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INNOVATIONS IN MATERIALS SCIENCE

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INNOVATIONS IN MATERIALS SCIENCE

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ABSTRACT BOOK

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Day 1- May 13, 2026

Regenerative Biomaterials and Medical Devices for Reconstructive Surgery

Dr. Guillermo A. Ameer, Northwestern University, USA

Abstract:

Regenerative engineering is the convergence of advances in materials science, physical sciences, stem cell and developmental biology, and translational medicine to develop tools that enable the regeneration and reconstruction of tissue and organ function. I will describe how materials can be engineered to play a critical role in treating tissue defects and dysfunction by promoting cellular processes that are conducive to regeneration. Applications of these materials to address musculoskeletal injuries will be discussed.

High-resolution label-free detection of alginate and elastin in tissue-engineered constructs using Raman spectroscopy

Alexander Khmaladze[a], Monireh Pourrahimi[a], Samaneh Ghazanfarpour[a], Alireza Sheikhsofla[a], Rafael Pena[b], Jennifer Morrissey[b], Sujith Chander Reddy Kollampally[c], Anna Sharikova[a], Yubing Xie[c], Melinda Larsen[b]*

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Abstract

Alginate is a natural polysaccharide found in brown algae and has a unique feature to form hydrogel upon encountering Ca2+. Its exceptional characteristics make alginate hydrogel highly desirable for a range of biomedical applications, such as drug delivery, wound healing, and in particular, tissue engineering and cell therapy, where it is used as scaffolding or cell delivery vehicles. After using alginate hydrogel for cell delivery in vivo, one of our objectives was to specifically detect alginate in tissue cryosections containing cell-scaffold constructs. Due to difficulties encountered in detecting alginate using immunohistochemistry with mouse-derived antibodies, we aimed to develop an alternative method to definitively identify alginate within tissue cryosection samples using Raman spectroscopy.

Elastin, a critical extracellular matrix protein, provides elasticity, resilience, and durability to tissues such as skin, lungs, and arteries. Its distinctive properties, such as self-assembly, long-term stability, and high elasticity, make it highly suitable for biomaterials like scaffolds and hydrogels. Elastin-derived

peptides (EDPs) also influence physiological and pathological processes, while elastin itself supports elastic recoil and regulates cellular responses. Combining elastin with natural polymers such as alginate improves the mechanical integrity and biological compatibility of tissue-engineered constructs. Elastin-like polypeptides (ELPs) have gained increasing interest for their biocompatibility, biodegradability, and non-immunogenicity in regenerative medicine applications. In our study, elastin-based hydrogels were used to promote cell growth. Our goal was to detect and map elastin in cryosectioned tissue samples containing these cell-laden scaffolds. We first attempted immunohistochemical detection using mouse-derived antibodies but faced challenges in specificity and signal clarity. As an alternative, we explored Raman spectroscopy, a non-invasive technique based on the analysis of vibrational energy modes.

Raman spectroscopy is a non-invasive analytical technique that employs scattered light to assess the vibrational energy modes present in a sample. By collecting the Raman spectra of samples containing alginate, freezing media, and tissue, we detected alginate specific Raman peaks at 816, 888, 959, 1309, 1433 cm^{-1}, and were able to discriminate the alginate from tissue and media. Also, Raman spectra were acquired from scaffolds containing elastin alone to identify unique spectral features. Key elastin-associated peaks like Amide III, Amide I, C–C stretching, and CH_2 bending vibrations were identified. Using these features and classical least squares (CLS) analysis, we successfully mapped elastin and alginate distributions overlaid on brightfield images. Raman spectroscopy thus proves to be a sensitive, label-free technique for characterizing elastin-based biomaterials in complex tissue environments.

Biography: Dr. Alexander Khmaladze is an Associate Professor in the Physics Department at State University of New York (SUNY) at Albany. He received his Ph.D. from the University of South Florida, where he published a number of papers on digital holographic phase imaging. He then accepted a postdoctoral position at the University of Michigan, where he worked on the application of near-infrared Raman Spectroscopy. Dr. Khmaladze joined the Physics Department of SUNY at Albany in September 2014. His research interests include Raman spectroscopy and microscopy, three-dimensional digital holographic imaging, microscope design, hyperspectral imaging of live cells and biological tissue imaging.

Advances in Styrenic Thermoplastic Elastomer Gels as Tunably Soft and Recyclable Materials

Richard John Spontak, North Carolina State University, USA

Wide-Bandgap Semiconductor Materials for Quantum Information (QI@RT) Room Temperature

S M Atiqur Rahman[1], Oded Ravid[1],Vishal Saravade[1,2],
*Zhe Chuan Feng[1], Benjamin Klein[1], and Ian Ferguson[1,]**

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[2]Department of Optical Engineering and NanoEngineering,
Rose-Hulman Institute of Technology, Terre Haute, IN 47803, USA

Abstract:

Quantum and neuromorphic computing have the potential to outperform classical computing in terms of speed, power consumption, and scalability. Accessing the spin of an electron is an ideal candidate for these applications because it could be used for memory storage, signal amplification and attenuation, and switching for logic applications. The spin of a material is directly related to its magnetic, electrical, and optical properties, and the control of spin, in addition to charge, is needed for the rapidly growing field of spintronic devices and materials. However, many of these materials exhibit only spintronic properties at cryogenic temperatures, which limits their practical applications. This paper considers the potential of wide-bandgap semiconductor materials as an emerging technology for quantum and neuromorphic computing. Understanding the RT ferromagnetism mechanism in these materials is essential for controlling spin and building practical spintronic devices for Quantum Information applications at Room Temperature (QI@RT). One such material system is the III-Nitrides, and, for example, Gadolinium-doped GaN grown has been shown to have ferromagnetism at RT that is potentially intrinsic and free-carrier mediated. However, the origin of ferromagnetism in GaGdN remains poorly understood, so the properties of GaGdN grown with different chemistries and implanted with O or C have been investigated in this work. Another approach is the use of II-VI semiconductor materials such as ZnO doped with transition metals, which will also be reviewed. ZnO-based materials have an additional advantage that they are both earth-abundant and non-toxic.

BIOGRAPHY:

Ian Ferguson is the former Dean of Southern Polytechnic College of Engineering and Engineering Technology at Kennesaw State University. His research expertise is in compound semiconductor materials and devices for sensors, illumination, energy harvesting, and spintronics applications. He is an international educator and researcher with over 575 refereed journal publications, conference proceedings, books, book chapters, and patents. He is a Fellow of the Royal Society of Arts, Manufactures and Commerce (FRSA), the American Vacuum Society, the Institute of Electrical and Electronic Engineering, the Institute of Physics, Optical, the International Society for Optical Engineering, and a Chartered Physicist.

