Soft Iontronics for Sensing and Energy Harvesting

Hyunhyub Ko

School of Energy and Chemical Engineering, Ulsan National Institute of Science and Technology (UNIST), Ulsan Metropolitan City, 44919, Republic of Korea

Abstract:

Traditional electron-based devices face fundamental limitations in energy efficiency and seamless integration with biological systems due to their rigid architectures and high power consumption. To overcome these challenges, ionotronics has emerged as an alternative platform that exploits ionic transport to enable soft, biocompatible, and ultra–low-power systems. Here, we present soft iontronic devices that provides self-sustained energy harvesting and neuromorphic computing. Addressing the need for autonomous power, we introduce two different energy-harvesting strategies. A bioinspired ionic heterojunction generator (BIAS) produces stimulus-free direct current via spontaneous interfacial ion migration, mimicking the electrocyte architecture of electric rays. In parallel, a MXene nanochannel–based hydrovoltaic generator (MHG) leverages ion–electron coupling within asymmetric nanochannels to generate robust power from trace amounts of water, independent of evaporation, humidity, or environmental fluctuations. Finally, to process sensory information with biological efficiency, we report a fully biodegradable multilayer artificial synapse (M-AS). Enabled by ion–dipole coupling and interfacial ion trapping, the synapse exhibits rich synaptic plasticity with sub biological energy consumption (0.85 fJ per event) and record-long memory retention, allowing reflexive and adaptive responses in eco-friendly neuromorphic systems. Together, these results establish soft iontronics as an efficient platform for self-powered sensing and intelligent information processing, offering a sustainable alternative to conventional electronics for next generation wearable, biointegrated, and neuromorphic technologies.

Cry Protein Crystals as a Platform for Revolutionizing Immobilized Enzyme Biocatalysis

Michael Chan

The Chinese University of Hong Kong, Hong Kong

Abstract:

Enzyme biocatalysts have the advantage of being able to perform multistep enantioselective and regioselective reactions in water, leading to fewer side products and reduced chemical waste than traditional synthetic catalysts. This makes them ideally suited for promoting the green chemistries needed to create a more sustainable world. The major barrier to the widespread use of enzymes is the cost and effort needed for enzyme purification, risk of enzyme inactivation, and in some cases, requirement of expensive cofactors. Our laboratory has recently developed a simple, robust and cost-effective strategy for the direct co-immobilization of multiple enzymes in cellulo by fusing or entrapping them in crystal-forming Cry proteins. The Cry-enzyme particles produced can be easily isolated by centrifugation obviating the need for costly enzyme purification. We further show that particle cationization enables the co-immobilization of cofactors with their enzyme counterparts thereby generating a self-sufficient cofactor-dependent biocatalyst that can be reused over multiple reaction cycles. We demonstrate the utilization of these catalysts in both batch and fixed bed reactor systems for catalytic reactions over extended periods (days to weeks) for the production of pharmaceutically relevant chiral precursors.

Natural Rubber Nanocomposites Based on ZnO-Decorated Carbon Nanotubes and Coupling Agent Interaction

Charoen Nakason*, Skulrat Pichaiyut and Naruemon Thongkong

Faculty of Science and Industrial Technology, Prince of Songkla University, 84000 Surat Thani Campus, Thailand

Abstract:

Natural rubber (NR) nanocomposites incorporating pristine carbon nanotubes (CNTs) and zinc oxide–decorated CNTs (CNT/ZnO) were fabricated using bis(triethoxysilylpropyl) tetrasulfide (TESPT) as an interfacial coupling agent. The combined effects of ZnO surface decoration and TESPT modification on curing behavior, mechanical performance, viscoelastic response, thermal stability, and electrical characteristics were systematically examined. ZnO-functionalized CNTs, particularly when used in conjunction with TESPT, significantly promoted vulcanization efficiency and resulted in pronounced improvements in tensile strength and modulus. Dynamic mechanical analysis indicated an upward shift in glass transition temperature (Tg) relative to the gum vulcanizate, reflecting restricted rubber chain mobility arising from enhanced filler–rubber interfacial interactions. Swelling measurements and bound rubber analysis further verified the formation of additional chemical linkages, with the highest crosslink density observed in TESPT-treated CNT/ZnO systems, consistent with the refined filler dispersion revealed by SEM. In addition, the incorporation of CNT/ZnO at optimized loading led to an increase in electrical conductivity of nearly five orders of magnitude, which was further amplified by TESPT, while the dielectric constant was also elevated due to intensified interfacial polarization effects.

Intracellular Peptide Self-assembly for Anti-cancer Therapy

Ja-Hyoung Ryu

Department of Chemistry, Ulsan National Institute of Science and Technology (UNIST) UNIST-gil 50, Ulju-gun, Ulsan 44919, South Korea

Abstract:

Self-assembly generates three-dimensional architectures through the non-covalent interactions of building blocks of various sizes, ranging from nanometers to micrometers, and the assembled structures may have new functions that the building blocks do not have. Cell self-assembly has attracted considerable attention in cancer treatment because it can overcome the side effects of conventional chemotherapy and the low therapeutic effect on drug-resistant cells. In addition, the trigger in the building block reacts with the specific environment of the cancer, such as pH, ions, redox reactions, enzymes, or receptors, facilitating cancer-targeted therapy. However, the precise control of self-assembly for the construction of nanostructures is difficult in harsh intracellular environments. To overcome this challenge, our team has investigated intracellular self-assembly, in particular, the self-assembly of cellular organelles. Compared with self-assembly in the cytoplasm of cells, organelle-targeted self-assembly has the advantage of being able to self-assemble without side effects under more stable conditions with a relatively low concentration of building blocks. These findings can provide a new insight into intracellular assembly for the regulation of cellular functions and a therapeutic approach and new targeting platform for the biomedical community.

A Genetically Encoded pH-Responsive Antimicrobial Crystals to Combat H. Pylori Infection and Restore Gut Dysbiosis

Marianne M. Lee

The Chinese University of Hong Kong, Hong Kong

Abstract:

Helicobacter pylori (*H. pylori*) is a human gastric pathogen that colonizes more than half of the world's population. Although most patients are asymptomatic, some cases will progress to more severe forms of the disease, including gastric cancer. Early intervention has shown to reduce gastric cancer risk. Unfortunately, the first-line treatment comprising a proton pump inhibitor and several antibiotics is becoming ineffective due to antibiotic resistance. Moreover, oral antibiotic treatment often induces gut microbiota perturbation leading to increased risk of infections caused by opportunistic pathogens.

We have designed a genetically encoded *H. pylori*-responsive microbicidal protein crystal based on Cry3Aa protein. The resultant crystal exhibits preferential binding to *H. pylori*, and when activated, promotes the targeted release of the antimicrobial peptide (AMP) at the infection site. Significantly, when the activated antimicrobial crystals are orally delivered to infected mice, the crystal framework protects its cargo AMP against degradation, resulting in enhanced in vivo efficacy against *H. pylori* infection. In contrast to antibiotics, treatment with the activated crystals results in minimal perturbation of the mouse gut microbiota, demonstrating that engineered Cry3Aa crystals can serve as an effective platform for the oral delivery of therapeutic peptides to treat gastrointestinal diseases.

3D-printed Carbon Microlattices: A Novel Scaffold Platform for Musculoskeletal Tissue Engineering

Monsur Islam*

Mechanical Engineering Department, Universidad Politécnica de Madrid, Madrid, Spain

Abstract:

Carbon-based materials have recently attracted growing attention in tissue engineering due to their unique combination of biocompatibility, electrical conductivity, and mechanical robustness, properties that directly address key shortcomings of polymeric scaffolds such as mechanical mismatch, degradation instability, and poor long-term functionality. Among the many carbon allotropes explored, including graphene oxide, carbon nanotubes, and glassy carbon, most approaches still rely on complex synthesis routes and offer limited control over scaffold geometry. To overcome these challenges, our work leverages high-resolution 3D printing followed by pyrolytic conversion to create architected pyrolytic carbon (PyC) microlattices with tunable geometry, stiffness, and surface functionality.

These 3D-printed PyC scaffolds exhibit exceptional structural fidelity and mimic the hierarchical mechanics of native musculoskeletal tissues while providing conductive interfaces that promote cell communication and mechanotransduction. We have systematically investigated their biocompatibility with osteoblasts and myoblasts, demonstrating excellent cell adhesion, proliferation, and morphology preservation across soft and hard tissue environments.

Furthermore, advanced imaging and quantitative analysis were employed to correlate lattice design parameters, such as strut size, porosity, and surface roughness, with cellular organization and tissue-specific responses.

Our findings highlight the potential of PyC as a new class of multifunctional scaffold material that integrates mechanical resilience, biointerface conductivity, and architectural precision. The ongoing in vitro and in vivo studies suggest that these microengineered carbon lattices can serve as universal platforms for musculoskeletal repair, providing new insights into how carbon architecture and microstructure can be tailored to regulate biological performance. This work establishes a pathway toward next-generation bioactive carbon scaffolds capable of bridging the gap between structural mechanics and functional tissue regeneration.

