapidly injected. The solution was immediately quenched in an ice bath to stop growth. The resulting nanocrystals were purified by several cycles of centrifugation in cyclohexane, and finally dispersed in cyclohexane.

Optical measurements were carried out at room temperature (295 K) in an ambient atmosphere using a FS_5-SS v2 Spectrophotometer. The emission was collected at 700 nm and detected by a single photon counting photomultiplier in temperature stabilised housing (PTM-980).

Our steady-state room temperature PL and PLE results reveal a narrow emission peak centered at 1.77 eV, which is nearly resonant with the band-edge absorption. The extremely small Stokes shift observed (<10 meV) is indicative of the small number of trap states in band gap energy region. This high spectral purity, combined with a Full Width at Half Maximum (FWHM) of less than 35 nm, positions $CsPbI_3$ as an exceptional material for high-definition light-emitting diodes (LEDs) and efficient intermediate-band solar cells. Furthermore, time-resolved photoluminescence (TRPL) measurements demonstrate a multi-exponential decay profile over a large temporal range. We interpret these dynamics through a rigorous tri-exponential recombination model, extracting individual lifetime components (τ_1=83.2 ns, τ_2=257.2 ns, and τ_3=674.2 ns). These components collectively suggest a high crystalline quality with effective suppression of surface defects and long-lived carrier states, supporting high efficiencies.

Obtained results demonstrate that the fully inorganic $CsPbI_3$ framework can deliver exceptional optoelectronic performance. The remaining challenge now is practical phase-stabilization of the active black α-phase, as well as the optimization of thin-film processing, to translate these high material-level efficiencies into robust, stable, and high-performance devices. Future research should prioritize advanced passivation techniques to further suppress the surface defect-related decay component (τ_1) and enhance the longevity of the active phase

KEYWORDS: Perovskites, Photovoltaics, Nanocrystals, Photoluminescence

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T10-16 POSTER

Development of regeneration methods for heterostructured photocatalysts in CO_2 gas-phase reduction systems

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Global climate change is an escalating issue driven by the accumulation of atmospheric greenhouse gases, which calls for an urgent transition toward sustainable carbon management [1]. One of the main aspects of this is the mitigation of CO_2 emissions, which requires innovative technologies capable of converting the highly stable CO_2 molecule into higher-value chemical compounds, such as methanol and formic acid [2]. Photocatalysis has been presented as a particularly promising strategy, using solar energy to facilitate catalytic CO_2 reduction under ambient conditions. However, the long-term industrial viability of these catalysts is often impeded by rapid deactivation and diminishing efficiency over time. Addressing these limitations through effective photocatalyst regeneration is therefore critical to maintaining high catalytic performance and ensuring the economic feasibility of solar-to-fuel conversion technologies.

Previously, our group has utilized different nanostructured heterostructures fabricated from metal oxides, chalcogenides, and carbon nanotubes for photocatalytic CO_2 reduction. Contrary to most research, where photocatalysis is realized through a liquid medium, our work has been focused on the photocatalytic processes occurring in the gas phase [3]. The main reason for photocatalyst decay in gas-phase systems is the progressive contamination of the material surface, often resulting from the strong adsorption of carbon-based intermediates or the accumulation of carbon buildup [4]. These side products block active sites and prevent the catalyst from absorbing incoming light, which in turn lowers efficiency. To counteract this, several reactivation strategies are employed, such as thermal oxidation, solvent extraction, or photo-oxidative cleaning to break down contaminants using light or UV irradiation.

While thermal oxidation is highly effective and fast, higher temperatures risk destroying sensitive nanostructures and inducing phase changes [5]. Similarly, photo-oxidative cleaning offers a convenient approach but is often limited by slow reaction rates and an inability to remove deeply embedded or non-reactive residues. Solvent washing is gentle but requires a tedious drying process and risks potential structural collapse due to capillary forces. For solid photocatalysts in the gas phase, low-temperature thermal oxidation is the easiest method and could generally prove most effective, as it allows for the complete removal of contaminants without the structural damage or extra waste associated with chemical washing.

This study examines the optimization of thermal oxidation as the main regeneration method, balancing the need for complete surface cleaning with the preservation of catalyst morphology. By exploring these potential recovery conditions, this research aims to provide a more practical strategy for maintaining the long-term performance and durability of solid-state photocatalysts in gas-phase environments.

KEYWORDS: Photocatalyst regeneration, CO 2, Reduction, Nanostructured photocatalysts, Metal oxides

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T10-17 POSTER

Boosting the durability and activity of platinum-based cathode catalysts for PEM fuel cells: the role of cerium and cobalt doping on graphene oxide support

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The transition towards a sustainable hydrogen economy involves the development of highly efficient and durable electrocatalysts for Proton Exchange Membrane Fuel Cells (PEMFC). Since platinum (Pt) still remains the commercial catalyst, its high cost and susceptibility to degradation under acid specific operating conditions in PEMFC limit large-scale commercialization. This study investigates a series of mono-, bi-, and trimetalic nanocatalysts (Pt-Co, Pt-Ce, and Pt-Co-Ce) anchored on Graphene Oxide (GO) supports, synthesized via a controlled microwave chemical route. The doping of Cobalt (Co) and Cerium (Ce) aims to modulate the electronic structure of Pt and enhance the catalyst's durability. Cerium, through its Ce_3+/Ce_4+ redox oxygen storage capacity, acts as a sacrificial agent against oxidative stress, while Cobalt promotes the compressive strain on Pt lattices, optimizing the Oxygen Reduction Reaction (ORR) kinetics.

The samples were characterized by TEM, BET and TGA, and the electrochemical performance was evaluated by cyclic voltammetry (CV), linear sweep voltammetry (LSV) and chronoamperometry (CA). The obtained results indicate that the trimetallic Pt-Co-Ce/rGO electrocatalyst exhibits improved electrochemical activity and superior stability for the oxygen reduction reaction (ORR), compared to monometallic and bimetallic materials. In addition, electrocatalysts were also evaluated for the hydrogen evolution reaction (HER), the results indicating that all samples have HER activity and good short-term electrochemical stability under the applied test conditions.

These results highlight the potential of modifying Pt/rGO by controlled introduction of Co and Ce as an effective strategy for improving electrocatalytic activity and stability, contributing to the development of Pt-based materials with superior performance for electrochemical energy conversion applications.

KEYWORDS: PEM fuel cells, Pt-based catalysts, Graphene oxide support, Cerium and cobalt doping

ACKNOWLEDGEMENTS: This work was supported by the project PN 23 15 01 03, Contract No. 20N/2023, Core Program within the National Research Development and Innovation Plan 2022-2027, financed by Ministry of Research, Innovation, Digitization of Romania and by the project RO-HydroHub "Romanian Hydrogen and New Energy Technologies Hub", contract nr. G2025-113330/ 2025, SMIS code: 351358, financed from European funds via the POCIDIF 2021-2027 Program.

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T10-18 POSTER

Ultrasound-assisted biodiesel production from brown grease using WS_2 nanocatalyst

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Abstract

Biodiesel is a promising renewable alternative to fossil fuels; however, the high cost of edible oil feedstocks limits its large-scale implementation[1]. Brown grease (BG), a waste-derived lipid resource, is a low-cost, sustainable alternative, though its high free fatty acid content poses significant processing challenges[2]. This study investigates nanostructured tungsten disulfide (WS_2) as a heterogeneous catalyst for ultrasound-assisted biodiesel production from BG. WS_2 exhibits high thermal and chemical stability, resistance to deactivation, and a layered structure with abundant catalytically active edge sites, enabling enhanced adsorption and accelerated reaction kinetics[3].

The catalyst was characterized and evaluated in simultaneous esterification and transesterification reactions, and key process parameters including temperature, reaction time, catalyst loading, and methanol to oil molar ratio were systematically optimized. Under ultrasonic irradiation at 80 kHz and 100 W, the biodiesel yield increased with temperature, reaching about 74% at 80 °C within 1 hr. Increasing the methanol content further improved conversion, with optimal performance observed at an oleic acid to methanol ratio of 1:141. Catalyst loading studies identified 16 wt. % WS_2 as optimal. Notably, particle size reduction through ball milling significantly enhanced catalytic performance, and under optimized conditions the milled catalyst achieved a maximum biodiesel yield of about 92%.

The enhanced catalytic activity is attributed to the high surface area and tunable electronic properties of nanoscale WS_2, combined with cavitation-induced micro-mixing effects generated during sonication[4]. The proposed approach offers a scalable and economically attractive pathway for waste-to-energy conversion[5]. These findings highlight the strong potential of WS_2-based nanocatalysts for advancing sustainable biodiesel production technologies.

KEYWORDS: Biodiesel, Brown grease, WS_2 nanocatalyst, Ultrasound-assisted reaction, Heterogeneous catalysis

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T10-19 POSTER

Impact of the physicochemical properties of titanium dioxide nanoparticles on the absorption efficiency in rapeseed (brassica napus l.)

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The rapid integration of nanotechnology into the agrochemical sector inevitably increases the risk of metallic nanomaterial accumulation in soil substrates. Titanium dioxide (TiO_2) is one of the most prevalent anthropogenic agents in the environment. Understanding the absorption and transport mechanisms of these particles in plants is critical for assessing ecological risks and the safety of food chains. The aim of this study is to quantitatively and qualitatively evaluate the absorption of TiO_2 nanoparticles by the root system of rapeseed, as well as to analyze the patterns of their systemic translocation into the aerial organs of the plant.

The study was conducted under controlled soil conditions (pot experiment). Plants were exposed to TiO_2 nanoparticle suspensions (particle size 20-50 nm) at various concentrations: 0, 50, and 100 ml/L. The analysis assessed the impact of the nanomaterials on plant physiological parameters and their accumulation dynamics in various plant tissues. The results demonstrate the capacity of Brassica napus L. to absorb TiO_2 nanoparticles from the soil environment. It was found that absorption efficiency is directly dependent on the degree of nanoparticle dispersion and their concentration in the substrate. Despite morphological barriers in the plants, a portion of the nanoparticles successfully migrates through the xylem vessels, reaching vegetative organs.