Diamond and Diamond-like Carbon Materials for Medical Applications

Roger Narayan, University of North Carolina and North Carolina State University, USA

Abstract

Over the past three decades, the use of microcrystalline diamond, nanocrystalline diamond, ultrananocrystalline diamond, and diamond-like carbon thin films for medical applications has been considered. The physical, chemical, mechanical, and adhesion characteristics of hard carbon thin films will be discussed. In vitro studies of cell interactions with nanocrystalline diamond and diamond-like carbon thin films will be described. In addition, recent developments in the use of nanocrystalline diamond and diamond-like carbon thin films in micro- and nanoscale devices will be reviewed.

Development of thermal diodes and thermal switches using unusual thermal conductivity of silver chalcogenides

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Abstract

The concept of thermal management, which aims to effectively reuse large amounts of waste heat, has attracted considerable interest for reducing energy consumption. Achieving advanced thermal management requires the development of high-performance functional devices, including thermal diodes that rectify heat flux and thermal switches that flexibly control heat flow using external parameters. In this talk, I will present our recent progress in developing composite-type thermal diodes and capacitor-type thermal switches based on silver chalcogenides. Silver chalcogenides Ag_2(S, Se, Te), which exhibit extremely low lattice thermal conductivity below 0.5 W m^{-1} K^{-1} due to strong anharmonic lattice vibrations, a semiconducting electronic structure, and structural phase transitions below 450 K.[1, 2] These characteristics make silver chalcogenides promising candidates for the thermal diodes and switches that are difficult to achieve with conventional solid materials.

Composite-type thermal diodes require combining two materials with different temperature dependences of thermal conductivity, where stronger temperature dependence leads to larger rectification. Silver chalcogenides undergoing semiconductor-metal transitions show pronounced step-like changes in electronic thermal conductivity, which are further amplified by their negligible lattice thermal conductivity. By systematically investigating the temperature, composition, and Ag-

impurity-concentration dependences, we achieved a relatively large thermal rectification ratio, defined as $|\boldsymbol{j}_{\mathbf{q}\_\mathrm{forward}}|/|\boldsymbol{j}_{\mathbf{q}\_\mathrm{reverse}}|$ of 3.3.[2, 3]

For thermal switches, we developed capacitor-type devices that enable active modulation of thermal conductivity through carrier accumulation at electrode-dielectric interfaces via bias voltage. By employing silver chalcogenides as electrode materials, we obtained a reversible and reproducible switching ratio ~1.9 with sub-second response times. Owing to the extremely low lattice thermal conductivity and semiconducting characteristic of silver chalcogenides, modulation of the electronic contribution to thermal conductivity becomes observable. [4, 5]

The talk will further review future guidelines for enhancing the performance of composite-type thermal diodes and capacitor-type thermal switches.

[1] K. Hirata *et al.*, *AIP Adv.* **13**, 035122 (2023).
[2] K. Hirata *et al.*, *J. Electron. Mater.* **49** 2895 (2020).
[3] K. Hirata *et al.*, *Sci. Technol. Adv. Mater.* **26** 2549674 (2025).
[4] R. Toida *et al.*, *J. Thermoelectr. Soc. Jpn.* **22** 3 (2025).
[5] K. Hirata *et al.*, *Sci. Technol. Adv. Mater.* **26** 2590797 (2025).

Biography:
Keisuke Hirata is an assistant professor at the department of advanced materials science, graduate school of frontier sciences, The University of Tokyo, Japan. He received his Ph.D. in Engineering from Toyota Technological Institute in 2023, where he studied the unusual behaviors in thermal conductivity of silver chalcogenides and development of thermal management devices under the supervision of Prof. Tsunehiro Takeuchi. His research interests include materials science, solid-state physics, thermoelectric conversion, and phonon engineering.

Solid-State Engineered Boron Nitride Nanotube-Reinforced Aluminum Nanocomposites for Multifunctional Performance

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Abstract

The development of lightweight structural materials with integrated multifunctional properties remains a critical challenge for advanced aerospace, energy, and radiation environments. In particular, achieving simultaneous improvements in wear resistance and radiation shielding within aluminum-based systems requires precise control over reinforcement distribution and interfacial stability. In this study, one-dimensional boron nitride nanotubes (BNNTs) are incorporated into an aluminum matrix through a cold spray solid-state processing approach, enabling the preservation of nanoscale

reinforcement integrity while avoiding deleterious interfacial reactions typically associated with high-temperature processing. BNNTs were uniformly dispersed onto aluminum powders via ultrasonication, resulting in a homogeneous composite feedstock. The resulting nanocomposites exhibit significant microstructural refinement, characterized by uniformly distributed BNNT networks along interparticle boundaries, leading to a reduction in porosity from 8% to 4% and a ~40% increase in interfacial deformation and consolidation. These structural modifications directly translate to enhanced functional performance, including a 21% reduction in coefficient of friction and a 65% decrease in wear volume under dry sliding conditions. Furthermore, the incorporation of BNNTs results in a 35.1% improvement in neutron radiation shielding, attributed to the high neutron absorption cross-section of boron and the effective distribution of nanotube networks within the matrix. The observed multifunctional enhancements highlight the critical role of nanoscale reinforcement architecture and solid-state microstructural engineering in tailoring material performance. This work demonstrates a scalable pathway for designing next-generation aluminum-based nanocomposites with coupled tribological and radiation shielding capabilities. Future efforts will extend this framework toward ceramic-rich systems to further expand the functional design space for extreme environment applications.

Biography:

Dr. Denny John is a Research Scientist in the Department of Mechanical and Materials Engineering at Florida International University. His research focuses on solid-state processing and nanocomposite design, particularly high strain-rate deposition, microstructure engineering, and multifunctional materials for extreme environments. He has authored over 30 peer-reviewed publications and holds multiple granted and licensed patents. His work spans metal matrix composites, ceramics, and advanced coatings with applications in aerospace, energy, and defense. He has collaborated with agencies including NASA and the Army Research Laboratory on next-generation materials systems.

Phonon Anharmonicity in Thermoelectric Binary Chalcogenides

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Abstract

Thermoelectric (TE) materials can convert “waste” heat into electricity, offering environmentally friendly solutions for power generation. The thermal-to-electrical energy conversion efficiency of TE materials is represented by their dimensionless figure-of-merit, *ZT*, which depends on interrelated transport properties, such as the Seebeck coefficient, electrical conductivity, and thermal conductivity. For efficient energy conversion, TE materials must exhibit low lattice thermal conductivity and simultaneously high Seebeck coefficient and electrical conductivity. Recently, materials such as binary

chalcogenides (with *ZT* >2) have been reported to exhibit intrinsically low lattice thermal conductivity attributed to their high phonon anharmonicity. Here, we present evidence of phonon anharmonicity in two chalcogenide systems (SnSe and GeTe), which were characterized by temperature-dependent specific heat and thermal transport measurements, as well as by temperature-dependent Raman spectroscopy. Our results enabled us to quantify anharmonicity in chalcogenide TE materials and to provide insights into the importance of phonon-engineering approaches to improve TE material performance.