Biography:

Dr. Monsur Islam is a Ramón y Cajal Fellow (tenure-track faculty) at Universidad Politécnica de Madrid in Spain. His research bridges materials science, additive micro/nanomanufacturing, and biomedical engineering, with a focus on 3D-printed pyrolytic carbon and multifunctional scaffolds for musculoskeletal regeneration. He previously worked at IMDEA Materials Institute (Spain), Karlsruhe Institute of Technology (Germany), and Clemson University (USA), where he earned his PhD in 2018. Dr. Islam has authored over 70 peer-reviewed publications in leading journals including Advanced Functional Materials, Advanced Healthcare Materials, Matter, and Small Structures, and leads international collaborations on architected biomaterials and sustainable additive manufacturing.

PLAL-Synthesized Metallic Nanoparticles as SERS Platforms for Trace Detection of the Flavonoid Nobiletin

Satyam Shinde

Department of Physics, Pandit Deendayal Energy University, Gandhinagar, Gujarat, India

Abstract:

This study explores the enhancement of Raman scattering of the flavonoid Nobiletin using Surface-enhanced Raman Spectroscopy (SERS), a powerful technique that leverages metallic nanostructures to amplify inherently weak RAMAN signals. To systematically investigates factors influencing signal enhancement, copper, silver and gold nanoparticles are synthesized via Pulsed laser ablation in Liquid (PLAL) and employed as SERS active substrate. Flavonoids are a rich class of plant secondary metabolites widely recognized for their diverse bioactivities, Nobiletin (hexamethoxyflavone), abundant in citrus peels, has attracted substantial attention due to its promising biological activities including antioxidant, anti-inflammatory, anticancer, and neuroprotective effects. Accurate and sensitive detection of nobiletin is essential in application such as nutraceutical development, food quality assessment, and pharmacological research, where trace-level monitoring is often required. In the present work, nobiletin solutions at varying concentrations will be treated with the synthesized metallic nanoparticles to evaluate the enhancements of their Raman signals. By comparing the performance of copper, silver, and gold nanoparticles as SERS substrates, the study aims to optimize experimental conditions for achieving reproducible and sensitive detection. This methodology provides a versatile and non-destructive approach for flavonoid analysis, offering a foundation for ultrasensitive detection of bioactive natural products. The study highlights the potential of PLAL-synthesized nanoparticles to serve as effective SERS platforms, facilitating applications in nutraceutical research and biomedical studies.

Metabolites Quantifiable by Magnetic Resonance in Spinal Cord Injury Implanted with Plasma-Synthesized Polymer in Vivo

Axayacatl Morales-Guadarrama[1*], Diana Osorio-Londoño[1], Yessica Heras-Romero[2], Laura Alvarez-Mejía[2], Christopher René Torres-SanMiguel[3], Juan Morales-Corona[2] and Roberto Olayo-González[2]

[1]Centro Nacional de Imagenología e Instrumentación Médica (CI[3]M), Depto. de Ingeniería Eléctrica, Universidad Autónoma Metropolitana, CDMX, México.
[2]Depto. De Física, Universidad Autónoma Metropolitana, CDMX, México.
[3]Unidad Profesional Zacatenco, Instituto Politécnico Nacional, Escuela Superior de Ingeniería Mecánica y Eléctrica, CDMX, México.

Abstract:

Traumatic spinal cord injury (SCI) causes severe neurological disability, with significant medical and socioeconomic repercussions for patients and their families. It is estimated that more than 2.5 million people worldwide live with SCI. Various treatments have been reported following SCI. Most strategies have not significantly restored motor or sensory function, and currently, there is no clinically accepted therapeutic strategy.
We have reported that rats implanted with plasma-synthesized materials containing amines (pP-NH) regained voluntary movement in the joints of the lower extremities after SCI.
Experiments with pP-NH are underway for potential clinical application. The use of plasma-synthesized pyrrole-derived polymers for neuroprotection and central nervous system rewiring is protected by patents worldwide. In this study, pP-NH was implanted in a spinal cord injury (SCI), and subjects were monitored using in vivo magnetic resonance imaging (MRI). Physicochemical changes were determined by in vivo metabolite quantification during the progression of motor recovery after SCI implantation with pP-NH.
The feasibility of in vivo monitoring of functional recovery using magnetic resonance spectroscopy was demonstrated. Furthermore, data and tools such as diffusion tensor analysis are presented, which could expand the use of quantitative MRI variables as a complementary assessment for clinical diagnosis.

Direct Repair of Spent Li-ion Batteries

Zheng Liang[1,2]

[1]*Frontiers Science Center for Transformative Molecules, Shanghai Jiao Tong University, Shanghai, China*
[2]*Shenzhen Recycle Energy Tech. Co., Ltd.*

Abstract:

With the development of renewable energy industry, the use and waste of lithium-ion batteries are increasing day by day. China relies heavily on imported lithium and cobalt resources, so it is of strategic significance for the renewable energy industry to develop battery recycling technique and realize resource sustainability. The existing pyrometallurgical and hydrometallurgical recycling methods are based on molecular structure destruction and re-extraction, which requires extreme conditions, such as high temperature and corrosive agents, to destroy the molecular structure because the covalent bonds in the cathode materials are very stable, and the subsequent separation and extraction steps are lengthy. As a result, the overall economic and environmental benefits need to be improved. The direct repair method has a greater potential to repair battery materials especially cathode materials at the molecular scale and shorten the recovery process from the principle. However, due to the lack of understanding of the mechanism, the existing direct repair method takes "lithium replenishment" as the only means and simply borrows the existing lithium replenishment method, ignoring the series of problems caused by the continuous phase transition in the actual material failure process, so its actual large-scale application has not been reported yet. After a long period of research, the applicant realized that direct repair is the inverse process of material failure, and the key is to deeply reveal the mechanism of continuous phase transition during the failure process, so as to guide the design of recycling methods that can be applied on a large scale, and finally realize the direct repair of actual end-of-life battery materials.

Study of hole transport layer for highly efficient Sn-Pb perovskite solar cells

Dong Hoe Kim

Department of Materials Science and Engineering, Korea university, Seoul, Republic of Korea

Abstract:

Due to their unique bandgap tunability and excellent optoelectrical properties, perovskites are an attractive choice as ideal light-absorbing materials for next-generation solar cells. Among the various types of perovskites, those with a mixture of tin (Sn) and lead (Pb) in the B-site have a narrow band gap. This allows them to absorb light up to the near infrared. Theoretically, this means that they could be used to make single-junction solar cells with higher efficiency than Pb-based perovskite solar cells. In addition, they could be part of tandem solar cells that exceed 30% efficiency. As a result, narrow bandgap perovskites have gained importance in perovskite solar cell research. So far, the efficiency of Sn-Pb perovskite solar cells has reached up to 24.5%. For further breakthroughs, it's critical to look at the interface between the materials.

For example, poly[3,4-ethylene dioxythiophene]-poly[styrene sulfonate] (PEDOT:PSS) has been commonly used as a hole transport layer (HTL) from the beginning because it matches the energy levels well. However, the PEDOT:PSS has several drawbacks such as acidic nature, sensitivity to moisture, and its relatively lower electrical conductivity for hole transport. These issues mainly lead to a less ideal buried interface with Sn-Pb perovskite, making it less efficient compared to Pb-based perovskites.

In this talk, I will present how we have tried to solve such problems on the hole transport layer in Sn-Pb perovskite through i) additives, ii) surface treatment of the PEDOT:PSS and iii) introduction of alternative HTLs for the Sn-Pb perovskite. I believe that the results of these studies on the hole transport layer will provide some insights to open the next chapter of Sn-Pb perovskite research.

Biography:

Dong Hoe Kim is an associate professor in Department of Materials Science and Engineering at Korea University. He received his Ph.D. (2015) from Seoul National University. He worked at the NREL as a postdoc and researcher III from 2015 to 2019. His research interests include organic and inorganic hybrid material synthesis and their application on various types of perovskite solar cells, such as single junction, all-perovskite tandem solar cells, and perovskite/Si tandem solar cells.

Rational Backbone Planarization toward Doping-Resilient Polymeric Hole Transport Layers for Scalable Perovskite Solar Cells

Minjun Kim*

Department of Chemistry, Kyonggi University, Suwon, Gyeonggi-do 16227, Republic of Korea

Abstract:

As perovskite solar cells (PSCs) move closer to practical deployment, hole-transport materials (HTMs) that combine long-term operational stability with large-area processability are critically needed. A major limitation of conventional polymeric HTMs lies in their strong sensitivity to dopant concentration, which often leads to heterogeneous dopant distributions, charge localization, and poor reproducibility, particularly under high dopant loading and scalable processing conditions.