KEYWORDS: Rapeseed, Brassica napus L, Titanium dioxide, Absorption, Translocation

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T10-20 E-POSTER

Numerical study of the effect of boron on oxygen vacancy stability and migration in ZnO electron-transport layers for perovskite solar cells

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The long-term stability of the ZnO/perovskite interface remains a major challenge for the commercialization of corresponding perovskite solar cells. Oxygen vacancies (V_O) at the ZnO are considered to play an important role in interfacial degradation by introducing trap states and affecting defect-assisted ion migration.

The aim of this study is to theoretically evaluate the effectiveness of interstitial boron (B_i) as a passivating agent for neutral and charged (2+) oxygen vacancies in ZnO. We focus on understanding the formation energetics and stability of defect complexes and the kinetic impact of B_i on vacancy migration. All calculations were performed within the DFT framework using the Quantum ESPRESSO package [1]. The exchange-correlation potential was treated using PBE + U (with U = 7.5 eV on Zn). The CI-NEB method [2] was employed to determine the minimum energy paths and activation barriers for vacancy diffusion.

Our calculations show that boron atoms energetically prefer to occupy sites adjacent to oxygen vacancies, forming stable complexes with a binding energy of -1.6 eV. PDOS analysis indicates that boron doping effectively shifts the vacancy-induced deep levels toward the conduction band edge. Furthermore, CI-NEB results suggest that boron not only electronically passivates defects but also physically "anchors" them in the lattice. Thus, interstitial boron acts as a dual-action stabilizer for ZnO. Interstitial boron provides energetic passivation through defect complex formation and kinetic stabilization by suppressing vacancy migration, making it a promising defect-engineering element for high-stability perovskite-based optoelectronics.

KEYWORDS: ZnO electron-transport layer, Oxygen vacancy migration, Boron doping, Perovskite solar cells, DFT calculations

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T10-21 POSTER

Fe_3O_4 nanoparticles treatment of wheat can reduce the oxidative stress caused by flooding and increased vitality

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The climatic variability result in plants being exposed to multiple abiotic stresses. Flooding is one of the major abiotic stresses affecting crop productivity. Nanoparticles can accumulate in plant roots and tissues and disrupting nutrient uptake, reducing growth. However, some nanoparticles can enhance plant resistance to abiotic stress. Wheat is one of the most important crops in the world. Therefore, the goal of this work was to study effect of Fe_3O_4 nanoparticles on flooding stress resistance in the wheat (Triticum aestivum L.), using as stress markers as a fermentative and nonfermentive antioxidants, and the functioning of photosystem and photosynthetic pigments as a plant vitality indicator.

Four groups of plants were formed: control plants without nanoparticle treatment and flooding, control plants without nanoparticle treatment, but with flooding, plants with nanoparticle treatment with flooding and plants with nanoparticle treatment but without flooding. The plants were cultivated in a Environmental Climate Chamber (Sanyo, Japan) under controlled conditions. Fe_3O_4 NPs were applied daily by watering the plants with aqueous NP suspensions at concentrations of 50 mg/L. To induce flooding stress, the pots were placed in trays filled with water to a level of 2 cm above the substrate surface. The Fe_3O_4 nanoparticles were synthesized using the Massart method. Superoxide dismutase (SOD) was analyzed by spectrophotometry. The concentrations of chlorophyll (Chl a, Chl b) and total carotenoids were determined spectrophotometrically UV-Vis pulse spectrophotometer (DeNovix DS-7, US). Photochemical activity of photosystem II (PSII), as determined through chlorophyll a fluorescence analysis. Chlorophyll fluorescence was measured using Chlorophyll Fluorometer, OS-30p, OPTI-SCIENCES, US. Proteins accumulation was determined by fluorometry (Invitrogen Qubit fluorimeter).It was shown, that in control plants without nanoparticle treatment under flooding, SOD activity increased by 22% compared to the control without flooding but the treatment of plants with nanoparticles reduced the stress caused by flooding by a factor of two, also the carotenoid content in wheat under flooding in the control plants increased by 23% compared to the control without flooding, while in the nanoparticle treatment plants, under flooding the carotenoid content increased only by 15%. The chlorophyll a/b ratio and Fv/Fm was increased in the nanoparticle treatment plant group under flooding conditions, which indicates that nanoparticle treatment under these conditions can contribute stabilization of photosynthetic pigments. Protein accumulation in wheat root of nanoparticle treatment plant group under flooding conditions was increased by 50%.

Fe_3O_4 Nanoparticles treatment of wheat can reduce the oxidative stress caused by flooding and increased protein accumulation and vitality. The results of this study confirm the potential of Fe_3O_4 nanoparticles for practical applications.

KEYWORDS: Crops, Fe 3, O 4, Chlorophyll, SOD

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T10-22 POSTER

Tuning the exceptional reactivity of CeO_2 nanomaterials for decontamination

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Nanocrystalline cerium dioxide (CeO_2, nanoceria) stands out in environmental catalysis [1] due to its unique surface chemistry [2], valence fluctuations (Ce^{3+}/Ce^{4+}), and enzyme-mimicking activities. This work explores the fundamental relations between defect engineering in ceria and its exceptional performance in capturing and destroying highly resilient toxic molecules. By optimizing low-temperature synthesis routes [3], we successfully maximize the density of surface hydroxyl groups and oxygen vacancies, which drive spontaneous hydrolytic and nucleophilic pathways at ambient temperature without external UV illumination. To translate these outstanding powder properties into scalable applications and prevent nanoparticle agglomeration, the engineered CeO_2 was immobilized into polymeric nanofiber matrices via conventional electrospinning and high-throughput hybrid spinning. The fundamental reactivity of the oxide-specifically its phosphatase-like activity-was verified through the rapid nucleophilic cleavage of stable bonds in widely used agrochemicals, such as the insecticide chlorpyrifos and glyphosate formulations (Roundup). Beyond pesticides, the extraordinary versatility of CeO_2 surface sites was proven by the successful degradation of critical emerging pollutants, including sulfonamide antibiotics [4] and sulfonylurea herbicides or chemical warfare agents [3]. Analytical tracking using operando DRIFTS [5] and HPLC/DAD/MS [3,4] demonstrates that the materials achieve simultaneous high-capacity adsorption and immediate chemical neutralization into non-toxic fragments. This study highlights how tailoring the intrinsic defect chemistry of CeO_2-based materials and their integration into fibrous mats offers an interesting solution for advanced water purification.

KEYWORDS: Nanoceria, Nanofibrous membrane, Pesticides, Surface chemistry, Environmental catalysis

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T10-23 POSTER

Engineering CeO_2-based hybrid nanomaterials for dark and solar-driven degradation of emerging water pollutants

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The increasing occurrence of persistent organic pollutants in aquatic environments, including endocrine disruptors, pharmaceuticals, pesticides and herbicides, necessitates the development of advanced materials for sustainable water remediation [1].

Among various semiconductor systems, nanocrystalline CeO_2 has attracted considerable attention owing to its unique redox flexibility, oxygen-vacancy-rich structure, and ability to operate under both illuminated and dark conditions.

Our research focuses on the development of CeO_2-based hybrid nanomaterials designed to integrate photocatalytic activity with intrinsic dark-phase reactivity. Particular attention is devoted to photocatalytically active systems incorporating graphene oxide, g-C_3N_4, Ce-Bi mixed oxides/oxynitrates, metal diborides (MB_2), molybdenum cluster-modified nanoceria and membrane-supported CeO_2 architectures. The engineered heterointerfaces promote efficient charge separation, extend light absorption, suppress electron-hole recombination, and enhance the generation of reactive oxygen species, resulting in improved degradation of organic contaminants under UV and solar irradiation.

Beyond their photocatalytic performance, CeO_2-based materials exhibit a unique capability for pollutant transformation in the absence of illumination. Oxygen vacancies, reversible Ce^{3+}/Ce^{4+} redox cycling, and highly reactive surface sites enable reactive adsorption and catalytic hydrolysis processes that initiate contaminant degradation even under dark conditions. This dual-mode behavior distinguishes ceria-based systems from conventional photocatalysts and broadens their applicability under realistic environmental conditions.

The developed materials were successfully applied to the degradation of bisphenol analogues (BPA, BPS, and BPF), organophosphate esters, sulfonamide antibiotics, and other environmentally relevant contaminants. The results demonstrate that rational engineering of CeO_2-based hybrid interfaces enables synergistic integration of dark-phase catalytic activity and solar-driven photocatalysis within a single multifunctional remediation platform [2-5]. Collectively, these studies demonstrate that rational engineering of CeO_2-based hybrid interfaces enables seamless integration of dark- and light-driven degradation pathways within a single multifunctional remediation platform.

KEYWORDS: Ceria-based hybrids, Dark-phase catalysis, Solar photocatalysis, Reactive oxygen species, Emerging pollutants

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T10-24 POSTER

Nanoceria as molecular scissors: hydrolytic cleavage of environmentally and biologically relevant compounds

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Nanoceria (CeO_2) has attracted considerable interest owing to its unique redox and acid-base properties, high oxygen mobility, tunable surface chemistry and cost-effectiveness. These features make it a versatile material for applications in catalysis, environmental remediation, and nanozyme technologies. In recent years, increasing attention has been paid to its ability to promote hydrolytic bond cleavage under mild conditions. While most studies have focused on the degradation of organophosphorus compounds, including pesticides [1] and chemical warfare agents [2], recent work has shown that amide-containing substrates, such as sulfonamide antibiotics [3], are also highly susceptible to CeO_2-catalyzed hydrolysis, highlighting the potential of nanoceria for selective amide bond cleavage.

In this contribution, nanocrystalline CeO_2 materials prepared by precipitation methods were synthesized and comprehensively characterized using a range of structural and surface-sensitive techniques, with special focus on their acid-base properties and their role in catalytic hydrolysis. We demonstrate that nanoceria is capable of promoting the hydrolysis of various amide-containing compounds, including sulfonylurea herbicides, β-lactam antibiotics, and peptide-based substrates, under ambient conditions and in the absence of any external activation. Particular attention is devoted to establishing structure-activity relationships, elucidating reaction pathways, and understanding the factors governing bond-cleavage selectivity.

The obtained results provide new insights into the catalytic behaviour of CeO_2 towards environmentally relevant pollutants and biologically important molecules. Beyond applications in water treatment, the demonstrated ability of nanoceria to promote selective cleavage of amide bonds opens opportunities for the development of artificial nanozymes and advanced catalytic systems for pharmaceutical and biotechnological processes.