This work was performed in collaboration with Prof. Y.Y. Chen's group in Academia Sinica, Taiwan; Prof. A.M. Rao's group at Clemson University; and Dr. Rahul Rao in Air Force Research Laboratory, WPAFB, Dayton, OH, 45433 USA.

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Biography:

Sriparna Bhattacharya is a Research Associate Professor at the Department of Physics and Astronomy, and a Faculty Scholar at the School of Health Research at Clemson University. Her research interests include energy generation, harvesting, and energy storage, as well as chemical imaging for biomedical applications. Recently, she collaborated with Prof. H. J. Goldsmid, aka, the 'Father of Thermoelectrics,' (School of Physics, University of New South Wales, Sydney, Australia), to develop a new evaluation method for thermoelectric materials. This study was featured as the *Editor's Pick* by the Editorial Board of the *Journal of Applied Physics*.

Magnetostriction Effect in Ultra Fine Grain Size Nickel

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Abstract

Ferromagnetic materials such as nickel exhibits magnetostriction and reverse magnetostriction effects under cyclic deformation. This phenomenon is best described as the dimensional changes caused by the application of a magnetic field. The distribution of magnetic domains is affected by the distribution of internal stresses. In regions of inhomogeneous stresses due to heterogeneous dislocation substructures and grain constraint, the magnetization tends to align itself parallel to the

direction where the internal stresses can be relaxed by magnetostriction. Positive magnetostriction occurs when the material expands along the direction of magnetization, whereas negative magnetostriction occurs when the material contracts along the direction of magnetization. Reverse magnetostriction on the other hand, also referred to as the Villari effect, results when stress is applied to a ferromagnetic material. The stress-induced magnetization causes an elongation in addition to the elastic elongation caused by the tensile stress. For a negative magnetostrictive material, the magnetization is increased in the direction of an applied compressive stress and causes additional contraction of the material along that direction. In nickel, both tensile and compressive stresses cause magnetic domains to align perpendicular and parallel to the stress axis, respectively, and thus inducing a magnetostrictive strain.

Magnetostriction is a function of plastic strain amplitude and grain size. The magnetostriction effect in conventional grain size is more pronounced at low effective plastic strain amplitudes, e.g. at $\varepsilon_{pa,eff} = 1.0x10^{-4}$, and is significantly reduced at higher strain amplitudes, e.g., at $\varepsilon_{pa,eff} = 1.0x10^{-3}$. The saturation dislocation structures at $\varepsilon_{pa,eff} = 1.0x10^{-3}$ consist of mainly dislocation cells, which inhibit the magnetostriction effect.

The magnetostriction effect is observed to progressively reduce with a decrease in grain size; more significant in single crystal nickel, and reduced in fine conventional grain nickel with a grain size of 24 µm. For the ultra fine grain nickel, UFG, the magnetostriction is significantly reduced. UFG nickel subjected effective plastic strain amplitude between $\varepsilon_{pa,eff} = 1.0x10^{-4}$ and $\varepsilon_{pa,eff} = 1.0x10^{-3}$ does not show any magnetostrictive behavior. The saturation dislocation structures observed at $\varepsilon_{pa,eff} = 1.0x10^{-3}$ UFG nickel consist of mainly dislocation cells, which inhibit the magnetostriction effect. While conventional grain size nickel exhibits higher saturation magnetization than UFG nickel, coercivity is higher for UFG nickel, which correspond to less magnetostrictive effect compared to CG nickel. These observations indicate that grain refinement in UFG nickel causes an increase in internal friction of the domain walls which would be expected to inhibit the reverse magnetostriction.

Biography:

I hold a PhD in mechanical engineering from Clarkson University, USA. I have 27 years of teaching experience at the University of Botswana, Department of Mechanical. I have served as Head of Department, Mechanical Engineering; University of Botswana Representative for Africa-Uninet Research Network. Member of Technical Committees at Botswana Bureau of Standards. My research interests are Materials and Manufacturing. Member of the Human Resource Development Committee (HRDC) Manufacturing Sector. My collaboration include: the Smart Manufacturing Engineering Education for Knowledge Economy (SME2KE) consortium; and the University of Botswana-University of Pennsylvania partnership for rehabilitation of stroke patients using robotics.

Interface-Driven Performance Enhancement in Energy Storage Systems

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Abstract

With the growing demand for high-performance energy storage technologies, achieving stable and reliable device performance has become increasingly critical. Energy storage system performance is governed by the coupled interplay of electrode materials, electrolyte properties, and interfacial phenomena that dictate electrochemical kinetics, stability, and operational lifetime. In particular, the interfacial processes at the electrode–electrolyte interface play a crucial role in its performance. As more batteries are required to operate under high energy density, and long-cycle operations. The interfacial instability, such as parasitic reactions, uneven ion transport, and mechanical degradation—remains a critical bottleneck. Accordingly, engineering the surface interface to regulate electrode–electrolyte interactions has emerged as a key strategy for improving cell performance. In lithium metal batteries, the highly reactive lithium metal forms unstable solid-electrolyte interphase (SEI) with electrolyte, leading to dendrite formation and rapid capacity decay.

Our work centers on interfacial engineering using functional groups to regulate electrode–electrolyte interactions. Rather than treating materials as passive structural components, we design chemically active interfaces in which specific functional groups govern ion transport, interphase chemistry, and surface reaction pathways. In cellulose-based systems, abundant hydroxyl and carboxyl groups minimize interfacial free energy, and enhance electrolyte affinity, thereby promoting the formation of stable and uniform SEI layers. In parallel, through amide-functionalization on multiwalled carbon nanotube (A-MWCNT) interlayer. The polar amide groups regulate ion distribution and polysulfide interactions, facilitate the formation of thinner and more conductive SEI layers, and suppress shuttle effects. The functional-group-mediated interfacial regulation provides an effective strategy for stabilizing battery interfaces and improving electrochemical performance.

Biography: My research interests center on the electrochemical energy storage interfaces, with emphasis on electrode–electrolyte interactions, interphase chemistry, and interfacial stability. I am interested in exploring the surface chemistry, wettability, and interfacial kinetics that govern ion transport, degradation, and electrochemical performance in energy storage system. Beyond energy storage systems, I am interested in advanced materials processing, including flash sintering of ceramics, as an energy-efficient approach to functional materials manufacturing. I also have broader interests in sustainable materials design, battery recycling, and low-carbon technologies.