Here, we present a backbone-engineering strategy to address these challenges through the design of PDVB14, a PTAA-derived random copolymer incorporating planar divinylbenzene (DVB) units. PDVB14 is synthesized via a compositionally reliable Buchwald–Hartwig C–N cross-coupling approach, enabling precise structural modulation while maintaining synthetic robustness. The introduction of DVB units enhances backbone planarity and electronic coherence, stabilizing radical-cation states and suppressing charge localization upon chemical doping. In addition, controlled short-range π-aggregation supports efficient and stable hole transport across a broad dopant concentration range.

When employed as a hole-transport layer in PSCs, PDVB14 exhibits minimal performance dependence on dopant concentration and consistently delivers high power conversion efficiencies. This doping-resilient behavior is retained in large-area devices (1.0 cm^2), demonstrating the scalability of the material platform. PDVB14-based devices also show significantly improved thermal, photochemical, and humidity stability compared to PTAA-based counterparts. Dopant-distribution mapping further reveals highly uniform lithium profiles across centimeter-scale films, providing direct evidence of improved dopant homogeneity under solution processing.

Overall, this work demonstrates how rational backbone planarization can overcome intrinsic structural and electronic limitations of PTAA, offering a robust molecular design framework for stable, doping-resilient, and manufacturing-compatible polymeric HTMs for next-generation perovskite photovoltaics.

Electrochemical Properties of C-Si-N Ternary Composites as Negative Electrodes for Lithium-ion Batteries

Jeewon Jang*, Seongwoo Lee, SangyupLee*, and Soon-Ki Jeong*

Department of Energy Engineering, Soonchunhyang University, 22, Soonchunhyang-ro, Sinchang-myeon, Asan-si, Chungcheongnam-do 31538, Republic of Korea

Abstract:

Silicon-based anodes offer high theoretical capacity but suffer from extreme volume expansion and low conductivity, limiting practical use. This study investigates nitrogen-containing C–Si–N ternary composite electrodes designed to mitigate these issues. We fabricated a previously unreported multi-phase core–shell structure with a conductive graphite core, a Si-rich intermediate layer, and an N-rich outer layer formed via simultaneous nitridation and carbonization, producing a mechanically reinforced and chemically stable multi-layer shell distinct from conventional single-layer coatings.

C–Si–N electrodes were synthesized and evaluated in 2032-type coin cells (0.01–1.5 V, CC-CV/CC), with cyclic voltammetry at 0.5 mV s^{-1} in a three-electrode cell. FIB-SEM confirmed the graphite-core, multi-phase shell, while XPS and XRD verified SiNx and carbon layers.

Electrochemical testing revealed significantly reduced structural degradation and volume expansion compared to C–Si electrodes, attributed to the mechanically protective SiNx shell and stabilized SEI. Nitrogen-content variation enabled identification of the optimal composition. These results demonstrate that graphite-core, multi-phase C–Si–N composites provide a stable and high-performance platform for next-generation silicon-based anodes.

Polysaccharide/Molecularly Imprinted Polymer Composite Hydrogel Beads as Selective Tetracycline Adsorbents

Joanna Kurczewska

Adam Mickiewicz University, Faculty of Chemistry, Poznań, Poland

Abstract:

Tetracycline (TC) is a broad-spectrum antibiotic extensively applied in medicine and agriculture, resulting in its increasing concentrations in water and soil. Hydrogel beads are of great interest as potential adsorbents for various impurities. The rational design of hydrogel beads, based on natural polysaccharides and incorporating additional components, can substantially enhance their performance in targeted applications.

The aim of the present study was to obtain and characterize a series of alginate (ALG)- and chitosan (CS)-based hydrogel beads for TC removal from aqueous solutions and soil. The composite beads were formulated using ALG or CS matrices incorporating halloysite-supported molecularly imprinted polymers (Hal@MIP). Molecularly imprinted polymers (MIPs) represent a class of synthetic polymers engineered with selective recognition sites that are complementary in shape, size, and functional groups to the template molecules. Halloysite (Hal), a naturally occurring aluminosilicate clay, served as a solid support for the synthesis of MIPs. The adsorption properties of the composite beads were compared with those of pure ALG or CS beads, beads containing only Hal, and beads with non-supported MIPs. Halloysite contributed to enhanced thermal stability, improved accessibility of MIP binding sites, and reduced TC desorption from soil samples, while the MIPs provided molecular selectivity toward the target antibiotic. Importantly, the adsorbents retained their adsorption capacity in real water and soil samples. Finally, alginate demonstrated a substantial enhancement in adsorption capacity compared to chitosan.

The maximum TC adsorption capacity reached 281 mg g^{-1} for ALG_Hal@MIP. The high adsorption efficiency was attributed to pore filling, along with contributions from electrostatic interactions, complexation, hydrogen bonding, and π–π electron donor–acceptor interactions. These findings suggest that the selected composite hydrogel beads are promising and competitive materials for water purification and soil remediation.

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Lignite Based Bicyclo [3.3.1] Nonanes for Treating Neurodegenerative Diseases and Cashew nut Liquid Based "High ortho-novolacs" for Microelectronics and e-beam Lithography for Nano-Patterning and for Making Nano-devices

Sujeet Kumar Thakur[1] and Sambasivan Venkat Eswaran[2*]

[1]BEMMS(4C-1G), Foundation for Innovation and Technology Transfer, Indian Institute of Technology, Hauz Khas, New Delhi-110016, India
[2]Ex: Head (Chemistry Department) and Dean (Academics), St Stephen's College, Delhi, 110007; Hony. Prof. Amity University, Noida, Uttar Pradesh-201313, India; Ex-Adjunct Prof. (Hony.) Deakin University, Australia; Teri Deakin Nano Biotechnology Centre, Gwal Pahari, TERI Gram, Gurgaon, Haryana 122 002, India. Professor of Practice, KPRIET, Avinashi Road, Arasur, Coimbatore, 641407, India.

Abastract:

Lignite is being used all over the world for generating electricity but because of concerns about pollution its use is going to be banned in most countries. As this resource is available in plenty all over the world, there is an urgent need to develop alternative uses for this raw material.

Described here is the isolation/preparation of new bicyclo [3.3.1] nonanes (BCNs) based polymers/oligomers using lignite from Neyveli, Tamil Nadu, India. These have been characterized using modern spectroscopic techniques. Most useful is the analysis of an 'envelope' peak observed in its mass spectrum. Based on this, the molecular weight of the polymeric species has been determined ($\overline{Mn}$ =31217 2 and $\overline{Mw}$ =33393.1259) and polydispersity index (PDI=1.06). Similarly, 'pentameric' and 'oligomeric' BCN have been isolated and these are water soluble. On the basis of computational studies these are expected to be good candidates for treating neurodegenerative diseases (like Alzheimer's, Parkinson's, Dementia & Huntington's Diseases).

These show a Ninhydrin positive test and thus, these are non-proteinogenic amino acid (NPAA) units, previously not described in literature. Some of these have been upscaled by us to the tune of a few kilograms. These compounds possess mild anti-viral activity and show anti-bacterial activity against both Gram positive & Gram-Negative bacteria and thus could be used for producing anti-bacterial coated fabrics.

'Auf-28', lignite from Germany has given similar results, the isolated compound which is again water soluble has been characterized spectroscopically and this also shows the 'envelope' peak in its mass spectrum. (Analysis gave $\overline{Mn}$ = 20053.26 and $\overline{Mw}$ =20160.46 and PDI=1.005)
Cashew Nut Shell Liquid (CNSL) is available in considerable quantities, not only in India but also in Thailand, we have successfully prepared "high ortho-novolac" resins using a two-step procedure, the polymer has been characterized using most spectroscopic techniques,

particularly useful in these cases have been the use of Gel-Permeation Chromatography (GPC), Nuclear Magnetic Resonance (NMR) Spectroscopy and the observation of an 'envelope' peak in its mass spectrum. (Analysis of the latter has given, $\overline{Mn}$ = 23728.84 value and $\overline{Mw}$ =23855.15 and polydispersity index (PDI=1.005). These have been used by us for doing photo-microlithography and for use in microelectronics. The t-BOC derivatives of the same are candidates for e-beam lithography (EBL) for nano-patterning and for making nano-devices.

We seek international collaboration for upscaling and for industrial use of our work.