KEYWORDS: Nanoceria materials, Hydrolytic catalysis, Water pollutants, Peptide clevage, Nanozymes

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T10-25 E-POSTER

High-energy processing modification of carbon-containing composites based on light metals for alternative energy

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Today, many areas of nanotechnology are associated with carbon nanomaterials and are focused on the development of advanced materials for various industrial applications, including energy storage and energy conversion systems. However, a number of challenges still hinder the widespread implementation of alternative energy technologies. These include high cost, operational complexity, and degradation of materials used in thermionic energy converters (TECs). Conventional TECs based on refractory metals provide high electron emission current density only at elevated temperatures typical of nuclear reactors or high-temperature combustion environments. Therefore, for broader practical application of direct energy conversion systems, it is necessary to significantly reduce the operating temperature of TEC cathodes while maintaining their electron emission performance to a level achievable using moderate heat sources such as household-scale heat generators or solar concentrators.

This work is devoted to the synthesis and optimization of titanium-based composites with different contents of carbon nanotubes (CNTs). CNTs with a diameter of 18 ± 6 nm were used. The composites were prepared by mechanochemical synthesis, followed by compaction under pressures of 3-4 MPa.

To evaluate the suitability of these materials as cathodes for energy converters, information on the surface state and structure of the investigated materials is required. Laser processing enables controlled modification of surface morphology, defect structure, and electronic properties, which can enhance electrochemical activity, electrical conductivity, and operational stability. Therefore, the samples were subjected to laser annealing at 200 °C, 360 °C, and 400 °C with a holding time of 10 minutes in both vacuum and air atmospheres.

X-ray diffraction analysis revealed that the samples contain α-Ti, titanium oxide, titanium carbide, and carbon phases. With increasing annealing temperature, a decrease in oxide and carbon-related phases was observed, which can be attributed to complex surface processes induced by thermal and laser treatment, including phase transformations and interfacial reactions. Microscopic studies showed significant surface modification after annealing, characterized by the formation of a complex, multicomponent, and non-uniform surface structure.

The obtained results demonstrate that titanium-based CNT composites are promising candidates for cathode materials in low-temperature thermionic energy converters.

KEYWORDS: Ti-carbon nanocomposites, Carbon nanotubes, Titanium powder, Electrophysical properties, Laser annealing

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T10-26 E-POSTER

Evaluating the degree of supercooling in erythritol-based Al_2O_3 and TiO_2 nanofluids

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The use of erythritol as a thermal energy storage material is limited by its susceptibility to pronounced supercooling. Thermograms were used to experimentally study the effect of nanoparticles on this phenomenon. Analysis of the obtained thermograms shows that the addition of Al_2O_3 and TiO_2 nanoparticles, contrary to theoretical concepts regarding the role of nucleators, initially appeared to increase the supercooling of nanofluids compared to pure erythritol. The authors attribute these effects to the influence of nanoparticles on the thermophysical properties of erythritol and an increase in the rate of temperature change during cooling.

The report demonstrates that Al_2O_3 and TiO_2 nanoparticles increase the density, thermal conductivity, and viscosity of erythritol while decreasing its specific heat. These altered thermophysical properties accelerate the cooling rate, leading to greater supercooling.

The authors concluded that a direct experimental study of the degree of supercooling and a simple comparison of supercooling values between the base material and nanofluids are insufficiently accurate, since the cooling process occurs at different rates. At higher cooling rates, nanofluids "pass" the point of equilibrium phase transition faster than stable crystallization centers can form. This effect leads to the false conclusion that nanoparticles are ineffective in reducing the supercooling of erythritol.

An analysis of the dependence of supercooling on the normalized cooling rate showed that this value is actually lower for erythritol-based nanofluids than for the pure substance. The method used for processing thermograms confirms that Al_2O_3 and TiO_2 nanoparticles serve as centers of heterogeneous nucleation. At concentrations of 1.1 % and 1.13 %, the introduction of additives reduces the supercooling value by approximately 5-6 °C. The results demonstrate the effectiveness of using these nanoparticles to initiate crystallization when experimental data is correctly interpreted.

KEYWORDS: Thermal energy storage, Erythritol, Nanoparticles, Supercooling

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Track 11

Nanobiomedical Research and Translational Applications

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T11-01 INVITED

Engineering dynamic nanobiomaterial interfaces for controlled biointeractions and functional stability

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Advances in nanobiomaterials have enabled unprecedented control over biological interactions at interfaces, offering new strategies for regulating cellular behavior and biomolecular function. This presentation provides an overview of our research on the design of dynamic and stimuli-responsive nanostructured systems [1] that modulate interactions between synthetic materials and biological entities. By integrating principles of polymer chemistry, interfacial engineering, and biomolecular stabilization, we develop functional materials capable of selectively controlling adhesion, activity, and stability in complex biological environments.

Key contributions include the development of nanostructured interfaces for label-free manipulation and sorting of particulates [3], as well as nonenzymatic strategies for cell harvesting through decoupling of adhesive and disjoining interactions [2]. In parallel, we explore molecular brush architectures for enhancing the thermal and operational stability of enzymes, enabling robust catalytic performance under otherwise denaturing conditions [4], [5]. These approaches highlight the role of nanoscale architecture and interfacial dynamics in dictating biological outcomes.

Collectively, this work establishes a versatile framework for engineering adaptive biointerfaces with tunable functionality. The insights gained provide new opportunities for applications in biocatalysis, regenerative medicine, and bioseparation technologies, bridging the gap between material design and biological performance.

KEYWORDS: Nanobiomaterials, Stimuli-Responsive interfaces, Biointerface engineering, Enzyme stabilization, Cell-Material interactions

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T11-02 INVITED

"Green" carbon dots and nanohybrides for theranostic application

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Carbon dots (CDs) and their doped nanohybrids are zero-dimensional fluorescent nanoparticles that combine excellent biocompatibility, tunable photoluminescence, and ease of surface functionalization, making them highly attractive for nanobiomedicine. Green synthesis routes using renewable biowastes (coffee grounds, citric acid/urea) and simple solvothermal/microwave-assisted methods further enhance their sustainability while preserving low cost and minimal environmental impact. Recent advances have demonstrated that incorporation of paramagnetic $Gd3^+$ ions into fluorinated or coffee-waste-derived CDs yields multifunctional nanohybrids capable of simultaneous fluorescence imaging and magnetic resonance imaging (MRI) contrast enhancement, while retaining intrinsic photoacoustic, photothermal, and antimicrobial properties.

The key challenge for clinical translation of theranostic nanomaterials remains achieving high biocompatibility and multimodal functionality without toxicity after prolonged exposure. Here we show that "green" $Gd3^+$-doped carbon dots and nanohybrids synthesized from biocompatible precursors exhibit ultrasmall sizes (2-10 nm or 40-80 nm aggregates), strong T_1/T_2 MRI contrast across field strengths, bright multi-color fluorescence, and efficient cellular uptake into nuclei without altering cell viability in 3T3-L_1 and A_{549} lines up to 1 mg/mL. In vivo studies in mice confirmed no significant lethality, normalized hematological and biochemical parameters, and minimal organ histopathology after repeated dosing. When combined with laser irradiation, these nanoparticles significantly slowed Lewis lung carcinoma growth and increased survival by >30 %, while topical application accelerated healing of phosphorus oxide-induced cutaneous burns via antimicrobial, anti-inflammatory, and cytoprotective effects [1].

These findings demonstrate that green-synthesized Gd-doped CDs overcome the toxicity limitations of conventional contrast agents and expand theranostic capabilities beyond imaging to include photoacoustic therapy and wound management. The results advance the development of safe, eco-friendly multimodal nanoprobes and open new avenues for personalized nanomedicine in oncology and regenerative therapies [2].

KEYWORDS: Carbon dots, Therapies, Antimicrobial effects, Hematological and biochemical parameters

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T11-03 INVITED

Cisplatin-crosslinked DNA nanoparticles for radiotherapeutic applications

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DNA nanostructures are promising carriers for multimodal theranostics due to their precise self-assembly and unparalleled functionalization site addressability; however, poor physiological stability remains a significant barrier to clinical translation [1]. In this work, we enhanced the stability of two DNA-based nanostructures: DNA nanoblocks (6x6x64 nt) [2] and condensed ssDNA scaffolds [3]. Both systems were stabilized using cisplatin, which serves as a dual-purpose cross-linking agent and chemotherapeutic/radiosensitizing payload [4]. Structural integrity was verified via Atomic Force Microscopy (AFM) and Transmission Electron Microscopy (TEM), while Inductively Coupled Plasma Mass Spectrometry (ICP-MS) quantified cisplatin loading. Cytotoxic evaluation revealed distinct performance profiles between the two platforms. Cisplatin-cross-linked DNA nanoblocks (CxDN) exhibited pronounced cytotoxicity at nanomolar concentrations in FaDu and MCF_7 cancer cell lines (MTT assay), supported by ICP-MS and fluorescence microscopy showing sustained intracellular platinum retention for up to 96 h. In contrast, fully cross-linked ssDNA scaffolds (CxSS) did not induce significant cytotoxicity in FaDu cells within 24 h. Furthermore, γ-irradiation survival assays demonstrated that both CxSS and CxDN effectively radiosensitized FaDu cells at high doses, whereas MCF_7 cells showed limited sensitization for CxDNs despite similar uptake, suggesting cell-line-specific modulation of radiation response.

In vivo biodistribution of $IRDye_{800}$-labeled CxDN in nude mice showed rapid systemic clearance ($t_{1/2} \approx 30$ min) with predominant accumulation in the liver and kidneys. Persistent ex vivo fluorescence up to 48 h suggests significant tissue retention before hepatobiliary and renal clearance. Overall, while cisplatin cross-linking successfully yields stable, multifunctional nanostructures with potent chemo-radiosensitizing activity, further surface modification is required to extend systemic circulation and improve targeting efficiency for clinical applications.