Day 2-May 14, 2026

Photopolymerization-Based 3D Printing of Medical Devices

Roger Narayan, University of North Carolina and North Carolina State University, USA

Abstract

Photopolymerization-based 3D printing methods, such as two-photon polymerization and digital micromirror device-based stereolithography, have been used to create biomedical devices with small-scale features for a wide range of medical applications. For instance, two-photon polymerization is a 3D printing method that uses pulses from a titanium-sapphire or fiber laser to excite photoinitiator molecules in a photosensitive resin, for selective polymerization of the resin. Polymerization of biomedical devices containing microscale and sub-microscale features occurs because two-photon absorption is nonlinear with respect to incident light intensity. Two-photon polymerization has been used for 3D printing of biomedical devices with microscale and sub-microscale features from photosensitive polymers (including acrylate-containing materials) and organically modified ceramic materials (including zirconium oxide hybrid materials). Several types of medical devices, including tissue-engineering scaffolds, drug delivery devices, and sensors, have been 3D-printed using two-photon polymerization. For example, we used two-photon polymerization to 3D-print small-scale lancet-shaped devices known as microneedles; these devices have potential applications in transdermal drug delivery or transdermal detection of analytes in body fluids. Methods to optimize the processing parameters and postprocessing steps for medical device applications will be described. For example, innovations in biologically appropriate photoinitiators for medical applications will be described. Functional evaluation (including biological evaluation) of two-photon polymerization-created medical devices will be considered. Appropriate steps in the development of photopolymerization-based 3d printing methods for commercially scalable manufacturing will be discussed.

Nanoceria: Small Materials, Big Impact

Sudipta Seal, University of Central Florida, USA

A New Perspective on Piezotronic and Thermoelectric Coupling:

Flexible Platforms for Synergistic Energy Scavenging and Peltier-Caloric Effects

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Abstract

Advances in the development of flexible piezoelectric and thermoelectric materials have provided an important avenue for the exploration of energy scavenging through the thermodynamic coupling of orthogonal energy-scavenging modalities. Recently, hybrid thermo/piezo-electric generator devices (T/PEGs) based on flexible, layered, thin-film architectures have been shown to drive a kind of thermodynamic entanglement of the piezoelectric and Seebeck effects. The hallmark of such entangled thermodynamics lies in the non-additive power generation characteristic of the combined effects. The efficacy of energy scavenging from such a hybrid device can be made to exceed that of its two components independently. In this work, a basic coupled heat engine model is shown to provide insight into the origins of synergistic power generation. These models further suggest the emergence of other combined thermodynamic properties such as a kinetic Peltier-Caloric Effect (PCE) traced to Onsager reciprocity. We report the observation of this effect in T/PEG systems as a confirmation of this perspective of thermodynamic inseparability.

Evaluating the Effectiveness of Camel Hair Filters in Wind Catchers for Air Quality Improvement and Natural Ventilation Comfort in Vernacular Saudi Architecture

Laila Alkhtani[1]

[1] *Department of Interior Design, College of Arts and Design, Princess Nourah bint Abdulrahman University, Saudi Arabia*

Abstract

The development of sustainable functional materials for environmental applications is an emerging focus within materials science. This study investigates camel hair, a naturally abundant keratin-based fiber, as an innovative bio-derived filtration material for indoor carbon pollutant mitigation. The research evaluates the material’s physicochemical performance under controlled ventilation conditions using an experimentally designed duct-flow system that simulates realistic mechanical airflow environments.

An IoT-enabled monitoring framework was implemented to quantify filtration performance, integrating calibrated MQ135 gas sensors for carbonaceous pollutant detection and SHT31

sensors for simultaneous temperature and relative humidity measurements. Sensor arrays positioned upstream and downstream of the material layer enabled differential assessment of adsorption and retention behavior. Results indicate consistent reductions in pollutant concentrations across the camel hair medium, demonstrating promising filtration efficiency attributable to its fibrous microstructure and surface interaction characteristics. In addition, the material exhibited measurable hygrothermal moderation, suggesting intrinsic moisture-buffering properties linked to keratin fiber morphology.

The findings highlight camel hair as a multifunctional bio-based material combining pollutant mitigation with passive environmental regulation. From a materials science perspective, the study supports the potential of naturally derived fibrous materials as low-energy, circular alternatives to synthetic filtration media. Further investigation into structural characterization, surface treatment, and long-term performance could facilitate integration into advanced indoor air purification systems and sustainable material design strategies.

Biography:

Prof. Laila Amer Al-Qahtani is a Professor of Interior Design at Princess Nourah bint Abdulrahman University, Saudi Arabia, and is recognized as the first Saudi woman to attain full professorship in interior design. Her work integrates academic research, teaching, and professional consultancy, with a focus on sustainable interior environments, material innovation, and design solutions adapted to local and global contexts. She has published extensively in international journals and has participated in numerous conferences worldwide. A dedicated innovator, she holds several Saudi patents and has received international awards for her inventions exhibited across Europe and Asia.

Multifunctional Nanomaterial Design for Heterogeneous Catalyzed C—O, N—H, C—H Functionalization

Md. Shahajahan Kutubi[1] Katsutoshi Sato[2], Katsutoshi Nagaoka[2]*

[1] *Department of Chemistry, Noakhali Science and Technology University, Bangladesh*
[2] *Chemical Systems Engineering, Graduate School of Engineering, Nagoya, Japan*

Abstract

In Organic Synthesis, heterogeneous catalysis has recently become a powerful platform to design the sustainable technologies, that are currently revolutionizing organic synthesis by activating typical bonds: C–O, N–H, and C–H in a selective, sustainable, and recyclable pathway to modern organic synthesis, enabling streamlined routes to pharmaceuticals, fine chemicals, and advanced materials. Multifunctional nanomaterial development has come out in potential research frontlines as a powerful strategy to address the growing demand for efficient, selective, and sustainable catalytic chemical transformations playing a pivotal role in the development of materials for the sustainable life

in modern society, but it is very challenging to perfectly design them for catalysis due to proper acid-base properties, defects, deactivation etc. Therefore, the scientists have recently concentrated multifunctional heterogeneous catalytic systems for C–O, N–H, and C–H functionalizations for industrial synthesis. In this presentation, the research work reveals the rational design of advanced heterogeneous nano-catalysts capable of promoting C–O, N–H, and C–H bond functionalization with high activity and tunable selectivity. By integrating multiple active sites within nanostructured platform—such as metal nanoparticles, acid–base functionalities, and defects-engineered supports—such catalysts revealed synergistic catalytic effects that enhanced reaction efficiency with a broader substrate scope. These catalysts were synthesized through controlled methods enabling precise tuning of particle size, morphology, crystallinity and surface composition. Comprehensive characterization revealed the critical role of metal–support interactions, electronic modulation, and spatial confinement, which governed the enhancement of catalytic performance. The developed systems demonstrated excellent stability and recyclability under mild reaction conditions, highlighting their potential in the practical applications. Furthermore, the cooperative interactions between adjacent active sites facilitated selective activation of inert C–H bonds, as well as efficient transformation of C–O and N–H functionalities highlighting their mechanistic insights into bond activation pathways. This presentation would introduce a platform for designing next-generation multifunctional catalysts and offers new perspectives for advancing sustainable chemical synthesis.