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Biogenic Cockle-Derived Calcium Chloride: A Potential Agent For Biomedical Applications

Bridget C.N. Obitte[1]* and Fabian .I. Ezema[2] and Eva Hemmer[3]

[1]*University of Nigeria, Nsukka, Department of Science Laboratory Technology, Enugu, Nigeria*
[2]*University of Nigeria, Nsukka, Department of Physics and Astronomy, Enugu, Nigeria*
[3]*University of Ottawa, Department of Chemistry and Biomolecular Sciences, Ottawa, Canada*

Abstract:

Cockle shell (Tegillarca granosa) of biogenic origin, often considered waste material, rich in calcium carbonate ($CaCO_3$), abundant and low-cost was used to synthesize calcium chloride ($CaCl_2$) via the acid precipitation method. The aim of this work is to synthesize, and optimize calcium chloride ($CaCl_2$) from cockle shell $CaCO_3$ entrapped in UCNPs synthesized by solvothermal technique for biomedical applications. X-ray diffraction (XRD), scanning electron microscopy (SEM), and photoluminescence spectra were used to characterize the samples. The results were compared with the commercial $CaCl_2$. The XRD results revealed that the synthesized $CaCl_2$ was of the dihydrate form. Samples L3 (commercial) and E2 (cockle) were indexed with prominent β-phase and a minor α-phase at 27.24º with peak orientation at (111). Average crystallite size for L3, E2, and L9 are 17.26, 26.57 and 17.08 nm respectively. E2 and L9 had strongest PL compared to L3 with $CaCl_2$ of 0.05g, 0.0g and 0.1g resp. SEM images of L3 and L9 are a combination of nanorods and spherical with intra-agglomeration pores, while E2 is of spherical agglomerates. It can be concluded that the $NaYF_4$:Yb^{3+},Er^{3+}@unpurified$CaCl_2$ nanoparticles (E2) is a potential candidate for biomedical applications. Research is still ongoing on the formulated encapsulated microbeads for colon cancer targeting. Therefore, cockle-derived calcium chloride entrapped in UCNPs can serve as a potential agent for improved luminescence for bioimaging.

Development of A Serum-Derived Exosome Nanocarrier for Intracellular Delivery of Antibiotics Against Multidrug-Resistant *Escherichia Coli* Causing Neonatal Sepsis

Pallabi Chatterjee[1]*, Nimbal Kalita[2], Mukesh Kumar Gupta[2,3], Anamika Singh[2], and Utkarsh Jain[1]

[1]*School of Health Sciences & Technology, UPES, Dehradun, Uttarakhand – 248007, India*
[2]*Department of Biotechnology and Medical Engineering, National Institute of Technology (NIT) Rourkela, Odisha – 769008, India*

[3]*ICMR-National Animal Resource Facility for Biomedical Research (NARFBR), Genome Valley, Shamirpet (M), Hyderabad, Telangana- 500078, India*

Abstract:

Neonatal sepsis, a bloodstream infection affecting infants under 28 days, has a global incidence of about 3,930 per 100,000 live births and poses a greater threat in preterm infants, where early-onset cases often result from vertical transmission from the maternal genital tract. A major cause of early-onset neonatal sepsis is multidrug-resistant *Escherichia coli*, which primarily targets immune cells. Conventional high-dose antibiotic therapy increases adverse effects due to premature drug dissociation before cellular uptake. To overcome this limitation, exosome-based nanocarriers deliver antibiotics directly into cells, preventing systemic dissociation in the blood. This study explores the in vitro effectiveness of exosome-encapsulated colistin sulfate (ExoCol) against a multidrug-resistant Escherichia coli strain associated with neonatal sepsis. Human serum-derived exosomes, sized 30-150nm and biocompatible, were engineered to encapsulate colistin sulfate and characterized using various methods. The therapeutic potential of ExoCol was tested in RAW264.7 macrophages, confirming cellular uptake through confocal microscopy and assessing cytotoxicity with the MTT assay. Antibacterial effects against intracellular MDR E. coli were evaluated through CFU quantification, kill efficiency analysis via heat maps, live/dead imaging, and flow cytometry for bacteria quantification. After 24 hours of the treatment, ExoCol-treated cells maintained higher cell viability (80-90%) than the free antibiotic-treated cells (60-80%), and ExoCol demonstrated significantly greater intracellular drug release (88-97%) as compared to free colistin (20-50%). Moreover, ExoCol eradicated more intracellular bacteria (4 $\log_{10}$ CFU/ml) than the free colistin (1 $\log_{10}$ CFU/ml). Conclusively, these findings imply that antibacterial therapy mediated by exosomes decreases cytotoxicity and increases bacterial eradication with significant intracellular delivery. Therefore, ExoCol approaches as a promising nanotherapeutic for the treatment of neonatal sepsis. Future studies will involve *in vivo* models for further dose optimization, validate therapeutic efficacy and treatment strategies.

Enhanced Acute and Late Performances of Everolimus-eluting Bioresorbable Scaffold with 100-µm Strut in a Rabbit Iliac Artery

Dong Sung Won[1,2*], In Ho Lee[1], Ji Won Kim[1,2] Kang-Sik Lee[1] and Jung-Hoon Park[1,2]

[1]*Biomedical Engineering Research Center, Asan Institute for Life Sciences, Asan Medical Center, Seoul, Republic of Korea*

[2]*Department of Convergence Medicine, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Republic of Korea*

Abstract:

Purpose: Drug-eluting bioresorbable scaffolds (BRSs) have demonstrated promising results in clinical trials; however, the treatment mechanisms thin-strut drug-eluting BRSs for peripheral artery disease (PAD) have not yet been elucidated. This study investigated the efficacy and safety of the 100-µm strut everolimus-eluting BRS for treating PAD using a porcine arteriovenous shunt model and rabbit iliac artery balloon-injury model. Materials and Methods: The BRS was manufactured using a poly-L-lactic acid (PLLA) polymer with 2.75 mm diameter, 8 mm length, and 100-µm and 150-µm strut thickness. Everolimus (118 µg/cm2) was coated using an ultrasonic spray. Acute platelet and inflammatory cell adhesion were assessed using three porcine arteriovenous shunt model. Ten rabbits underwent 100-µm strut BRS placement after the balloon-injured procedure. Five rabbits sacrificed at 1-month and the remaining five at 6-months. The BRS performances were accessed by degradation behavior, platelet/macrophage aggregation, angiography, optical coherence tomography (OCT), histological, and immunofluorescence analysis.

Results:

Acute inflammation including neutrophils and monocytes cell adhesion was significantly lower in the 100-µm strut BRS than those in the 150-µm strut BRS ($p < 0.05$) in arteriovenous shunt model. The mean stenotic area and neointimal thickness did not differ significantly between 1- and 6-months in OCT analysis. Furthermore, the percentage of degradation after 6- months was significantly higher than after 1-month ($p < 0.001$). The histological findings in the degree of inflammatory cell infiltration at 1-month was significantly higher than that at 6 -onths ($p < 0.05$). In addition, CD68-positive and VCAM-1-positive cell deposition was significantly lower at 6-months than at 1-month ($p < 0.001$).

Conclusions:

The 100-µm strut everolimus-eluting BRS effectively inhibited acute thrombosis with inflammatory adhesion compared with the 150-µm strut. The BRS patency was successfully maintained for 6 months in the rabbit arterial hyperplasia model. The 100-µm strut everolimus- eluting BRS appears to be effective and safe for treating PAD.

Biography:

Dong-Sung Won, Ph.D. is Postdoctoral Researcher of Asan Medical Center in Korea. He received his master's and doctor of philosophy (PhD) degrees at a University of Ulsan College of Medicine

Effects of CHDM Chain Extender Composition on Properties of Bio-based TPU

B. Cho[1*], D. Kim[1] and D. J. Lee[1**]

[1]*Korea Institute of Materials Convergence Technology, Danggamseo-ro 152, Busanjin-gu, Busan, Republic of Korea*

Abstract:

This study investigates the effect of chain extender composition on the mechanical properties of bio-based thermoplastic polyurethanes (TPU). Bio-based TPU have attracted increasing attention as sustainable alternatives to petroleum-based elastomers; however, changes in segment interactions caused by bio-based polyols often lead to difficulties in achieving reliable property control. To address this issue, TPU were synthesized using mixed chain extender systems composed of linear 1,4-butanediol (BDO)) and 1,4-cyclohexanedimethanol (CHDM), with the CHDM content systemically varied from 0 to 50 mol%. All samples were prepared via a conventional prepolymer method under identical processing conditions to isolate the effect of chain extender composition. Mechanical properties were evaluated focusing on tensile strength and elongation at break. As the CHDM content increased, tensile strength improved up to an intermediate composition, while elongation at break gradually decreased. This behavior is attributed to increased hard-segment rigidity induced by the incorporation of cyclic chain extenders, resulting in a trade-off between strength and elongation was observed in the intermediate CHDM composition range of 25-37.5 mol%. These results demonstrate that the mechanical performance of bio-based TPU can be effectively tailored through precise control of chain extender composition, providing useful guidelines for the design of sustainable TPU materials.