KEYWORDS: Nanobiomedicine, DNA nanotechnology, Radiotherapy

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T11-04 INVITED

Harmonic response and heat dissipation effects of magnetic nanoparticles for theranostic applications

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The true value of research on magnetic nanoparticles lies not only in fundamental physics but is also in its becoming increasingly evident application to fields with high societal demand, such as diagnostics, medicine, and the environment. Their use as contrast agents in magnetic resonance imaging (MRI) is a prime example of this, with research centered on iron oxide nanoparticles has advancing across the boundaries of materials science, physics, chemistry, and medicine.

In recent years, the biomedical field has been exploring "theranostics," combining diagnosis and therapy [1, 2]. We have found that the nanoparticles we developed function as both diagnostic imaging tracers and as a hyperthermia therapy agents.

In this study, Gd and Zn doped Mn-ferrite NPs with various particle sizes and compositions were prepared using a wet-chemical method. Their local structures were analyzed by X-ray diffraction (XRD) and synchrotron X-ray absorption fine structure (XAFS) measurements. DC magnetization and AC magnetic susceptibility measurements were also performed.

Regarding its diagnostic properties, T_1 and T_2 relaxation measurements revealed that Gd-doped Mn-ferrite functions as an MRI contrast agent, demonstrating its diagnostic properties. To verify its effectiveness as a tracer for MPI, we measured the third-harmonic signal in an alternating magnetic field. Response intensity varied with particle size d. Particles with d = 10 and 14 nm exhibited large responses, which decreased successively for particles for 17 and 21 nm. Particles exhibiting superparamagnetic behavior in the magnetization measurements showed large responses.

Samples of Gd-doped Mn-Zn ferrite with high magnetization and magnetic anisotropy exhibited high signal intensity at low frequencies. However, as the drive field frequency increased, the effect of magnetic anisotropy had a greater effect, and it was confirmed that Gd-doped Mn-Zn ferrite with a particle size of 10.5 nm had a signal intensity approximately 22 times that of the control at a drive field frequency of 48 kHz. For Gd doped Mn-ferrite particles 14 nm or larger, which had a high, heat generation exceeding 42.5°C (315.5 K) -the temperature at which cancer cells die-was confirmed. The heat dissipation rate suggested that samples followed magnetic relaxation loss. This outcome supports their potential as a theranostic material enabling simultaneous treatment and diagnosis.

KEYWORDS: Magnetic nanoparticles, Theranostics, Imaging, Hyperthermia, XAFS

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T11-05 INVITED

Supracolloidal assemblies of gold nanoantennae for biosensing applications

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To date, plasmonic nanobiosensors mainly demonstrate relatively small resonance shifts accompanied with insufficient spectral resolution and peak discrimination, when detecting biomolecules. Addressing these challenges necessitates the development of new strategies and nanoarchitectures to enhance plasmonic performance. In this regard, exploring the self-assembly of varied geometric patterns, nanoparticle clusters, and ordered arrays of plasmonic metal nanostructures or nanoparticles has emerged as a promising solution. These architectures can give rise to additional resonant modes that are highly tunable and exhibit enhanced field confinement, resulting in stronger and narrower resonance signatures than those of single nanoparticles.

In this particular work we report the large area linear periodic assemblies of gold nanoparticles and evaluate their polarization-dependent biosensing performance through proof-of-concept studies. Two complementary fabrication strategies are investigated: (i) laser interference lithography (LIL), which enables high-fidelity patterning over moderate areas, and (ii) wrinkle-assisted patterning, a scalable and cost-effective alternative. Despite differences in structural morphology, both approaches deliver comparable sensing performance, highlighting the versatility and broad applicability of the proposed biosensing platform [1].

Sensor performance is first assessed using glycerol-water mixtures with well-defined refractive indices. Subsequently, the platform is biofunctionalized for the detection of antibodies against Tumor Necrosis Factor-Alpha, a pro-inflammatory cytokine closely associated with cancer progression and prognosis. Plasmonic resonance peak shifts of the AuNP assemblies are monitored throughout the functionalization and detection processes using polarized visible-near-infrared (vis-NIR) spectroscopy.

The results reveal a pronounced polarization-dependent plasmonic response, characterized by significant resonance wavelength shifts (Δλ). In particular, the longitudinal plasmon mode exhibits up to a fivefold signal enhancement compared with the transverse mode, a trend consistently observed for both LIL- and wrinkle-based templates. These findings demonstrate a promising supracolloidal nanostructuring strategy for the scalable fabrication of highly sensitive plasmonic biosensors and biochip platforms.

KEYWORDS: Gold nanoparticles, Plasmonic biosensors, Supracolloidal assemblies

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T11-06 ORAL

Antibacterial application of ZnO, CuO and Y_2O_3 nanomaterials

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More than 35,000 deaths each year in the EU, Iceland, and Norway are attributed to antimicrobial-resistant bacterial infections, highlighting the urgent need for alternative antimicrobial strategies. Unlike antibiotic-releasing coatings, metal oxide nanoparticles (NPs) offer sustained antimicrobial activity without promoting bacterial resistance. Owing to their durability, physicochemical stability, and relatively low cytotoxicity toward human cells, metallic NPs have emerged as promising candidates for antibacterial applications. In particular, CuO and ZnO nanoparticles have attracted significant attention due to their intrinsic antimicrobial properties and biological relevance as essential trace elements [1, 2].

Here, we showed that CuO, ZnO, and Y_2O_3 NPs and multimetal (Cu, Zn, and Y) NPs with different sizes and morphologies exhibit different surface properties and show promising antibacterial activity against Staphylococcus aureus and Escherichia coli. We prepared nanoparticles with various anionic salts of Zn, Cu, and Y, stabilised with tannic acid during synthesis. The NPs exhibited different morphologies and were characterized by different nanoparticle sizes and distributions. The developed NPS exhibited promising antibacterial action against Gram-positive Staphylococcus aureus and Gram-negative Escherichia coli.

Our findings reveal that nanoparticle size, morphology, and surface composition play a critical role in determining antibacterial performance. This study provides valuable insight into the rational design of nanoparticles aimed at enhancing antimicrobial effectiveness. The results establish a foundation for the development of next-generation biocompatible antimicrobial materials for biomedical applications.

KEYWORDS: CuO nanoparticles, ZnO nanoparticles, Y2O3 nanoparticles, Antibacterial application

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T11-07 ORAL REMOTE

Development and characterization of zinc oxide nanoparticles loaded PCL/CMC crosslinked composite films for enhanced in vitro wound healing applications

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Abstract:

Background: Effective wound management remains a significant clinical challenge, particularly for chronic wounds that require a delicate balance of moisture maintenance, structural support, and robust protection against microbial infection [1]. Conventional dressings often fail to provide simultaneous antibacterial action and optimal mechanical properties, leading to delayed healing and increased risk of complications [2].

Objective: This study aims to address these requirements by developing and characterizing a novel composite film integrating Zinc Oxide (ZnO) nanoparticles into a crosslinked matrix of Polycaprolactone (PCL) and Carboxymethyl Cellulose (CMC).

Methods: The fabrication started with the crosslinking process of PCL and CMC using acetic acid, followed by the incorporation of ZnO nanoparticles into the resulting polymer solution. To ensure the homogeneous dispersion of the nanoparticles, the mixture was subjected to probe sonication prior to film casting [3]. The structural and chemical properties were evaluated using X-Ray Diffraction (XRD) and Fourier Transform Infrared Spectroscopy (FTIR). Thermal stability and phase transitions were tested using Thermogravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC). Physical properties were assessed via contact angle measurements and swelling tests, while the therapeutic potential was evaluated through in vitro antibacterial assays, nanoparticle release studies by ICP-MS and MTT assays to evaluate its biocompatibility [4].

Results: XRD and FTIR analyses confirmed successful polymer interaction and the uniform distribution of ZnO nanoparticles within the matrix. Contact angle measurements and swelling tests confirmed that the addition of CMC significantly enhanced the hydrophilicity of the composite film compared to pure PCL, providing a more suitable environment for cell migration. Furthermore, in vitro assays demonstrated potent antibacterial activity against Staphylococcus aureus and Pseudomonas aeruginosa, supported by a sustained release profile of the ZnO nanoparticles [5]. Conclusion: The results suggest that the ZnO-PCL-CMC crosslinked film is demonstrating significant potential in vitro as a highly effective candidate for treating chronic and infected wounds, offering a synergistic balance of mechanical strength, biocompatibility, and superior infection control.

KEYWORDS: Composite film, ZnO nanoparticles, Wound healing, Polycaprolactone, Carboxymethyl cellulose

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T11-08 ORAL

Dual-affinity nanointerface for rapid translational detection of cardiac biomarkers via target-induced shielding mechanism

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Rapid detection of cardiac biomarkers is critical for timely diagnosis and management of acute cardiovascular diseases, however conventional immunoassays often suffer from slow response, limited sensitivity, and low adaptability to point-of-care detection. Herein, we developed a colorimetric assay based on a target-induced shielding at a dual-affinity probe interface for detection of cardiac troponin I (cTnI) and N-terminal pro-B-type natriuretic peptide (NT-proBNP). Both biomarkers are clinically relevant gold standard biomarkers of acute myocardial infarction (AMI) and heart failure (HF) [1-2]. The assay leverages on dual-affinity probe that act as an inhibitor to the enzyme (urease) and have the co-presence on its surface of affinity molecules against biomarkers. Upon addition of target biomarker, the probe selectively binds to it and a shielding layer is formed that renders the enzyme free in solution. Consequently, the activity of enzyme generates a pink-colored end-point for visual detection in <15 min. Comprehensive biophysical characterization using microscale thermophoresis (MST), biolayer interferometry (BLI), and isothermal titration calorimetry (ITC) confirmed strong target-probe interactions and elucidated the shielding mechanism. Importantly, the assay demonstrated negligible interference in complex biological matrices, maintaining analytical performance in MST up to 50% human serum [3]. The platform achieved a detection limit as low as 0.088 ng/mL for cTnI, with high specificity, reproducibility, and recovery in spiked serum. The robustness of assay highlights its translational potential for rapid, visual, and point-of-care cardiac diagnostics, offering a versatile framework adaptable to diverse protein biomarkers in nanobiomedical applications.