Biography:

Dr. Md. Shahajahan Kutubi (PhD/Eng.) studied chemistry in B.Sc./M.Sc. at Jahangirnagar University, Bangladesh and under the Japan Government's MEXT Scholarship, he graduated 2nd M.Sc. in Ecomaterial Science and Engineering, and Ph.D. in Energy and Materials Science at Saga University, Japan. His research focuses on the design of homogeneous/heterogeneous catalysts for organic synthesis, industrial processes, CO_2/CO hydrogenation to e-fuels: liquid-fuel, city-gas, value-added chemicals, *etc.*, revealing greener processes: decrease of chemical pollution/industrial waste, and prevention of catalyst deactivation/sintering and metal leaching. He worked as a project researcher in academic, chemical industry (a chief/project PI), and Japan's national projects of NEDO and JST-Agency, Japan.

Electrochemical Evaluation of Polycarbazole-Supported $MnFe_2O_4$ Nanohybrids for Advanced Electrochemical Applications

*Sara Ou Hassou[1], Mary Taylor [1,2], Rajeev Kumar[1], Amit Kumar[1] and Ufana Riaz [1,2]**
Biomedical/Biotechnology Research Institute, North Carolina Central University, Durham, NC, USA

Abstract

Manganese ferrite ($MnFe_2O_4$) has attracted considerable research interest owing to its favorable magnetic and electrical properties, which make it a promising candidate for a wide range of technological applications. In addition, its high chemical stability and demonstrated activity toward oxygen and hydrogen evolution reactions further highlight its potential in energy storage, electrocatalysis, and sensing technologies. Despite these advantages, the intrinsic electrical conductivity and interfacial charge-transfer characteristics of $MnFe_2O_4$ remain limiting factors for achieving optimal performance in such applications. To address these limitations, the integration of $MnFe_2O_4$ with a conductive and chemically stable polymeric support offers an effective strategy. In this context, polycarbazole (PCz) was selected due to its intrinsic electrical conductivity, facile synthesis and processability, excellent environmental stability, and notable redox activity in aqueous media. Incorporation of PCz is expected to improve the electrical connectivity, structural stability, and electrochemical responsiveness of $MnFe_2O_4$. The formation of a $MnFe_2O_4$/PCz composite is anticipated to promote synergistic interactions between the inorganic ferrite and the conductive polymer matrix, leading to enhanced charge-transfer kinetics, increased electrochemically active surface area, and improved operational durability. Consequently, this hybrid material presents a compelling platform for advanced applications in electrocatalysis, energy storage systems, and environmental sensing, offering a rational approach to enhancing the functional performance of metal ferrite–based materials.

Keywords: Manganese ferrite; Polycarbazole; Polymer–ferrite hybrids; Electrocatalysis; Oxygen evolution reaction (OER);Hydrogen evolution reaction (HER)

Reframing Materials Characterization: Integrating Design Thinking to Accelerate Insight in Complex Polymer and Composite Systems

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Abstract

Across research and manufacturing environments, materials characterization is often treated as a static or confirmatory step, as a means to validate incremental outcomes rather than to inspire new directions. Yet in today's complex, multidisciplinary R&D landscape, the most impactful insights arise not merely from precision testing, but from strategic interpretation and iterative learning. This presentation introduces a framework that applies design-thinking principles to materials testing and characterization in order to transform the process from one of verification to one of discovery.

Drawing from cross-sector projects involving polymer coatings, biodegradable films, and composite formulations, this work illustrates how merging processing and molecular characterization techniques within iterative feedback loops can reveal meaningful relationships between formulation, structure, and performance. Rather than approaching testing as a final stage of validation, the proposed method positions it as a creative and hypothesis-generating activity in product development, where characterization results directly inform reformulation, process adjustment, or prototype redesign.

At the core of this approach is the design-thinking cycle of empathize, define, ideate, prototype, and test, reframed for technical teams. By encouraging scientists and engineers to consider the broader context of a material's function, from manufacturability and sustainability to end-user interaction, materials testing becomes a platform for cross-disciplinary collaboration. In practice, this model helps

integrate human-centered insights with technical data, bridging the gap between R&D, process engineering, and product design.

The presentation will share structured methods for embedding iterative design loops into conventional characterization workflows, including how to:

Use rapid feedback cycles to refine formulations in real time;
Connect processing conditions to property outcomes through systems mapping;
Translate complex data into actionable design or manufacturing decisions;
Build cross-functional teams that blend analytical and creative problem solving.
By combining scientific rigor with innovation mindset, this framework enables teams to accelerate materials discovery while maintaining reliability and reproducibility. It also promotes sustainability by reducing wasted cycles and focusing experimental resources where they have the most impact.
Ultimately, Reframing Materials Characterization challenges the traditional notion of testing as a passive checkpoint, positioning it instead as a dynamic and collaborative driver of materials innovation. Attendees will leave with practical strategies to make characterization more integrative, exploratory, and aligned with real-world application goals, advancing not only how materials are measured, but how they are imagined.

Keywords:

Materials Testing and Characterization, Polymer Composites, Processing–Structure–Property Relationships, Design Thinking, Innovation in R&D, Sustainable Materials

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Dielectric and magnetic properties of the FE-$Tb_{0.3}Dy_{0.7}Fe_2O_{4.5}$ multiferroic composites