Cellulose Nanofiber Aerogel from Banana Peduncle/Carbon Nanomaterials As Bio-Adsorbents for Effective Adsorption of Heavy Metal Ions

Anjar Priyatmojo[1], Moch Saifur Rijal[1], Humam Eddy Prabowo[2], Arie Wibowo[3,4], and Lia A.T.W. Asri[4,*]

[1]*Doctoral Program of Materials Science and Engineering, Faculty of Mechanical and Aerospace Engineering, Institut Teknologi Bandung, Bandung, West Java, Indonesia*
[2]*Extraxtive Metallurgical Technology Study Program, Faculty of Vocational Study, Hasanuddin University, Makassar, South Sulawesi, Indonesia*
[3]*Material Science and Engineering Research Group, Faculty of Mechanical and Aerospace Engineering, Institut Teknologi Bandung, West Java, Indonesia*
[4]*Research Center for Nanoscience and Nanotechnology, Institut Teknologi Bandung, Bandung, Indonesia*

Abstract:

Heavy metal pollution from industrial activities can pose significant environmental and health risks due to the toxic and carcinogenic properties of heavy metals. Therefore, measures are needed to reduce, or even eliminate, heavy metal content in polluted water. The adsorption method remains in use today, requiring effective adsorbent materials to bind metal ions. This study aims to develop a cellulose nanofiber-based aerogel derived from banana peduncle waste, incorporating graphene oxide (GO) and carbon dots (CDs) as bio-adsorbents for Pb(II), Cd(II), and Cr(VI) ions. Scanning electron microscopy analysis confirmed that conventional and unidirectional freeze-drying methods produced irregular and anisotropic pores, respectively. The addition of GO and CDs enhanced pore wall density and interconnectivity while preserving the directional pore orientation modulated by the freezing method. Porosity values were higher for anisotropic pore aerogels compared to irregular pore aerogels, with the CNF+2GO anisotropic aerogel achieving the highest porosity of 98%. Anisotropic pore structures consistently outperformed their irregular counterparts across all metal ions and adsorbent compositions, owing to enhanced mass transfer and greater active-site accessibility. The incorporation of GO and CDs substantially improved adsorption capacity compared to pristine CNF aerogels, with GO exhibiting superior performance due to its higher initial concentration (10 mg/mL vs 4 mg/mL for CDs). Based on the Langmuir isotherm model, the anisotropic CNF+2GO aerogel showed the highest adsorption capacity for the three metal ions tested, namely 47.17 mg/g for Pb(II), 24.75 mg/g for Cr(VI), and 19.08 mg/g for Cd(II). In conclusion, this study successfully developed a sustainable bio-adsorbent from banana stalk waste, offering a promising and environmentally friendly approach to reducing heavy metal pollution in water.

Keywords: cellulose nanofiber; aerogel; heavy metal; adsorbent

Molecular Dynamic Study of PEGDE/Ionic Liquid Based Electrochemically Debondable Epoxy Adhesive Systems

Taeyoung Yoon

Changwon National University, Changwon, South Korea

Abstract:

Electrochemically debondable adhesives (EDA) have emerged as a promising strategy for improving the recyclability and repairability of electric vehicle (EV) battery systems. In this study, we investigate the molecular dynamics (MD) behavior of a PEGDE-based ionic liquid epoxy system to elucidate the ion transport mechanisms and structural characteristics responsible for electrochemical debonding performance. The epoxy network is formulated with YD-128 resin, GO-A3533 curing agent, and EMIM-TFSI ionic liquid, while polyethylene glycol diglycidyl ether (PEGDE) is incorporated at various weight fractions (0–20 wt%) to modulate network flexibility and ion conduction pathways. All-atom MD simulations are performed following crosslinking of 60–70% and equilibration at NVT conditions, with analysis focused on mean square displacement (MSD), diffusion coefficients, ion cluster distribution, and ionic conductivity derived via the Nernst–Einstein relation. The results reveal a strong dependence of ion mobility on PEGDE content. Both cationic and anionic MSD values increase with PEGDE addition, leading to enhanced diffusion coefficients particularly at intermediate PEGDE levels. Ion cluster analyses show that PEGDE disrupts ion aggregation, increasing the proportion of free ions while reducing the formation of large ionic clusters. Correspondingly, ionic conductivity exhibits a non-linear trend, achieving its maximum at 10 wt% PEGDE, where the free-ion fraction is also the highest. Excessive PEGDE leads to diminishing conductivity due to network over-plasticization. Preliminary experimental validation supports the computational findings. Mechanical testing (stress–strain and shear strength) confirms reduced adhesion strength upon voltage application, consistent with enhanced ion mobility enabling electrochemical debonding. A debonded metal surface after redox activation further demonstrates the practical applicability of the proposed EDA system. Overall, this study provides a molecular-level understanding of PEGDE-dependent ion transport and its critical role in the electrochemically triggered debonding behavior of EDA materials. The insights gained offer design guidelines for next-generation recyclable adhesive systems for EV battery technologies

Active Hyperparameters Training in Adaptive Physical Neural Networks

Sheng-Chung Chen[1]*, Shih-Chuan Hung[2], Sheng-Ting Huang[2], and Der-Hsien Lien[2]

[1]*Institute of Pioneer Semiconductor Innovation, National Yang Ming Chiao Tung University, Hsinchu, Taiwan*

[2]*Institute of Electronic, National Yang Ming Chiao Tung University, Hsinchu, Taiwan*

Abstract:

Deep learning has become a fundamental technology for artificial intelligence, enabling a wide range of applications including image recognition, autonomous systems, and intelligent sensing.

However, the continued scaling of deep learning models is increasingly constrained by the high energy consumption and hardware overhead associated with GPU-based digital computation, particularly for edge and resource-limited platforms. This work presents a physical neural network that directly exploits semiconductor devices to perform both linear and nonlinear neural operations within the same physical framework. Unlike conventional digital implementations, where weight multiplication, bias addition, and activation functions are executed separately on GPUs, the proposed approach leverages the intrinsic electrical behavior of transistors to realize these functions in the analog domain. Specifically, transistor-based devices are employed not only as tunable activation functions, utilizing their nonlinear current– voltage characteristics, but also as circuit elements that naturally implement multiplication and addition corresponding to neural network weights and biases. By adjusting device operating parameters such as the drain voltage, the degree of nonlinearity can be continuously tuned, enabling the physical realization of commonly used activation functions, including ReLU-, sigmoid-, and softmax-like responses.

Meanwhile, linear transformations are inherently performed through device-level current summation and voltage modulation. This unified physical computing paradigm effectively combines the functionality of linear layers and activation layers into a single hardware block, substantially reducing the dependence on GPU-based computation. As a result, the proposed physical neural network lowers energy consumption, reduces data movement overhead, and accelerates training convergence by embedding computation directly into device physics. These advantages demonstrate that physical neural networks with device-level linear and nonlinear co-processing offer a promising and energy-efficient alternative to conventional deep learning architectures, particularly for edge computing, autonomous vehicles, and robotic systems where power efficiency and hardware compactness are critical.

Monolithic 3D CFETs with Reversible Stacking for Logic and Memory Integration

Tzu-Ting Weng[1]*, Yu-Lun Chueh[2] and Der-Hsien Lien[1]

[1]*Institute of Electronics, National Yang Ming Chiao Tung University, Hsinchu, Taiwan*
[2]*Department of Materials Science and Engineering, National Tsing Hua University, Hsinchu, Taiwan*

Abstract:

Monolithic three-dimensional integration has emerged as a transformative approach to overcome the physical and architectural limitations of planar device scaling. By enabling nanoscale vertical stacking of transistors with fine-pitch interlayer connections, M3D integration provides a path toward high-density, energy-efficient logic and memory systems. However, its implementation is constrained by the strict back-end-of-line thermal budget, which must remain below 400 °C to prevent degradation of underlying interconnects and device layers. This challenge necessitates the development of low-temperature, CMOS-compatible materials and processes. In this work, we present a monolithic 3D complementary field-effect transistor architecture employing low-temperature-deposited n-type indium oxide (In_2O_3) and p-type tellurium (Te). In_2O_3 thin films are deposited by atomic layer deposition at 250 °C, while Te is grown via cryogenic thermal evaporation at −80 °C. This combination enables a reversible stacking scheme, supporting both n/p and p/n configurations. Using these materials, we realize CMOS inverters, multilayer logic stacks, and a fully functional monolithic 3D static random-access memory cell, all fabricated at temperatures below 300 °C—fully compliant with BEOL integration requirements.

Fluorine-Free Siloxane-Polymer Hetero-structured Binder Enabling Durable High-Voltage Ni-Rich Cathodes

Hyeon-Gyun Im*, Dong Jun Kang, and Junho Jang

Korea Electrotechnology Research Institute (KERI), Changwon-si, Kyungsangnam-do, Republic of Korea

Abstract:

We introduce a fluorine-free, quasi-interpenetrating siloxane–polymer hetero-structured binder made by in-situ sol–gel process. Its strong interactions and robust Si–O–Si network improve adhesion and structural integrity, enabling durable high-voltage performance and practical loading operation in Ni-rich cathodes.