KEYWORDS: Dual-affinity probe, Colorimetric assay, Cardiac biomarkers, Point-of-care diagnostics, Probe shielding layer

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Posters

T11-09 E-POSTER

The anticancer properties of metal nanocomposites obtained in xanthan and SiO_2/ polyacrylamide matrices: A comparative study

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Increasing multidrug resistance of tumors is a global health concern. Nanomedicine based on metal nanoparticles and metal nanocomposites is at the forefront of therapeutic strategies aimed at helping to resolve this problem. We aimed to examine the anticancer activity of metal nanocomposites obtained in chemically different polymer carriers: bacterial polysaccharide xanthan (X) and the polymer inorganic hybrid SiO_2/grafted polyacrylamide (H). Methods: The water soluble nanocomposites with long lasting stability were synthesized in situ by $NaBH_4$ reduction and studied using XRD, UV Vis absorbance, FTIR, and TEM methods; their particle size, evaluated by TEM, was within the low nanoscale range of <10 nm. The anticancer activity was examined based on viability testing by the MTT test and the half inhibition concentrations IC_{50}.

As shown, the systems could be separated into three groups with very high, high, and low activity, based on IC_{50}. The dependence of anticancer efficacy on cell type, metal type, and matrix type was found. The Ag and Co systems, AgH, AgX, CoH, and CoX, exhibited very high activity against B_{95}-8 cells, with IC_{50} of 1-6 µg/ml, close to that of anticancer drugs. Wish cells were highly sensitive to AgH, AgX, NiH, and CoH, with IC_{50} of 7-10 µg/ml. AgH and CoX showed low activity for the control MDCK cells, with IC_{50} of 15-20 µg/ml. NiX (IC_{50} of 15-20 µg/ml) was the least active against any cell type. Among the cells, the most sensitive were B_{95}-8, and the least sensitive were MDCK cells, according to the order: MDCK<Wish<B_{95}-8. As we found, the metal activity was critically dependent on the carrier type. Xanthan greatly strengthened the effects of Ag against B_{95}-8 and MDCK cells, but dramatically reduced Ni toxicity for all cell types and Co toxicity against Wish cells. By itself, xanthan was not toxic to any cell type; however, it highly improved Ag efficacy against B_{95}-8 cells and dramatically weakened Ni efficacy against all studied cells. The effects of Co in the xanthan carrier were dependent on cell type. We assumed possible synergism of Ag and xanthan actions in B_{95}-8 cells and antagonism of Ni and xanthan actions in all studied cells.

Based on the experiments, we concluded that in situ synthesis of metal nanocomposites allowed the obtaining of metal nanoparticles in the low nanometer range with high anticancer activity and promise for oncomedicine. The carrier was critical for nanocomposite activity and was capable of either potentiating or abolishing the anticancer effects, while being nontoxic to the cells. The dependence of the observed effects on metal type, cell type, and carrier, and the underlying mechanisms, require detailed studies in future research.

KEYWORDS: Metal nanocomposites, Anticancer activity, Silver and cobalt nanoparticles, Xanthan and SiO2/polyacrylamide matrices, Cytotoxicity (IC50)

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T11-10 POSTER

Evaluation of the effect of protein adsorption on the mechanical bactericidal activity of nanostructured surfaces

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Nanostructured surfaces inspired by cicada wings are known to exhibit bactericidal activity and have attracted attention as novel antimicrobial materials that do not rely on chemical agents. This bactericidal effect is reported to persist semi-permanently as long as the nanostructure remains intact and does not affect human cells, making such surfaces promising candidates for surface modification of medical devices that come into direct contact with the human body. However, under practical biomedical conditions, these surfaces may be exposed to blood and bodily fluids, which may potentially inactivate their bactericidal function. Despite this concern, there have been few studies investigating whether the bactericidal effect is maintained after the adsorption of biological components such as proteins, and this issue remains unclear. In this study, we quantitatively investigated the effect of protein adsorption on the physicochemical property and bactericidal activity of nanostructured surfaces, with the aim of clarifying how protein contamination influences their water contact angles and mechanical bactericidal performance.

In summary, protein (BSA) adsorption markedly altered surface wettability and led to a concentration-dependent reduction in bactericidal activity. Although bactericidal performance was diminished under protein-rich conditions, it was not completely lost, indicating partial retention of mechanical bactericidal functionality. These findings highlight protein adsorption as a critical challenge for the practical application of nanostructured bactericidal surfaces in biomedical devices and suggest that strategies to suppress protein adsorption will be essential for maintaining bactericidal performance in biological environments.

KEYWORDS: Mechano-bactericidal surfaces, Protein adsorption, Nanostructured surfaces, Antibacterial coatings

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T11-11 E-POSTER

Sodium citrate potentiated degradation of $HepG_2$ spheroids by supramolecular nanocomplexes and pharmacological ascorbic acid

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The use of sodium citrate (SCT) to potentiate the antitumor activity of therapeutic agents has attracted increasing attention in recent years. The underlying mechanism is believed to involve enhanced intracellular transport in tumor cells and reduced density of tumor structures.

In the present study, we evaluated the capacity of citrate to augment the cytotoxic efficacy of supramolecular complexes based on orthovanadates or nanoceria and containing menadione (or polyphenols as an alternative quinone source) when combined with pharmacological concentrations of ascorbic acid (AA).The synergistic interaction between AA and nanoceria-based complexes that produces a pan-killing effect had previously been confirmed in both 2D and 3D models of murine L_{929} fibrosarcoma. In the current experiments, this synergy was successfully reproduced in long-term monolayer cultures of $HepG_2$ cells. However, the 3D $HepG_2$ spheroid model demonstrated substantially higher resistance to treatment than L_{929} spheroids, owing to the markedly greater structural density of $HepG_2$ aggregates.

To disrupt the compact intercellular architecture maintained by CaZ^+ ions, citrate was introduced as a specific CaZ^+ chelator. Careful selection of effective citrate concentrations resulted in loosening of the spheroid matrix, followed by progressive degradation during prolonged co-incubation with the nanocomplexes and ascorbic acid.

Furthermore, extended exposure to the citrate-ascorbic acid-nanoparticle system in combination with polyphenols similarly induced $HepG_2$ spheroid degradation, accompanied by sustained cytotoxic activity thereafter.

KEYWORDS: Sodium citrate, Supramolecular complexes, Ascorbic acid, Polyphenols, Spheroid

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T11-12 E-POSTER

Synergistic photoprotective effects of carbon-cerium dioxide nanocomposites on mouse bone marrow cells under UV-a irradiation

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Ultraviolet (UV) irradiation is a cornerstone of photoactivated biomedical technologies; however, it inevitably induces oxidative stress via the generation of intracellular reactive oxygen species (ROS). This results in dose-dependent morphological alterations, metabolic shifts, and diminished cell viability. Consequently, understanding how nanomaterials modulate cellular responses under UV-A exposure is essential for engineering biocompatible, light-responsive systems. This study investigates the photobiological impacts of carbon particles (CPs), cerium dioxide nanoparticles (CeO_2 NPs), and hybrid carbon-cerium dioxide nanocomposites (C-CeO_2 NCs) on mouse bone marrow cells (MBMCs) under controlled 390 nm UV- A irradiation. Our results demonstrate that CPs exhibit concentration-dependent cytotoxicity, with exacerbated phototoxicity at high concentrations, yet significant ROS reduction at lower doses. Conversely, CeO_2 NPs show minimal intrinsic toxicity and robust antioxidant activity, effectively attenuating UV-induced oxidative stress. Notably, the C-CeO_2 NCs exhibit a balanced biological response, integrating the antioxidant properties of ceria with the radical-scavenging and electron-transfer capabilities of carbon to preserve cellular structural integrity. Comprehensive morphological, morphometric, and immunocytochemical analyses of key regulatory markers (p53, p21, Bcl-2, E-cadherin, β-catenin, and Ki-67) reveal that the nanocomposite composition modulates interconnected pathways governing MBMC proliferation, survival, and adhesion.

These findings highlight the potential of carbon-ceria nanostructures as redox-active biomaterials for applications requiring precise photomodulation and cellular protection against photodamage.

Potential fields of application include skin tissue engineering, light-exposed implants, photodynamic therapy, ophthalmic systems, light-responsive drug delivery systems, regenerative medicine, and advanced dermatological formulations.

KEYWORDS: Nanocomposites, Ultraviolet, Photoprotective effects

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T11-13 E-POSTER

Biological potential of 3D printing for bone-replacing implants

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The regeneration of critical bone defects resulting from trauma, oncological resections, or systemic diseases remains a significant clinical challenge due to the limitations of traditional autografting. Modern three-dimensional (3D) bioprinting technology enables the fabrication of customized scaffolds with precise anatomical geometry by combining biopolymers and bioactive inorganic phases. [1, 2] However, the development of biomaterials capable of accurately mimicking the natural extracellular matrix of bone - while providing appropriate mechanical properties and biological cues for regeneration - remains an unresolved issue. Here we show that photochemical crosslinking using riboflavin, combined with the integration of hydroxyapatite, allows for the formation of structurally stable biomimetic collagen matrices. [3] We found that upon UV irradiation, riboflavin initiates the formation of intermolecular covalent bonds within collagen, which increases mechanical integrity and elastic modulus while preserving the native fibrillar architecture of the material. Furthermore, the adaptation of the FRESH methodology in combination with physicochemical stimuli (vacuum degassing, moderate pressure, and controlled thermal modulation) ensured the formation of a composite with a hierarchically organized microstructure. These structural features are critically important for facilitating nutrient transport, cellular infiltration, and effective tissue integration in vivo. [4] We anticipate this approach to be a robust foundation for the development of advanced osteoconductive and osteoinductive biomaterials. Ultimately, the application of such optimized 3D-bioprinted implants holds significant potential for improving clinical outcomes in regenerative medicine and bone tissue engineering.

KEYWORDS: 3D bioprinting, Bone tissue engineering, Collagen-hydroxyapatite composites, Photochemical crosslinking, Regenerative medicine

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T11-14 POSTER

Antioxidant and hemostatic chitosan nanocomposite films modified with quercetin, graphene oxide and microcrystalline cellulose: in vitro biocompatibility assessment

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Natural polymer-based films have attracted considerable attention as biomedical coating materials due to their favorable biological and mechanical properties. Among them, chitosan films have been widely investigated as coating platforms and as wound-healing dressings. In the context of wound repair, polyphenol-modified, chitosan-based composites can further enhance antimicrobial, antioxidant, and regenerative responses, thereby accelerating tissue regeneration [1].