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Abstract

The paper presents the technology and structural, microstructural, dielectric, and magnetic properties of the FE-TDF multiferroic composites. In the composites, the matrix was the ferroelectric (FE) material (in amount 90%), while the magnetic phase was $Tb_{0.3}Dy_{0.7}Fe_2O_{4.5}$ in amount 10%. Both composite components were obtained by the classical method of sintering simple oxides. Three compositions of multiferroic composites were obtained, i.e., (i) $0.9(BaTiO_3) - 0.1(Tb_{0.3}Dy_{0.7}Fe_2O_{4.5})$ (BT-TDF), (ii) $0.9(Pb_{0.90}Ba_{0.10}(Zr_{0.53}Ti_{0.47})O_3+2\%at.Nb_2O_5) - 0.1(Tb_{0.3}Dy_{0.7}Fe_2O_{4.5})$ (PZT1-TDF), (iii) $0.9(Pb(Zr_{0.51}Ti_{0.49})O_3+0.2\%at.Bi_2O_3+0.03\%at.Nb_2O_5 +0.06\%at.MnO_2) - 0.1(Tb_{0.3}Dy_{0.7}Fe_2O_{4.5})$, (PZT2-TDF). The sintering of FE-TDF composite samples was carried out by the free sintering method under the conditions: T=1250 °C, t=2 h. X-ray studies of FE-TDF ceramic composites revealed strong reflections from the ferroelectric component and weak reflections from the magnetic component. In the microstructure of FE-TDF composites, grains of magnetic (TDF) material are distributed in the ferroelectric (FE) matrix of the composite. The FE matrix of multiferroic composites is characterized by dense packing, with strongly interconnected ferroelectric grains. In the case of the PZT1-TDF composite, the microstructure exhibits greater grain size irregularity and higher porosity. In dielectric tests of composite materials, a clearly visible phase transition from ferroelectric to paraelectric phase (at T_C) with high permittivity values. The BT-TDF multiferroic composite exhibits intermediate permittivity values 826 at room temperature (RT), and 1421 at T_C, at 1 kHz. The multiferroic composites designed on the basis of PZT-type material, i.e., PZT1-TDF and PZT2-TDF, exhibit higher permittivity values at T_C (4884 and 6852, respectively, for 1 kHz) and lower at RT (519 and 321, respectively, for 1 kHz). All composite compositions exhibit low dielectric loss values, namely, 826, 519, and 321 (at RT) for BT-TDF, PZT1-TDF, and PZT2-TDF, respectively. In DC electrical conductivity tests, the BT-TDF composition exhibits higher conductivity compared to PZT1-TDF and PZT2-TDF composites. The magnetic properties of the FE-TDF ceramic composites are typical for ferroelectro-ferromagnetic composite materials, characterized by narrow magnetic hysteresis loops. The research revealed that the FE-TDF ceramic composite exhibits good dielectric and magnetic properties, making it suitable for microelectric applications.

Biography:

Dariusz Bochenek, Professor.
Prof. dr hab. Dariusz Bochenek is currently employed as a Professor at the University of Silesia in Katowice (Poland) and is the head of a research group at the Institute of Materials Engineering dealing with the production and testing of ceramic materials and multiferroic composite materials with functional properties for microelectronic and micromechatronic applications. He is a member of the Polish Ceramic Society PTCr's board. He is also a member of the Polish Society of Microscopy PTMi, the European Microscopy Society (EMS), and the International Federation of Societies for Electron Microscopy (IFSM). He has published 140 research articles placed in the SCOPUS database.

Dielectric and magnetic properties of PZT-Ferrite multiferroic composites

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Abstract

The work presents the results of research on the P-F_{HP} multiferroic composites based on doped PZT-type and ferrite materials. In the multiferroic composites, the doped PZT-type material with chemical formula $Pb(Zr_{0.51}Ti_{0.49})O_3$+ 0.2%at.$Bi_2O_3$+0.03%at.$Nb_2O_5$+0.06%at.$MnO_2$ (P) was the ferroelectric

component, and $Ni_{0.5}Zn_{0.5}Fe_2O_4$ (F) ferrite was the magnetic component. Six multiferroic composite P-F_{HP} with different percentages of its components were sintered by hot pressing method (1200 °C/ 1 h / 5 MPa): (i) 90/10 (90P-10F_{HP}), (ii) 85/15 (85P-15F_{HP}), (iii) 80/20 (80P-20F_{HP}), (iv) 60/40 (60P-40F_{HP}), (v) 40/60 (40P-60F_{HP}), and (vi) 20/80 (20P-80F_{HP}). The effect of chemical composition on the X-ray, microstructural, dielectric, and magnetic properties of multiferroic composite materials was investigated. The P-F_{HP} multiferroic composites exhibit both magnetic and electric properties simultaneously. At room temperature, the magnetization values are from 50.5 Am^2/kg (for 20P-80F_{HP}) to 4.7 Am^2/kg (for 90P-10F_{HP}), while the permittivity values are from 167 (for 20P-80F_{HP}) to 575 (for 90P-10F_{HP}), and dielectric tangent loss values are from 0.74 (for 20P-80F_{HP}) to 0.017 (for 90P-10F_{HP}). The conducted research shows that increasing the amount of ferrite in the P-F_{HP} multiferroic composite worsens the dielectric properties, and the DC electrical conductivity increases significantly, which limits the possibilities of wide application. P-F_{HP} composite materials with a dominant ferroelectric component (90P-10F_{HP}) exhibit the most optimal magnetic and dielectric parameters. Such multiferroic composite materials show favorable functional properties adequate for use in microelectronic applications, e.g., electromagnetic converters and new types of memory.

Biography:

Dr Dagmara Brzezińska is currently employed as an assistant professor at the University of Silesia in Katowice (Poland) in a research group at the Institute of Materials Science and Engineering dealing with the production and research of ceramic materials and multiferroic composite materials with functional properties for microelectronic and micromechatronic applications. She has published 27 scientific articles in the research area listed in the SCOPUS database.

Enhanced CO2 detection using Schottky conduction mechanism in 2D MOF/MXene hybrid vertical sensing device

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1 North Dakota State University, USA 2 North Dakota State University, USA 3 North Dakota State University, USA Presenter Contact Details

Abstract

Achieving a room temperature solid state gas sensor that allows the precise detection of CO2 gas at ppm level is crucial for measuring higher levels indoor and outdoor places. The room temperature with fast-response CO2 sensors based on vertically layered heterostructures continues to be a challenging frontier in sensor development. In this work, we have successfully developed a vertical device for CO2 sensing in the range of 500–2000 ppm at 200 °C. The strategies for synthesizing stable MOF (UiO-66 (Zr)) on 2D MXene (Ti3C2Tx) layer have also been demonstrated. The sensing device was fabricated on ITO coated glass surface using a spin-coating method, with UV-ozone pretreatment to enhance substrate surface energy and improve adhesion. The structural and morphological characterization revealed the well-organized layered structure for UiO-66 (Zr)/Ti3C2Tx with a BET surface area of 1840 m2, pore size in the range 3.5–4 nm, with pore volume 0.1398 (cm3/g), led to fast response and

recovery times. The vertically with ITO/Au/Ti3C2Tx/UiO-66 (Zr)/Au configuration exhibited a higher gas response of ~ 36.67% at 200 °C and 2000 ppm with response and recovery times of ~ 1.0 min and 3.1 min, respectively. On the other hand, the Au/UiO-66 (Zr)/Au device showed a low gas response ~ 0.02% even at 450 °C and response/recovery times of 0.7/3.0 min. The device with pristine UiO-66 (Zr) have not shown a stable response even at 200 °C. We also evaluated the charge transport regime in Zr-based UiO-66 and UiO-66 (Zr) /Ti3C2Tx devices transitions from Poole–Frenkel conduction at lower temperatures to an Ohmic behavior at higher temperatures, which was strongly influenced by varying CO2 concentration. These findings reveal that the temperature and concentration dependent conduction mechanisms are critical for optimizing vertical CO2 sensors.