A Fluorine-Free Siloxane Nanohybrid-Type Binder Enabling Highly Stable Ni-Rich Layered Cathodes in Lithium-Ion Batteries

Junho Jang[1]*, Dong Jun Kang[1] and Hyeon-Gyun Im[1]

[1]*Insulation Materials Research Center, Electrical Materials Research Division, Korea Electrotechnology Research Institute (KERI), Changwon-si, Kyungsangnam-do, Republic of Korea*

Abstract:

This work presents a fluorine-free siloxane nanohybrid (SNH) binder engineered to enhance the performance and stability of Ni-rich layered cathodes in lithium-ion batteries (LIBs). Traditional poly(vinylidene fluoride) (PVDF) binders often suffer from weak adhesion and limited interfacial compatibility with cathode materials, which restricts their electrochemical performance. In contrast, the proposed SNH binder, enriched with hydroxyl functional groups, forms a robust organic–inorganic nanohybrid network that improves the interfacial stability and mechanical integrity of $LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$ (NCM811) cathodes. The strong interactions between the SNH binder, the active material, and the conductive network promote homogeneous electron and ion transport, while also reducing undesirable side reactions such as transition-metal dissolution. These features lead to significantly improved structural retention and interfacial stability during prolonged charge–discharge cycling. The SNH binder also suppresses structural degradation and mitigates the formation of unstable interphase species through its high silanol content and chemically stable backbone. Electrochemical evaluations demonstrate that electrodes utilizing the SNH binder exhibit markedly enhanced cycling stability and rate performance compared with those employing conventional fluorinated binders. Moreover, the SNH binder enables more uniform cathode–electrolyte interphase formation, effectively maintaining the structural robustness of Ni-rich cathodes under demanding operating conditions. Overall, the SNH binder provides a promising fluorine-free alternative to conventional PVDF systems, offering a simple and efficient strategy to improve the durability and energy performance of high-energy LIBs.

Tunable Interfaces In Nanolayered Bimetallics

Irene J. Beyerlein
Materials Department, Department of Mechanical Engineering, UCSB, Santa Barbara, USA

Abstract:

Bimetallic nanolayered materials are advanced materials known for their exceptional mechanical strength, radiation damage tolerance, and thermal stability. In this talk, we will focus on the mechanical behavior of nanolayered metallic composites made with extraordinarily "thick" biphase interfaces. We will discuss efforts to characterize and design the morphology, size, and chemistry of the interface, especially in its third dimension (normal to the interface plane). Results from a phase field model developed to simulate the dynamic interactions of individual dislocations and these three-dimensional interfaces under applied stress will be presented. The talk will share our experimental and computational findings to date, which indicate that strength, strain delocalization, and dislocation/interface interactions are sensitive to interface thickness and through-thickness chemical gradients. We will conclude with a discussion on the intriguing possibility to design heterostructured thick interfaces to attenuate strain concentrations and postpone instabilities without sacrificing strength.

Poly(2-oxazoline)s as Multifunctional Polymers for the Synthesis of Functional Adsorbents in Environmental Applications

Michał Cegłowski

Department of Supramolecular Chemistry, Faculty of Chemistry, Adam Mickiewicz University, Poznań, Poland

Abstract:

The increasing presence of organic contaminants, such as herbicides, pharmaceuticals, and explosives in water sources, is a serious environmental challenge. Standard analysis methods are accurate but often slow, expensive, and require difficult sample preparation. To address these issues, new functional adsorbents based on poly(2-oxazoline)s (PAOx) and polyethyleneimine (PEI) have been developed. PAOx is synthesized through cationic ring-opening polymerization, a method that allows for precise control over the polymer chain length and structure. These polymer backbones are then modified using simple chemical reactions, such as the addition of amines or "click" chemistry, to insert specific functional groups that improve how the material interacts with target molecules.
Research focuses on producing two specific types of materials: Molecularly Imprinted Polymers (MIPs) and porous polymers made by High Internal Phase Emulsion (HIPE). The MIPs are designed with specific molecular recognition cavities that exhibit high affinity and selectivity for target molecules, significantly outperforming non-imprinted control polymers. HIPE materials are created by polymerizing a mixture where solvent droplets are trapped inside a continuous phase, resulting in a highly porous, sponge-like structure with a large surface area.

A key innovation of this work is the synergistic coupling of these adsorbents with ambient ionization mass spectrometry, specifically Flowing Atmospheric-Pressure Afterglow (FAPA-MS). This approach integrates selective analyte preconcentration directly on the polymer with rapid, direct-readout quantification, effectively eliminating extensive sample preparation steps. We demonstrate the successful application of this methodology for the sensitive detection of diverse analytes, including herbicides (e.g., 2,4-D, 2,4,5-T), polyfluoroalkyl substances (e.g., PFOS), and explosives (e.g., RDX, PETN). The engineered MIPs exhibit very low detection limits (LODs) and high recovery rates in complex matrices such as river water and wastewater, establishing a powerful strategy for next-generation environmental monitoring.

Enhanced Pb(II) Removal from Water using a Compressible Bio-inspired Adsorbent

Maximilien Masquelier[1,2], Loïc Jierry[2] and Caroline Bertagnolli[1]*

[1]*Strasbourg University, CNRS, IPHC UMR 7178, F-67000, Strasbourg, France*
[2]*Institut Charles Sadron, UPR 22, F-67034 Strasbourg Cedex 2, France*

Abstract:

Efficient recovery of metal ions from water has become a critical challenge due to both their environmental impact and their growing economic value. Increasing demand for critical metals, combined with stricter environmental regulations highlights the urgent need for sustainable and high-performance technologies for trace metal removal from wastewater. In this context, adsorption-based processes using innovative materials offer promising alternatives to conventional separation techniques. Recent studies have demonstrated that open-cell polymer foams coated with bio-inspired polyphenolic films exhibit excellent adsorption properties toward metal ions [1,2]. Their intrinsic compressibility represents a major advantage, as it does not hinder performance but instead enhances the specific adsorption surface within a given volume. Inspired by recent advances in catalysis showing that compression of solid supports can intensify reaction and coating processes [3], this work investigates the use of mechanical compression to intensify sorption phenomena. An elastic sorbent was developed by depositing a non-toxic polydopamine (PDA) coating onto a melamine open-cell foam. Pb(II) ions were selected as a model contaminant to establish a proof of concept. The preparation and physicochemical characterization of the sorbent were carried out, followed by adsorption and desorption studies. In batch experiments under stirring, the sorbent exhibited an adsorption capacity of 248 $mg \cdot g^{-1}$. A custom-designed compression device enabled precise control of compression ratio and frequency allowing investigation of adsorption kinetics and efficiency under compression–relaxation cycles. The results demonstrate that controlled compression significantly enhances mass transfer, adsorption kinetics, and desorption efficiency compared to static conditions. This approach highlights the strong potential of compressible, bio-inspired sorbents for process intensification and sustainable trace metal recovery from water.

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Multiscale Investigation of [DBNH][Maba] (3-Methylaminobutanoate) Protic Ionic Liquid for CO_2 Capture: Insights from MD and DFT

Rohit Srivastava[1]*, Dhyani Vadgama[2], Vaishnavi Khalas[3], and Satyam Shinde[4]

[1]*Pandit Deendayal Energy University, Gandhinagar, Gujarat, India*

Abstract:

Amino acid-based protic ionic liquids (PAAILs) have emerged as sustainable alternatives for carbon capture due to their biodegradability, tunable structures, and strong CO_2 affinity. In particular, the [DBNH][Maba] system, comprising 1,5-diazabicyclo[4.3.0]non-5-enium ($DBNH^+$) and 3-(methylamino)butanoate ($Maba^-$), is important because $DBNH^+$ acts as a strong organic base with high proton affinity, while $Maba^-$ provides an amino-functional site that enhances CO_2 reactivity and selectivity. This study employs a combined Density Functional Theory (DFT) and Molecular Dynamics (MD) approach to unravel the molecular-level interactions and thermodynamic properties of [DBNH][Maba]. DFT calculations examine the adsorption energy, charge transfer, and orbital interactions between CO_2 and the ionic liquid, confirming favourable binding through carbamate-like and zwitterionic mechanisms. MD simulations explore physical absorption, diffusion coefficients, and temperature-dependent viscosity, emphasising the influence of side-chain flexibility and hydrogen bonding on CO_2 transport and capture performance. The amino-bearing anion ($[Maba]^-$) notably enhances ion mobility and creates favourable microenvironments for CO_2 approach, as indicated by radial distribution functions, residence-time analyses, and cluster dynamics. Overall, [DBNH][Maba] demonstrates a low-energy, reversible CO_2 capture mechanism, positioning it as a strong candidate for both direct air capture and flue gas treatment. This work provides molecular insight that guides the design of next-generation amino acid ionic liquids for environmentally sustainable carbon sequestration.