The aim of this study was to assess the toxicity of chitosan-based nanocomposites modified with varying concentrations of quercetin, as well as with graphene oxide and microcrystalline cellulose, towards human erythrocytes, skin fibroblast cell lines, and peripheral blood mononuclear cells (PBMCs), using both direct and indirect contact between the material and the biological models. Furthermore, the protective properties of the composites were assessed using a hydrogen peroxide-induced oxidative stress model. The hemostatic potential of the chitosan films, including their effects on blood clotting and clot dissolution, was also examined.

The results demonstrated that the chitosan films exhibited minimal hemolytic activity toward erythrocytes, at approximately 5%. A similar trend was observed in the context of cellular viability studies, wherein the films exhibited a marginal reduction in cell viability, ranging from 10 to 15%, across all the variants examined. The presence of quercetin resulted in an enhancement of the antioxidant properties of the films, as evidenced by the oxidative stress model. In addition, the chitosan films exhibited hemostatic properties by modulating blood clotting and promoting clot dissolution. These findings suggest that chitosan-based films have potential for use in hemostatic applications and justify further investigation in wound-healing systems. Furthermore, the combination of chitosan with bioactive compounds may yield novel beneficial effects or augment existing ones, thereby optimising patient outcomes and reducing healthcare expenditures.

KEYWORDS: Chitosan nanocomposites, Quercetin-modified chitosan, Graphene oxide, Microcrystalline cellulose, Wound healing

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T11-15 E-POSTER

Activated carbon particles promote mitochondrial dysfunction and apoptosis under nitrosative stress in vitro

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Dietary and environmental exposure to inorganic nitrates (NO_3^-) and nitrites (NO_2^-) significantly disrupts redox homeostasis, promoting oxidative and nitrosative stress. This induces lipid peroxidation, protein tyrosine nitration, and S-nitrosylation of thiol groups, resulting in mitochondrial dysfunction ultimately leading to apoptosis or necrosis depending on exposure severity. In this context, activated carbon particles (ACP) represent a promising nanobiotechnological strategy for mitigating NO_2^-/NO_3^--induced toxicity due to their high surface area and redox-modulating properties.

The study investigates the effects of ACP on mouse aortic endothelial cells (MAEC) treated with IC_{50} doses of NO_2^- or NO_3^-. The results show that the addition of ACP to the MAEC culture medium increased mitochondrial transmembrane potential (MTP) by 2.1-fold and reactive oxygen species (ROS) production by 2.3-fold. Apoptosis and necrosis were assessed by multiparametric flow cytometry using Annexin V and 7-aminoactinomycin D. Early apoptosis increased from a spontaneous level of 4.7% to 20.4% following ACP treatment. Exposure to NO_2^- and NO_3^- alone increased MTP by 2.3- and 2.1-fold, respectively, while ROS production increased by 1.5- and 1.8-fold. Apoptosis levels also rose by 3.8- and 3.0-fold compared to intact cells. Combined treatment with ACP and NO_2^- or NO_3^- showed no additive effects on MTP or ROS production. MTP increased by 2.1-2.2-fold and ROS by 1.7-2.0-fold relative to intact cells. However, combined exposure further elevated apoptosis by 1.5-2.6-fold compared to ACP treatment alone. Notably, necrosis and late-stage apoptosis remained minimal (≤0.43%) across all experimental groups, indicating that NO_2^-/NO_3^- primarily act via regulatory signaling rather than direct cytotoxicity.

Overall, our results suggest that both NO_2^-/NO_3^- and ACP significantly affect cellular stress responses, including mitochondrial function and redox balance, while combined exposure does not confer protective effects and instead enhances apoptosis. Furthermore, these findings indicate that engineered nanomaterials can modulate key stress-response pathways and thereby influence cell fate under environmental exposure conditions.

KEYWORDS: Inorganic nitrates and nitrites, Reactive oxygen species, Mitochondrial transmembrane potential, Apoptosis

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T11-16 E-POSTER

UV-activated (Gd,Y)VO_4:Eu^{3+} nanocrystals as sources of oxygen-independent ROS after external stimuli removal

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The hypoxic microenvironment in solid tumors largely contributes to the failure of PDT in most tumor treatments [1]. Classical PDT relies heavily on the presence of dissolved oxygen to generate cytotoxic singlet oxygen ($^1O_2$), which makes this method inherently ineffective in oxygen-deprived regions of a tumor [2]. To overcome these fundamental constraints, we developed defect-engineered (Gd,Y)VO_4:Eu^{3+} nanocrystals (NCs), that can produce radical species such as •OH through water oxidation after UV pre-irradiation.

These orthovanadate NCs are characterized by a high density of oxygen vacancies [3], that act as metastable traps for photo-generated holes created during UV pre-irradiation. The charge carried by the holes that are trapped does not recombine quickly. Rather, holes escape slowly and are mainly dictated by the process of moving to the particle surface by diffusion. Once reaching the particle surface, the trapped carriers eventually react (after a relatively long period of time since the light has turned off) with a water molecule to produce •OH. Unlike conventional photosensitizers, these NCs facilitate the production of •OH directly from water molecules, ensuring a robust, oxygen-independent cytotoxic mechanism. This unique "memory effect" allows for the sustained generation of radicals long after the initial light stimulus has been removed, providing a sophisticated strategy for treating malignant cells in hypoxic environments where traditional modalities fail.

The pro-oxidative activities of UV-activated (Gd,Y)VO_4:Eu^{3+} NCs were confirmed through several methods, which employed luminescence spectroscopy to monitor the conversion of a coumarin probe into fluorescent 7-hydroxycoumarin as a direct indicator of sustained •OH production. This robust oxidative capacity in aqueous environments was further highlighted by tracking the accelerated oxidation of ascorbic acid, which showed a significant loss and depletion in the presence of the pre-irradiated NCs. Finally, lipid oxidation analysis of phosphatidylcholine suspensions demonstrated significant oxidative damage through the formation of conjugated dienes, further validating the ability of the activated NCs to trigger radical chain reactions.

The defect-engineered NCs can produce efficient radicals independent of the continuous light supply and dissolved oxygen and therefore allow the creation of highly innovative strategies to treat malignant tissues within hypoxic environments that have always represented the fundamental limitations associated with the classical methodology of PDT.

KEYWORDS: Pro-oxidative activity, OH radical, Orthovanadate nanocrystal, UV pre-irradiation

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T11-17 E-POSTER

Dual control of pro-oxidant behavior in nanoceria via iron doping and facet engineering

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For over two decades, cerium oxide nanocrystals (nanoceria) have been studied predominantly as antioxidants. Recent efforts, however, have shifted toward exploiting their pH-triggered pro-oxidant activity for applications in oncology, antimicrobials, and catalysis[1]. A major challenge in this field is the inefficient transition from scavenging to generating reactive oxygen species (ROS) at acidic pH. This study investigates how iron (Fe^{3+}) doping and morphology engineering can be used to accelerate this transition and maximize catalytic output.

Our data reveal that Fe^{3+} incorporation increases peroxidase-like activity by facilitating oxygen vacancy formation through charge compensation. This effect follows a non-linear trend, reaching a maximum at 5% doping-a threshold that significantly surpasses the performance of both 3% and 10% concentrations. Furthermore, the activity is strongly dictated by the exposed crystallographic facets. Cubic nanocrystals, characterized by {100} planes, demonstrate 7-8 times higher efficiency than {111}-terminated octahedra, a result of lower defect formation energies on the cubic surface.

Kinetic analysis further reveals a fundamental divergence in the reaction pathways: {100} facets operate via a Ping-Pong mechanism, while {111} facets follow a sequential model. This distinction suggests that the interaction with hydrogen peroxide (H_2O_2) is facet-specific. The Ping-Pong pathway on {100} planes indicates a radical-based process, where H_2O_2 first dissociates into hydroxyl radicals (·OH) before substrate oxidation occurs. Conversely, the sequential mechanism on {111} planes implies a ternary complex formation, where H_2O_2 and the substrate (e.g., TMB) must be co-adsorbed for electron transfer to take place. These insights provide a precise strategy for tailoring the redox behavior of nanoceria, facilitating the development of more effective pro-oxidant therapeutic agents.

KEYWORDS: Ceria, Doping, Prooxidant, Morphology

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T11-18 E-POSTER

Polymeric cryogel materials for regeneration of living tissues and wound healing

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Currently, a relevant idea is the creation and study of polymer cryogels with effective antimicrobial action, which can be used for regeneration of living tissues and wound healing.

A series of polymer cryogel samples based on polyvinyl alcohol (PVA) with different contents of polyglutamic acid (PGA) (3, 5, 9 wt.%) and different concentrations of Ag_2O nanoparticles (0.01, 0.05, 0.1, 0.5, 1.0 wt.%) were created for regeneration of living tissues and wound healing. After synthesis, the samples were poured into polypropylene bags measuring 10×10 cm, sealed and sterilized in an autoclave at a temperature of 120 °C for 20 min. At the next stage, the samples were crosslinked by freezing/thawing for different times at a temperature of (-20 °C). The optimal time for the formation of crosslinked cryogels was established: for PVA-PGA-Ag_2O it was 150 min.

The synthesized series of cryogel materials were characterized by a complex of modern structural-morphological, physicochemical and physicomechanical methods. The water absorption of the samples was studied.

It was found that polyglutamic acid in the polymer matrix acted as a reducing agent for silver nitrate salts and a stabilizer of nanoparticles.

Studies of the created cryogel materials were conducted on a wide range of different microorganisms. In particular, the created materials were tested against opportunistic microorganisms, including gram-positive (*S. aureus, S. epidermidis*) and gram-negative (*E. coli, P. aeruginosa*) bacteria. The genotoxicity of the obtained samples was studied using the cytogenetic method and Comet Assay. The ability of the obtained materials to stimulate tissue regeneration was investigated on a model of fibroblast cell cultures. The level of wound healing was determined on a model of laboratory animals (rats) by macroscopic assessment, histological studies and determination of biochemical markers. As a result of comprehensive structural-morphological, physico-chemical, physico-mechanical and biological studies, optimal conditions were identified for the formation of cryogel materials with effective bactericidal action, which do not exhibit cyto- and genotoxic effects and can be used for the regeneration of living tissues and wound healing: concentration of polyvinyl alcohol and polyglutamic acid, freezing temperature and time, optimal concentration of metal nanoparticles.