Biography:

I am a PhD researcher in Electrical and Computer Engineering, working on advanced materials for electronic sensors, with a specific focus on CO_2-based chemiresistive sensors. I have published five research papers in the last two years, reflecting my active involvement in sensor materials and device optimization. I hold an MPhil in Microelectronics Engineering and Semiconductor Physics, which provided me strong grounding in semiconductor devices and fabrication technologies. I completed my undergraduate degree in Physics, which built my foundation in applied and solid-state physics. My research interests lie at the intersection of materials science, microelectronics, and gas sensing for environmental and industrial applications.

Seismic Strengthening Effect of Ultra-High-Molecular-Weight Polyethylene Fiber on Damaged Reinforced Concrete Column

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Abstract

This study evaluated the seismic repair and strengthening performance of reinforced concrete (RC) columns retrofitted with ultra-high-molecular-weight polyethylene (UHMWPE) fiber. Previous studies had already shown that UHMWPE fiber provides superior seismic strengthening efficiency compared with conventional carbon fiber and aramid fiber methods. In this study, RC columns were classified according to the degree of damage into three groups: minor-damage columns (URM), moderate-damage columns (URO), and severe-damage columns (URS). These damaged columns were repaired and reinforced with UHMWPE fiber and then tested under the same quasi-static loading conditions. Their behavior was compared with that of a non-reinforced column (NRF) and an undamaged UHMWPE-reinforced column (URF) reported in previous studies. The seismic performance of the specimens was analyzed in terms of strength, stiffness, ductility ratio, and energy dissipation capacity. Compared with NRF, the maximum strength increased by 14.91% for URF, 14.05% for URM, 14.00% for URO, and 6.50% for URS. In terms of initial stiffness, URF and URM showed increases of 29% and 15%, respectively, while URO and URS exhibited no significant improvement. The ductility ratio increased by 102.33% for URF, 63.50% for URM, 26.10% for URO, and 35.91% for URS. Energy dissipation capacity also improved significantly, increasing by 105.28% for URF and by 135.18%, 110.23%, and 120.00% for URM, URO, and URS, respectively. The results demonstrate that RC columns repaired from seismic damage and strengthened with UHMWPE fiber achieved clear improvements in strength, ductility, and energy dissipation capacity compared with non-reinforced columns. In addition, the repaired damaged columns showed seismic performance comparable to that of the undamaged UHMWPE-reinforced column. Therefore, UHMWPE fiber reinforcement can be considered an effective method for restoring and enhancing the seismic performance of earthquake-damaged RC columns by recovering their strength and ductility.

Biography:

Professor Chunho Chang is a faculty member in Civil Engineering specializing in structural mechanics, earthquake engineering, and the application of fiber-reinforced polymer (FRP) materials in construction. His research focuses on the seismic performance, strengthening, and rehabilitation of structures using advanced composite materials. He is actively involved in both research and higher education, contributing to the development of resilient and sustainable infrastructure systems. Professor Chang currently serves as President of the Korea Society for Advanced Composite Structures. He was also a researcher at the Pacific Earthquake Engineering Research Center (PEER) at the University of California, Berkeley.

Microstructure and Mechanical Behavior of $Al_{30}Ni_{30}Cr_{30}W_5Re_5$ Refractory High-Entropy Alloy Processed by Mechanical Alloying and Spark Plasma Sintering

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Abstract

$Al_{30}Ni_{30}Cr_{30}W_5Re_5$ refractory high-entropy alloy (RHEA) was synthesized via mechanical alloying followed by spark plasma sintering (SPS) at 800 °C and 900 °C. Phase formation and microstructural evolution were characterized using X-ray diffraction (XRD), scanning electron microscopy (SEM), and electron backscatter diffraction (EBSD). The alloy exhibited refined crystallite size and a homogeneous microstructure, with EBSD revealing significant grain refinement and well-defined crystallographic features. Energy-dispersive spectroscopy (EDS) confirmed uniform elemental distribution without noticeable segregation. Mechanical evaluation showed that increasing sintering temperature enhanced densification, leading to reduced porosity and improved hardness and compressive strength. The combined processing route promotes microstructural refinement and superior mechanical performance, highlighting the potential of this RHEA for high-temperature structural applications.

Keywords: Refractory high-entropy alloy; Mechanical alloying; Spark plasma sintering; Microstructure; Mechanical properties.

Biography:

Dr. D. Jeyasimman is an academic and researcher specializing in materials science and mechanical engineering, with a focus on advanced alloys, composites, and high-entropy materials. He holds a Ph.D. and has extensive experience in teaching core engineering subjects and guiding research scholars. His work emphasizes processing–microstructure–property relationships, particularly in areas such as mechanical alloying, spark plasma sintering, and failure analysis. Dr. Jeyasimman has published several research articles in reputed journals and actively contributes to funded research and academic administration. He is committed to promoting innovation, interdisciplinary research, and quality higher education, while mentoring students toward academic and professional excellence.

Toward Intelligent Wearable Bioelectronics: Integrating Nanomaterials, Sensing, and Data-Driven Health Monitoring

Rahim Esfandyarpour, University of California, USA

Pathways to 28% Efficiency: Material Optimization and Device Modelling of Perovskite/Kesterite Tandem Solar Cells

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Abstract

Kesterite-based solar cells are promising earth-abundant absorbers for low-cost tandem photovoltaics, yet improving their quality on transparent substrates remains challenging. In this work, we develop fully thin-film perovskite/kesterite tandem systems through complementary material and device optimization strategies.

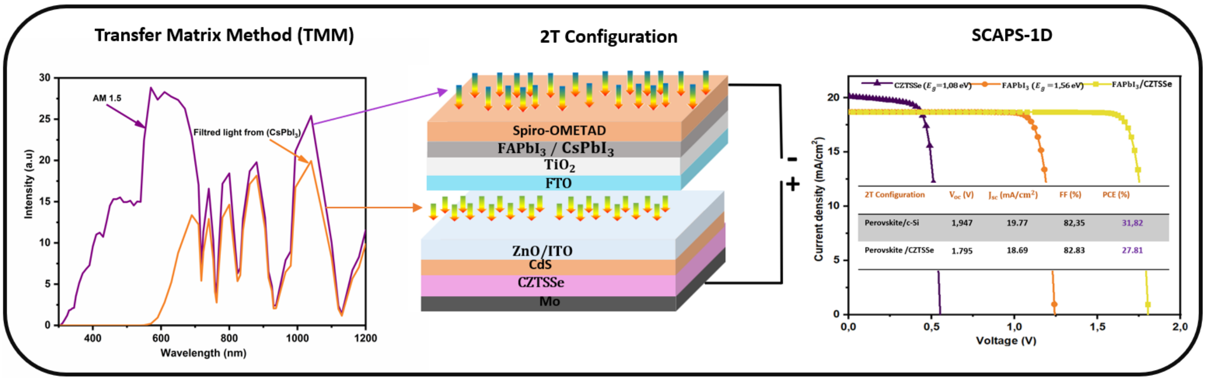
Silver alloying and sodium doping were applied to enhance the structural and optoelectronic properties of CZTS films grown on FTO by the sol-gel method. Structural analyses confirmed improved crystallinity and reduced defect density, while optical measurements showed a slight bandgap increase (1.53–1.57 eV). FDTD simulations were performed on the complete FTO/CZTS/CdS/ZnO/ITO stack, providing realistic optical input for tandem modeling.