Thermoplastic Composite Materials for Hydrogen Storage Under Pressure

Larbi Jaffel[2], Noamen Guermazi[2], Monia Grabow[1], Marc Jaouen[1], Cyran Le Guennec[1], and Yves Grohens[1]

[1]*ComposiTIC platform, Université Bretagne Sud, 2 allée Copernic, 56270 Ploemeur, France*
[2]*LGME lab, National Engineering School of Sfax, University of Sfax, 3038 Sfax, Tunisia*

Abstract :

This presentation focuses on innovative solutions for hydrogen storage within the context of the energy transition. Thermoplastic composite materials emerge as promising candidates due to their lightweight, strength, and recyclability for future pressure hydrogen tanks.

The central issue addressed is the insufficient exploration of the impact of manufacturing processes on the mechanical properties of carbon fiber-reinforced for critical applications such as hydrogen tanks. Filament winding and wet layup methods show promise, but their influence on the performance and durability of the composites requires thorough investigation.

The objectives are to analyze manufacturing processes, to characterize materials for evaluating their mechanical properties, to understand how manufacturing parameters (temperature, speed, fiber orientation) influence final material properties, to optimize these processes, and to develop predictive models to simulate the mechanical performance of the composites.

The adopted methodology includes the development of prototypes for hydrogen tanks, conducting mechanical tests on fabricated samples, performing statistical analysis to establish correlations between manufacturing parameters and mechanical properties, as well as developing analytical or numerical models to simulate the behavior of the composites, accounting for fiber-matrix interactions and potential manufacturing defects.
The tanks produced are typically evaluated during burst tests and are instrumented to monitor their behavior under pressure. Various monitoring technologies can be employed to understand their failure modes, including strain gauge tracking, Acoustic Emission (sensors on the tank and the walls of the burst chamber), video correlation, and Fiber Optics.

The expected impact is to shed light on how manufacturing processes affect the mechanical performance, optimize material design, and contribute to the development of more efficiente and durable hydrogen tanks. Such advancements are crucial for creating effective and economical hydrogen storage solutions essential for the transition to sustainable energy.

WS_2 & MoS_2 from 3D to 1D structures: Curvature and chirality induced properties of nanotubes

A. Zak[*1], M. Krishnappa[2], Y. Iwasa[3], A. Di Bartolomeo[4], Y. Gao[5], M. Bar-Sadan[6]

[1]*Holon Institute of technology, Holon, Israel;*
[2]*Nitte Meenakshi Institute of Technology, NITTE (Deemed to be University), Bangalore, India;*
[3]*The University of Tokyo, Tokyo, Japan;* [4]*University of Salerno, Salerno, Italy;*
[5]*Beijing Institute of Technology, China;* [6]*Ben-Gurion University of Negev, Beer-Sheva, Israel;*

Abstract:

Recent research on inorganic nanotubes (NTs) of WS_2 and MoS_2 has demonstrated that rolling the molecular layers into nanocylinders induces changes into crystalline structure, which endows the NTs with new properties, such as piezo-resistivity, programmable PVE, sliding ferroelectricity and memory ability. The discovery of bulk photovoltaic effect (BPVE) in INT-WS_2 demonstrates that the photocurrent in the nanotube-based device was orders of magnitude larger than in other BPVE materials. The BPVE does not require p–n junctions of traditional photovoltaic effect (PVE) for the generation of electric current, and occurs due to the intrinsic properties of INT-WS_2: small band gap (1.4-2.1 eV), broken inversion symmetry, and polar structure. This progress is significant for environmentally benign energy harvesting because the efficiency of PVE has been almost reached the theoretical limit. An exponential increase of the resistivity with tensile strain was demonstrated up to a recorded elongation of 16%, thereby making WS_2 NTs suitable for piezoresistive sensor applications. Notably, a fully functional artificial vision system has been demonstrated, leveraging the memory effect generated by programmable photoelectric responses and sliding ferroelectricity in multiwalled WS_2 nanotubes. High-density active sites on the surface of MoS_2 nanotubes demonstrate superior catalytic performance in electrochemical hydrogen evolution reactions (HER).

Dimensional Scaling Effects in Ultrathin Semiconductors

Der-Hsien Lien*

Institute of Electronics, National Yang-Ming Chiao Tung University, Hsinchu, Taiwan

Abstract:

Dimensional scaling fundamentally reshapes the physical properties of two-dimensional and ultrathin semiconductors, governing their optical and electrical properties. In layered materials such as TMDCs, reducing thickness enhances excitonic effects due to quantum confinement and reduced dielectric screening, which defines the optoelectronic performance of atomically thin 2D crystals. In contrast, disordered semiconductors exhibit percolation-limited transport, where scaling in all spatial dimensions alters the percolation threshold through path-confinement. This geometric constraint modulates the availability of conductive pathways and directly impacts threshold voltage and switching behavior. Percolation effects occurs at micrometer-scale dimensions, independent of electrostatic short-channel effects or quantum confinement. Experimental results from amorphous n-type and p-type transistors confirm a universal scaling behavior governed by their percolation behavior. In this talk, I show that dimensional scaling leads to distinct behaviors in ordered and disordered semiconductors, highlighting material topology as a critical factor for designing devices based on low-dimensional physics.

Programmable Patterning of Reconfigurable Microdroplets at surfaces

Young-Ki Kim[1]*
[1]*Department of Chemical Engineering, Pohang University of Science and Technology (POSTECH), Pohang, Gyeongbuk 37673, Republic of Korea*

Abstract:

Surface microdroplet of liquid crystals (LCs) is a promising optical platform that can manipulate characteristics of incident light via external stimuli, finding numerous optical applications. However, achieving organized arrays of LC microdroplets on a mass-scale remains a key challenge. Herein, we offer a simple and versatile strategy to form LC microdroplets at surfaces with precisely defined size, density, and lateral organization. We demonstrate a cycle of heating and cooling of a polymer matrix to cause diffusion and phase separation of LCs, leading to nucleation and growth of LC microdroplets on surfaces. The size and number density of microdroplets are controllable via temperature parameters. Especially, the nucleation location of LC microdroplets is found to be closely correlated with an LC-surface interfacial tension. By utilizing photo-sensitive surfaces, therefore, we can instantly form a multitude of LC microdroplets with a certain size specifically at pre-programmed locations. Moreover, the LC microdroplets' size, location, and internal organizations are reconfigurable, providing a new active element for existing and novel applications of surface microdroplets. This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (RS-2023-00302586, RS-2023-00212739, RS-2024-00411809).

Advanced Flexible Memristor RF Switch

Shih-Chieh Chen[1,2*], Yu-Tao Yang[3], Yun-Chien Tseng[1], Der-Hsien Lien[1,2]

[1]*Institute of Electronics, National Yang Ming Chiao Tung University, Hsinchu, Taiwan*
[2]*Institute of Pioneer Semiconductor Innovation, National Yang Ming Chiao Tung University, Hsinchu, Taiwan*
[3]*Strategic Technology Exploration Platform, MediaTek, San Jose, USA*

Abstract:

Next-generation wireless communication demands radio-frequency (RF) switches with high-frequency capability, low power consumption, and mechanical robustness, especially for flexible electronic systems. Here, we demonstrate a nanometer-scale oxide memristive RF switch based on a metal–insulator–metal structure incorporating a 5 nm hafnium oxide (HfO_2) active layer on a lithography-processable polyimide substrate. Owing to its intrinsic nonvolatile resistive switching behavior, the device operates with switching voltages below 1 V and maintains its impedance state without continuous power supply. The RF switch exhibits an ON-state resistance of ~32 Ω and an OFF-state capacitance of ~5.8 fF, corresponding to a cutoff frequency exceeding 840 GHz, with stable operation from 1 to 110 GHz, an insertion loss of ~2 dB in the ON state, and high isolation in the OFF state. The device maintains consistent electrical and RF performance after more than one million switching cycles and 2500 mechanical bending cycles. Furthermore, its process compatibility enables seamless integration with antennas in a 2.5D packaging architecture while preserving signal integrity. These results highlight the potential of nanometer-thick functional oxides for next-generation high-frequency and flexible electronic systems.