KEYWORDS: Cryogel, Polyglutamic acid, Wound surface

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T11-19 E-POSTER

Mechanistic divergence in NADPH-quercetin-nanozyme systems: Surface-associated electron transfer in orthovanadates versus semiquinone-associated redox activity in nanoceria

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Redox processes were investigated in model systems containing ultrasmall $GdYVO_4:Eu3^+$ orthovanadate nanoparticles and nanoceria (CeO_2, 2 nm) in the presence of NADPH and quercetin. Interest in such systems is driven by the growing relevance of artificial nanozymes capable of modulating redox homeostasis in biological environments. The ternary NADPH-quercetin-NP systems exhibited enhanced NADPH oxidation and evolution toward attenuated or quasi-stationary kinetic behavior at neutral and mildly acidic pH; however, the underlying mechanisms differed substantially between CeO_2 and orthovanadate nanoparticles. The results suggest that different mechanistic regimes operate in nanoceria- and orthovanadate-containing ternary NADPH-quercetin-nanoparticle systems. In the presence of nanoparticles and dissolved oxygen/peroxide, quercetin undergoes oxidation accompanied by formation of transient quercetin-derived redox intermediates, including semiquinone-like species, which may contribute to secondary electron-transfer reactions and reactive oxygen species generation. Short-time absorbance measurements demonstrated rapid activation of NADPH oxidation immediately after addition of quercetin, indicating efficient initial electron transfer in ternary systems. In contrast, longer fluorescence monitoring of NADPH over 10 min revealed progressive attenuation of the apparent oxidation rate following the initial activation phase. Thus, short-time kinetics mainly reflect rapid nanoparticle-mediated initiation processes, whereas longer fluorescence measurements characterize subsequent temporal stabilization of the redox system. The observed kinetic behavior did not demonstrate the progressive autoacceleration expected for sustained homogeneous semiquinone-driven redox cycling. Instead, the reactions exhibited an initial burst phase followed by attenuation or quasi-stationary behavior, suggesting an important contribution of interfacial and surface-associated electron-transfer processes. In nanoceria-containing systems, spectroscopic features were consistent with partial involvement of semiquinone-associated redox activity and transient quercetin-derived intermediates with partial diffusible character. In contrast, orthovanadate nanoparticles predominantly promoted coordination-mediated and surface-associated electron transfer without convincing evidence for self-sustaining bulk redox cycling. Thus, the data support coexistence of two distinct nanozyme-polyphenol interaction regimes: (i) semiquinone-associated redox activity with partial diffusible character in CeO_2 systems, and (ii) predominantly interfacial electron transfer in orthovanadate systems. These findings provide mechanistic insight into nanozyme-polyphenol interactions and demonstrate that nanoparticle composition critically determines the balance between surface-associated and diffusible redox pathways.

KEYWORDS: GdYVO4/Eu3+ nanoparticles, NADPH, Interfacial electron transfer, Semiquinone intermediates, Redox activity

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T11-20 POSTER

Biocompatible red emitting fluorinated carbon dots: Synthesis, optical properties and fluorescent cell imaging

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Carbon dots (CDs) have attracted considerable attention as fluorescent nanomaterials for biomedical applications owing to their excellent biocompatibility, low toxicity, tunable photoluminescence, and simple synthesis routes compared to traditional semiconductor quantum dots [1-3]. In particular, red-emitting carbon dots are highly desirable for bioimaging because they offer deeper tissue penetration, reduced autofluorescence background, and lower phototoxicity. This study reports a novel one-pot hydrothermal synthesis of biocompatible red-emitting fluorinated carbon dots (R_5F) using citric acid, urea, and m-trifluoromethylaniline as precursors in N,N-dimethylformamide medium. The obtained R_5F carbon dots were thoroughly characterized by dynamic light scattering (DLS), zeta-potential measurements, UV-Vis absorption spectroscopy, and fluorescence excitation-emission mapping. The particles exhibit a narrow size distribution in the range of 1-6 nm with a maximum at approximately 2 nm and demonstrate excellent colloidal stability in the physiological pH range, with zeta potential values below -20 mV at pH ≥ 8. Optical studies revealed multiple absorption bands corresponding to $\pi\rightarrow\pi^*$ and $n\rightarrow\pi^*$ transitions, along with strong red photoluminescence efficiently excited in the broad visible range (420-520 nm). Cytotoxicity evaluation performed on 3T3-L_1 fibroblast cells using real-time xCELLigence RTCA system showed high biocompatibility at concentrations up to 0.3 mg/mL, with no significant impact on cell proliferation. Fluorescent microscopy confirmed effective cellular uptake and bright red labeling primarily localized in the cytoplasm without any visible alterations in cell morphology or viability. Taken together, these findings demonstrate that the synthesized fluorinated carbon dots possess outstanding optical properties and excellent biocompatibility, making them highly promising, non-toxic fluorescent probes for longterm cell imaging, biomedical diagnostics, and other theranostic applications.

KEYWORDS: Fluorinated carbon dots, Fluorescence, Bioimaging, Optical properties, Cytotoxicity

ACKNOWLEDGEMENTS: This work was financially supported by EU Horizon 2020 Research and Innovation Staff Exchange Programme (RISE) under Marie Skłodowska-Curie Action (project "UNAT" No.101008159), National Research Foundation of Ukraine (project 2025.07/0098) and by Ministry of Education and Science of Ukraine (project 26BF07-03).

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T11-21 E-POSTER

Oxidase-like and peroxidase-like activities of CeO_2-x nanoparticles stimulating quercetin oxidation at neutral and slightly acidic pH

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The potential anticancer effect of quercetin (3, 3′, 4′, 5, 7-pentahydroxyflavone) is related to ROS (reactive oxygen species) generation accompanying the processes of autoxidation of quercetin molecules [1]. At the same time, this approach suffers from the fact that autoxidation of quercetin occurs preferably at alkaline pH (~10), while the medium of cancer cells is slightly acidic (pH ~ 6.1-6.9). At these pH values the spontaneous oxidation rates of quercetin are too slow to produce ROS in concentrations sufficient to hamper the growth or metabolism of tumor cells.

The rate of quercetin autooxidation can be sufficiently increased by both external conditions (pH, temperature) and presence of catalysts. In this study, we demonstrate a significant enhancement of quercetin oxidation in the presence of CeO_{2-x} nanoparticles observed not only at alkaline pH, but even at neutral and slightly acidic pH conditions (6.7-7.8). The experiments were carried out in the presence of O_2 and/or H_2O_2 as oxidants. The effect of combination of H_2O_2 and CeO_{2-x} NPs on the quercetin oxidation rate strongly overcomes the influence of these two components alone confirming their synergistic action. The origin of this synergy can be related to catalytic (peroxidase-like) activity of CeO_{2-x} NPs, i.e. the ability of these NPs to enhance the processes of oxidation of substrates (in this case, quercetin) by hydrogen peroxide. Kinetic analysis shows that the experimental data can be well described by the Michaelis-Menten model, confirming enzyme-like (oxidase- and peroxidase-mimicking) activities of CeO_{2-x} NPs. The high catalytic activity of CeO_{2-x} nanoparticles can be attributed to the favorable redox potential of the Ce^{3+}/Ce^{4+} couple, which facilitates efficient electron transfer and promotes quercetin oxidation under these conditions.

KEYWORDS: Quercetin, Nanoceria, Cancer, Reactive oxygen species

ACKNOWLEDGEMENTS: This research was supported by National Research Foundation of Ukraine, Grant № 2023.03/0050.

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Track 12

Enabling Technologies and Emerging Directions

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T12-01 INVITED

Exploiting the dynamical properties of nanoscale memristors for efficient information processing

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Memristive devices are commonly benchmarked by the multi-level programmability of their resistance states. Neural networks utilizing memristor crossbar arrays as synaptic layers largely rely on this feature. However, these "static" applications leave the rich dynamical properties of memristors largely unexploited. These dynamic features include not only the availability of ultra-short switching times of 10ps [1,2], but also the exponential voltage dependence of the resistive switching speed and the tunability of the dynamic fluctuations by voltage manipulation [3]. In my talk, I will review how such dynamical featues can be used for efficient information processing, such as (i) solving complex computational problems with memristive Hopfield neural networks [4], or (ii) performing time series analysis and prediction with dynamical memristor circuits [5].

KEYWORDS: Neuromorphic computing, Memristors, Reservoir computing, Time series prediction

ACKNOWLEDGEMENTS: The NKFI K143169 and 152611 research grants are acknowledged.

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T12-02 INVITED

Memristor-based physical reservoir computing for temporal signal classification at the edge

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Temporal signals are central to modern sensing, appearing in electroencephalogram (EEG) signals, electrocardiogram (ECG) recordings, and industrial vibration sensor metrics. Their classification remains difficult because such data are often noisy, nonstationary, artifact-contaminated, and governed by short- and long-range temporal dependencies [1]. Contemporary machine learning approaches can address these challenges, but they frequently require extensive preprocessing, recurrent architectures, or large training datasets, limiting their suitability for compact edge hardware [2]. Reservoir computing offers an alternative by projecting input sequences into a high-dimensional dynamical space, where temporal structure can be separated using a simple readout [3]. However, realizing such reservoirs in physical hardware remains challenging, particularly when nonlinear dynamics, fading memory, recurrent interaction, and sensor-compatible input encoding must be integrated within a compact substrate. In this work, a mycelium-inspired reservoir can successfully perform generalized temporal data classification by exploiting the echo state property of a memristive oscillator network. Herein, biological inspiration is drawn from mycelium's electrical spiking behavior, which informs the nonlinear oscillatory response at the cell level, and from its small-world network topology, characterized by high local clustering and short global path lengths, defining the reservoir's connectivity [4]. In this architecture, temporal samples are injected through an input layer and mapped onto a memristive oscillator grid composed of up to several hundred coupled oscillatory neurons. The resulting reservoir dynamics are then analyzed for each data sample through several physically interpretable features, including oscillation waveform amplitude, DC level, frequency, and RMS energy. These features form the extracted reservoir state and are passed to a single affine readout layer for classification. The combination of small-world topology and echo-state dynamics enables the reservoir to transform noisy temporal inputs into separable dynamical representations, which can be successfully classified by a readout layer. In addition, the generalized input interface makes the reservoir compatible with sensory front ends, including electrophysiological, optical, chemical, or mechanical sensing systems. These results position memristive oscillator reservoirs as promising hardware substrates for sensor-flexible temporal classification, with potential relevance to biomedical monitoring and low-power edge intelligence towards multi-modal sensing neuromorphic hardware.