In parallel, perovskite/CZTSSe tandem architectures were modeled using combined TMM optical simulations and SCAPS-1D electrical modeling. By optimizing perovskite bandgap and thickness for current matching, predicted efficiencies of up to ~28% were achieved.

These results highlight the strong potential of optimized perovskite/kesterite tandems as efficient and cost-effective next-generation photovoltaic systems.

Keywords

Tandem solar cells; Perovskite; CZTSS; CZTSSe; SCAPS-1D; FDTD simulation; TMM simulation



2T Configuration	V_{oc} (V)	J_{sc} (mA/cm^2)	FF (%)	PCE (%)
Perovskite/c-Si	1,947	19.77	82,35	31,82
Perovskite /CZTSSe	1.795	18.69	82.83	27.81

Graphical Abstract: Methodology Used in This Work

Spin Transistors Implemented with Quantum Materials

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Abstract

Spin field effect transistors (Spin-FETs) are a genre of unconventional transistors where transistor action is elicited from the electric field modulation of the spin polarization of charge carriers as opposed to the modulation of the carrier concentration that takes place in ordinary transistors. The first Spin-FET was proposed more than thirty-five years ago and relied on electric-field-induced Rashba or Dresselhaus spin-orbit interaction in narrow gap semiconductors to manipulate spin polarization. With the advent of quantum materials, a new Spin-FET modality has now been proposed and is beginning to attract attention. It does not rely on spin-orbit interaction but instead uses electrically generated mechanical strain to modulate the Dirac velocity of surface electrons in a 3D topological insulator (TI) . This rotates the spin polarization of the surface carriers in a 3D-TI and realizes Spin-FET action. The oddity is that the transfer characteristic (channel current versus gate voltage) of the transistor is oscillatory which enables unusual applications, such as a single-transistor frequency multiplier with miniscule energy dissipation. Yet another new class of Spin-FET exploits electric-field-tuned strain in a Weyl semimetal to modulate the spin properties. Here, the channel conductance shows oscillatory dependence on the channel length under zero strain owing to interference between two orthogonal propagating spin states. By choosing two different channel lengths, one can make the channel conductance increase with strain in one case and decrease in the other. This results in positive transconductance in one case and negative transconductance in the other. By connecting two such Spin-FETs in series, one can implement complementary-metal-oxide-semiconductor (CMOS) functionality at much lower energy cost than traditional CMOS.

Enhancing Antifouling Performance via Light-Induced Crosslinking of Ultrathin Polyzwitterionic Coatings

Charini Piumika Maladeniya, Oak Ridge National Laboratory, USA

Antifouling involves preventing the adhesion and proliferation of unwanted organisms such as bacteria, algae, and other microorganisms on surfaces. Polyzwitterions, a unique class of polyampholytes containing both positive and negative charges within each monomer unit, have emerged as highly effective antifouling materials. Their strong hydration capacity and high surface energy create both physical and energetic barriers that inhibit the adsorption of proteins and other biomolecules. In this study, we explore the use of polyzwitterions as ultrathin coatings for biofouling resistance, focusing on their synthesis, structural properties, and performance on solid substrates.

A sulfobetaine-based polyzwitterion, poly(2-vinylpyridine propanesulfonate) (P2VPPS), was synthesized via free-radical polymerization. A photoreactive benzophenone derivative was first covalently attached to a SiO_2 substrate through silane chemistry. Ultrathin P2VPPS films were then deposited onto the modified substrates using spin-coating and drop-casting techniques, enabling comparison of film thickness and antifouling behavior. Controlled crosslinking was achieved by exposing the films to 365 nm UV light, producing coatings with varying crosslinking densities.

The resulting films were characterized using X-ray photoelectron spectroscopy, X-ray reflectometry, contact angle measurements, atomic force microscopy, and sum frequency generation spectroscopy. Antifouling performance was evaluated using neutron reflectometry, quartz crystal microbalance with dissipation, and adsorption studies with amphiphilic β-casein protein. Additionally, multi-scale imaging of *Pantoea* species was conducted to assess microbial attachment. The results indicate that light-induced crosslinking significantly influences film structure and properties, with increased crosslinking leading to greater film thickness and higher protein retention.

Securing Critical Materials for Energy Systems: A Portfolio and Investment Perspective

Javier Mauricio León Ortega, MPA Columbia University, Colombia

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Effect of carbon compounds synthesized from recycled graphite (recovered from LIB batteries) on the energy density of solid-state supercapacitors.

Jorge Oliva, Center for Applied Physics and Advanced Technology Lab, Mexico

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Uncovering the Unique Properties of Ordered Nanostructures Using In Situ Studies and Numerical Simulations

Oomman K. Varghese, University of Houston, USA

Advanced Functionalization of Polymer and Biodegradable Nanocomposites Using Antioxidant and Antibacterial Additives

Ahmad Al-Jabareen, Al-Quds University, Palestine

Abstract:

Polymeric materials are widely used in modern engineering applications; however, conventional petroleum-based polymers face increasing environmental and performance limitations. Biodegradable polymers such as poly(lactic acid) (PLA) have emerged as sustainable alternatives due to their renewability and environmental compatibility, although they often suffer from limited thermal stability, brittleness, and slow crystallization behavior.

To address these challenges, the incorporation of functional additives—including inorganic nanoparticles, antioxidants, and antibacterial agents—has become an effective strategy to tailor polymer performance. In this work, polymer nanocomposites were developed using metal oxide-based additives synthesized via a controlled chemical route, producing near-spherical nanoparticles with an average size in the nanometer range (~80 nm).

The incorporation of these additives into polymer matrices resulted in enhanced thermal and mechanical properties. Specifically, the additives acted as nucleating agents, leading to an increase in crystallization temperature and degree of crystallinity. Mechanical testing demonstrated improvements in Young’s modulus, tensile strength, and fracture resistance, while a slight reduction in elongation at break was observed due to increased stiffness of the composite system. Morphological analysis confirmed good dispersion of nanoparticles within the polymer matrix, contributing to effective stress transfer and improved interfacial interactions.

In addition, the role of antioxidant additives in improving thermal stability and resistance to oxidative degradation is highlighted, particularly for biodegradable systems such as PLA. Antibacterial performance was also evaluated; however, results indicated limited antimicrobial activity, which is attributed to restricted release of active species from within the polymer matrix.

Overall, this study demonstrates that the integration of multifunctional additives into both conventional and biodegradable polymer systems provides a promising pathway toward developing advanced materials with enhanced performance and sustainability.

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