KEYWORDS: Memristive oscillatory networks, Physical reservoir computing, Bio-Inspired neuromorphic computing, Temporal data classification, Mycelium-Inspired networks

ACKNOWLEDGEMENTS: This research work was supported by the FUNGATERIA project, which received funding from the European Union's HORIZON-EIC-2021-PATHFINDER CHALLENGES program under grant agreement no. 101071145.

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T12-03 INVITED

Direct atomic layer processing (DALP®): spatially localized, multi-material fabrication for next-generation devices from discovery to manufacturing

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Progress in next-generation advanced electronic and functional devices, based on complex heterostructures and advanced materials integration, is increasingly constrained by the rigidity of conventional thin-film processing and patterning workflows. While these approaches deliver high material quality and uniformity, they offer limited flexibility for spatially localized, multi-material fabrication, three-dimensional thickness engineering, and rapid experimentation at the nanoscale within a single process flow.

ATLANT 3D introduces Direct Atomic Layer Processing (DALP®), a nanofabrication technology enabling digitally controlled, spatially localized deposition of multiple materials with atomic-scale precision. DALP allows different materials to be deposited sequentially and locally in a unified workflow, enabling manufacturing of complex material stacks, heterostructures, interfaces, and thickness gradients without intermediate lithographic patterning steps.

This presentation describes the DALP process architecture and its role in both combinatorial materials discovery and targeted device manufacturing for next-generation devices. By enabling programmable material placement, controlled thickness variation, and repeatable execution within a single platform, DALP supports accelerated materials exploration while also enabling the direct production of device-ready structures as part of broader manufacturing flows. Representative examples include multi-material nanoscale structures for advanced semiconductor and functional material applications, where precise interface control, spatial selectivity, repeatability, and manufacturability are critical. DALP expands the accessible design space of nanoscale fabrication and provides a a direct pathway from materials discovery to device-ready, manufacturable structures.

KEYWORDS: Nanofabrication, ALD, DALP, Atomic layer processing

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T12-04 ORAL

Understanding the structure to mechanics relationships in 3D printed nanoporous membranes

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Here, we present a design-driven fabrication strategy that integrates digital light processing (DLP) 3D printing with an established overall chemistry used on the fabrication of porous monoliths for chromatography, known as polymerization-induced phase separation (PIPS), to enable the formation of nanostructured porous materials beyond the intrinsic resolution limits of additive manufacturing. In this approach, monomers and pore-forming agents are polymerized in situ during printing, driving phase separation at the nanoscale and generating high-density symmetric nanoporous networks with controlled pore cavity dimensions. This strategy decouples macroscopic architecture from nanoscale pore formation, allowing their independent control within a single manufacturing step.

However, there is still limited data availability and understanding of the mechanical behaviour of photopolymerized nanoporous structures and how the polymerization kinetics interfere in the densification and microcrack formation often seen in post-processing and pressurized operations such as membrane filtration. This is predominantly due to the fact that stress distribution is uneven, tending to concentrate in pore walls and thus making it highly dependent on internal pore distribution and structure density. Our 3D printed membranes have a symmetrical sponge-like pore structure with size distribution between 12 and 25 nm, with a mean pore of 19 nm and thickness printing ranging from 100 to 400 µm. We aim to understand their compressive behaviour and the impact that integrating phase separation in situ during network development has on it by mimicking pressure-driven operations similar to those achieved during membrane filtration.

The main objective of our work is to embed the mechanical response of the 3DP membranes as a design parameter within the printing process, rather than treating mechanical compaction as an inevitable consequence of the fabrication process. The strategy combined controlled compression testing with cross-flow filtration experiments up to 6 bar to quantitatively link pressure-induced strain to changes in membrane porosity, pore size distribution and permeability. By correlating mechanical behavior with operational performance, we were able to monitor plastic compaction and creep behavior of the specimens, benchmarking it against commercial poly(amide) membranes which enables rational optimization of membrane fabrication for improved compaction resistance. Although demonstrated here in the context of membrane fabrication, this work establishes a new method to assess the mechanical stability and performance of nanoporous materials.

KEYWORDS: 3D printing, Polymerization induced phase separation (PIPS), Mechanical behavior, Membranes, Nanopores

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Posters

T12-05 POSTER

Analysis of low and high linear transfer radiation effects on data carrying DNA origami templates

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DNA has become an alternative material for data storage because of its high information density, sustainability, stability, and longevity [1]. An interesting means of data storage represents patterns of objects placed on DNA Origami nanostructures (DON). The DON technique allows to build any desired shape by folding a plasmid single strand, known as scaffold, with complementary short single strands, called staples[2]. Another feature is the precise addressing of organic or inorganic molecules on the template by staple extensions [3]. However, it's necessary to prove the efficiency and durability of DONs for data storage. In this project, we used Keller's group DONs design and streptavidin protein in defined patterns to support digital information encoding, storage, and retrieval [4].

As a first step, we show how streptavidin interacts with the origami structure and how variations in concentration, deposition conditions, and substrates affect binding yield in a specific arrangement. Additionally, since long-term data storage is the target application, a key aspect is simulating cumulative degradation by exposing DONs to ionizing radiation, specifically low-LET 16 MeV electrons and high-LET 1.5 GeV $^{16}O^{8+}$ projectiles [5]. This work focuses on the effects of radiation type, the presence of streptavidin during irradiation, binding configuration, and radical scavenger concentration on the sensitivity of the encoded patterns to radiation damage. The results provide proof of concept for scalable, efficient, and explored strategies for enhancing the long-term data preservation capabilities of nanostructures, contributing to the development of next-generation data storage technologies.

KEYWORDS: DNA origami, Data storage, Radiation

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T12-06 POSTER

Next-generation flexible PEM fuel cells enabled by MXene nanomaterials

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The vision of our work is to develop a lightweight, flexible, and high-performance PEM fuel cell platform by integrating MXene-based nanomaterials to enhance conductivity, durability, and water management-targeting emerging applications in wearables, UAVs, and portable power systems. The ongoing project will develop a new generation of flexible proton exchange membrane (PEM) fuel cells by integrating MXene nanomaterials into key components of the system. MXenes, a class of highly conductive and hydrophilic 2D materials, offer significant advantages in improving electrical conductivity, catalyst efficiency, and water management, while also enabling mechanical flexibility. By incorporating MXenes into the catalyst layer, membrane, and gas diffusion layer, the project seeks to enhance overall fuel cell performance, reduce reliance on precious metals such as platinum, and improve durability under dynamic operating conditions.

The core Innovation part is to integrate MXene type materials into key PEMFC component -a) Catalyst Layer Enhancement -MXene-supported catalysts (Pt/MXene or non-PGM) in order to improve catalyst dispersion, electron transport and reduce Pt loading and b) Gas Diffusion Layer (GDL) Engineering MXene coating for optimization of water transport and enhance durability under flex conditions.

Basic work are now to solve main technical challenges related to MXene oxidation and long-term stability, scalable and reproducible MXene synthesis and Mechanical durability under repeated flexing

The resulting technology will deliver lightweight, bendable, and high-performance fuel cells suitable for emerging applications such as UAVs, wearable devices, and portable power systems. In addition to targeting higher power density and improved efficiency, the project addresses key challenges related to material stability, scalability, and integration into flexible architectures. Ultimately, this initiative positions itself at the intersection of hydrogen energy and advanced nanomaterials, contributing to the development of next-generation, adaptable energy solutions and strengthening capabilities in deep-tech innovation.

KEYWORDS: Lightweight, Flexible PEM fuel cell, MXenes, Portable power systems

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T12-07 E-POSTER

Biomedical nanotechnology in Ukraine: Biosafety and policy aspects

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The rapid development of modern biomedical nanotechnologies underscores the need to develop new approaches to regulate biosafety issues, as well as the legal and social aspects of this field. In the context of the sustainable development strategy, this area is becoming not merely a subject of scientific interest but the foundation of a new bioeconomy. The aim of this study is to assess and clarify the specific features of the legislative regulation of research in this field at the national level.

To achieve the study's goal, an analysis of key Ukrainian normative documents available on the relevant official website (https://zakon.rada.gov.ua) was conducted to determine whether the legislation specifically contains the terms "nanotechnology", "nanomaterial", "nanoparticle", "nanomedicine", "nanorobot", etc.

The review of selected open-source normative documents indicates that terms with the prefix "nano" are not explicitly mentioned in these texts. Instead, these documents establish the broader biomedical and biosafety context into which nanomedicine is implicitly integrated, highlighting a distinct gap in nano-specific regulatory policies. The priority areas for the development of nanobiotechnologies in Ukraine include the creation of biomaterials for regenerative medicine, the development of biosensors, the biofunctionalisation of nanomaterials, the development of innovative technologies for controlled drug delivery, and biomedical imaging. Despite the enormous prospects, the use of nanomaterials requires strict biosafety control - strategic risk management for human life and environmental conditions.

In Ukraine, the legal regulation of biomedical nanotechnologies is currently undergoing active transformation and integration into the European Union (EU) acquis. At the legislative level, the regulation of legal aspects in this field is distributed across laws on healthcare and innovation. Within the framework of the Association Agreement with the EU, Ukraine has undertaken the obligation to harmonise its national legislation with European norms. This concerns several critical dimensions: 1. intellectual property: the development of "purple biotechnology" (patenting) is a mandatory condition for attracting investment; 2. regulation of novel food products: according to Regulation (EU) 2015/2283 of the European Parliament and of the Council, any innovative food or medical products created using nanomaterials must undergo a rigorous risk assessment procedure before entering the market; 3. institutional transparency: the effective functioning of the sector is possible only on the condition of overcoming corruption and creating an independent judicial system that guarantees the rule of law for developers and consumers.

KEYWORDS: Nanobiotechnology, Nanomedicine, Bioengineering, Biosafety, Legislative regulation

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