Sustainable CFRPs – biobased, reformable, and recyclable matrix materials via dual-chemistry vitrimers

William E. Dyer[1,2*], Niklas Lorenz[1], Baris Kumru[1], Shermin S. Goh[2]

[1]*Aerospace Structures and Materials, TU Delft aerospace engineering, Kluyverweg 1, 2629 HS, Delft, Netherlands.*

[2]*Institute of Materials Research and Engineering (IMRE), Agency for Science, Technology and Research (A*STAR), 2 Fusionopolis Way, Innovis #08-03, Singapore 138634, Republic of Singapore.*

Abstract:

Epoxy-amine resins are a leading plastic for CFRP composites, essential high-performance materials due to their high strength, stiffness, and ease of processability. Existing resins are petroleum-based, do not allow for reformability at end of life, and provide no route for recyclability under mild conditions. Additionally, fiber degradation from harsh conditions leads to a large loss of value as the fibers are the most energy-intensive component of CFRPs to produce. Biobased vitrimers present a potential alternative to this material wastage by enabling reformability and recyclability. Aromatic disulfide chemistry has been extensively explored due to its accessibility and compatibility with many epoxy systems, however degradation of the matrix network requires toxic reagents and limits their sustainability credentials. Recently silyl ether chemistry has been explored as a potentially dynamic bond for new vitrimer systems. Whilst relaxation is generally slow in silyl ether-containing networks they have the advantage of high mobility through rotation of the O-Si-O bonds and susceptibility to acid hydrolysis. These two properties could lead to enhanced resin characteristics and recycling capability. In this work a dual silyl ether/disulfide vitrimer is developed achieving thermomechanical properties comparable to existing thermosets including medium Tg (85-115 °C), stiffness of +3GPa, network relaxation, and recyclability at conditions below Tg (70 °C) and under mild conditions (acetone, 0.5M HCl). This more environmentally friendly recycling route is directly a result of the inclusion of silyl ether bonds in the network.

Epitaxial Metal/Semiconductor/Superconductor Heterostructures for Photonic, Plasmonic, and Quantum Applications

Shangjr (Felix) Gwo
Department of Physics, National Tsing-Hua University, Hsinchu 300044, Taiwan

Abstract:

Epitaxy is a crystal growth method, in which crystalline layers are formed with well-defined orientations with respect to the dissimilar crystalline structures of substrates (i.e., wafers). In electronic, photonic, and optoelectronic device applications, such as transistors, light-emitting diodes, and lasers, semiconductor heterostructures (quantum wells, nanostructures, and quantum dots) formed by epitaxy have been widely deployed as the high-performance device fabrication approach. In comparison, metal and superconductor structures used for plasmonic and quantum applications are typically made via less sophisticated material deposition methods. In the past decade, we have explored tunable and excellent material properties for plasmonic and quantum applications by using crystalline metallic and superconducting epitaxial films grown by molecular-beam epitaxy. In this talk, I will highlight the results of plasmonic metasurfaces and surface-enhance Raman spectroscopy substrates based on epitaxial metal films, including silver, aluminum, and titanium nitride. Furthermore, recent results of transition-metal and group-III nitride epitaxial structures consisting of superconductors, semiconductors, and metals, will be presented. Due to their exceptional and tunable properties, these epitaxial heterostructures can play a key role for demanding photonic, plasmonic, and quantum applications.

Biomimetic Nano-Coral SERS Platform: Four-Stage Optical Amplification for UltraSensitive Detection of Pesticide Leakage Pathways

Jinsung Park[1,2]*, Joohyung Park[1], Woochang Kim[1], Chihyun Kim[1], Hyunjun Park[1], Kyunghwan Chai[3], Gayoung Kim[3], Daeil Park[3], Wonjun Jo[2], Dayoung Chang[2], Chaeyoung Kang[2], Subeen Kim[2], and Deoeun Choi[1]

[1]*Department of Biomechatronics Engineering, Sungkyunkwan University, Suwon, Gyeonggi-do, Republic of Korea*
[2]*Department of MetaBioHealth, Sungkyunkwan University, Suwon, Gyeonggi-do, Republic of Korea*
[3]*Department of Biopharmaceutical Convergence, Sungkyunkwan University, Suwon, Gyeonggi-do, Republic of Korea*

Abstract:

This study presents the design of a bimetallic nano-coral structure inspired by the structural characteristics of deep-sea corals and its application as a Surface-Enhanced Raman Scattering (SERS) sensor. Corals thrive in extreme marine environments by maximizing nutrient absorption and photosynthetic efficiency through their highly porous architecture and large surface area. By emulating these natural features, we implemented a four-stage optical amplification strategy that integrates expanded optical cross-sections from two-dimensional nanopillar arrays, a gold/silver bimetallic composition for plasmonic enhancement, porous surface design for stronger analyte binding, and enlarged overall surface area for efficient adsorption. Electromagnetic simulations and experimental optimization verified significantly improved sensitivity and long-term stability compared with conventional nanostructures. The fabricated bimetallic nano-coral SERS platform was applied to the ultra-sensitive detection of thiram, a widely used but toxic pesticide. Laboratory testing confirmed an ultra-trace detection limit of 514.4 femtomolar (fM). More importantly, the sensor was validated in a series of realworld environmental matrices that mimic the actual contamination pathway through which pesticides can enter the human body. Specifically, thiram was detected in soil, river water, tap water, and finally drinking water—representing the sequential leakage and exposure route from agricultural fields to human consumption. In each stage, detection was achieved at concentrations well below the U.S. Environmental Protection Agency (EPA) safety threshold, underscoring the platform's reliability and practical relevance. In conclusion, this biomimetic strategy significantly advances SERS sensor technology by not only achieving record-level sensitivity but also demonstrating direct applicability to realistic contamination scenarios. The nano-coral platform therefore offers strong potential for real-time monitoring of hazardous pollutants, safeguarding both environmental quality and public health. Acknolwedgement This work was supported by the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (grant numbers: RS-2023-NR077066, RS-2024-00460957, RS-2024- 00438542, RS-2025-00561260, and RS-2025-00554830). Additional support was provided by the SMC-SKKU Future Convergence Research Program. Short Biography: Jinsung Park is a professor of Department of Bio-Mechatronic Engineering, Sungkyunkwan University, South Korea. He received B.S. and Ph.D. from Department of Mechanical Engineering, Korea University in 2007 and 2013, respectively. His research focuses on developing advanced biosensors and environmental sensors for healthcare and sustainability. This includes noninvasive diagnostic platforms for various biomarkers, multi-sensor systems for mental health monitoring, and sensor technologies for detecting environmental pollutants such as microplastics, heavy metals, and pesticides. He also explores nanostructure fabrication, electrochemical and SERS-based signal amplification, and AI-driven data analysis to enhance sensitivity, selectivity, and real-world applicability.

Antimony-Based Lead-Free Perovskite Thin Films for Highly Sensitive Ammonia (NH_3) Gas Detection

Myungkwan Song*

Energy & Environmental Materials Research Division, Korea Institute of Materials Science (KIMS), 797, Changwon-daero, Seongsan-gu, Changwon-si, Gyeongsangnam-do, 51508, Republic of Korea

Abstract:

Antimony (Sb)-based perovskite materials have emerged as promising alternatives to Pb halide perovskites for gas-sensing applications, offering reduced toxicity while maintaining high environmental sensitivity. Herein, we report a novel Sb-based perovskite, formamidinium $(FA)_3Sb_2Br_9$, as an environmentally friendly candidate for ammonia (NH_3) detection. $FA_3Sb_2Br_9$ can be synthesized *via* a simple solution-based method, and it exhibits high selectivity and sensitivity toward NH_3. Gas-sensing measurements revealed that the device showed a markedly higher response to NH_3 than to other gases, such as NO_x, CO, methanol, and methane. The device achieves a maximum gas response ($R = \Delta I(I_t - I_{air})/I_{air} \times 100$ (%) = 602.2, at 100 ppm NH_3), with a short response/recovery time (50.5/253.6 s), a low detection limit of 1 ppm, and excellent reversibility. Furthermore, the $FA_3Sb_2Br_9$ sensor demonstrated a linear dependence on the NH_3 concentration, long-term stability under ambient conditions over several months, and outstanding repeatability. These findings highlight the potential of Sb-based perovskites as promising materials for high-performance, Pb-free NH_3 gas sensors.

A Monolithic Graphene/Germanium Junction Field Effect Phototransistor

Zehao Song[1],*, Margarita Gindina[1], Liana Kartvelishvili[1], Vlad Kostianovski[1], and Ilya Goykhman[1],*

[1]*Institute of Applied Physics, Faculty of Science, and The Center for Nanoscience and Nanotechnology, Hebrew University of Jerusalem, Jerusalem, 91904, Israel*

Abstract:

Graphene photodetectors have attracted intense research interest owing to their unique opto-electrical properties, such as a broad optical response spectrum and high bandwidth. Nevertheless, the atomic thickness of single-layer graphene typically limits light absorption; it requires additional components to enhance absorption by integrating with a 3D bulk material, colloidal quantum dots, plasmonic nanostructures, or optical resonators. Meanwhile, CMOS compatibility and broadband spectral range in the short-wave infrared make Germanium a cost-effective, scalable material platform for spectroscopy and imaging. In this presentation, we will introduce a monolithic graphene/germanium junction field-effect phototransistor (JFET) realized by a standard CMOS fabrication process. Compared with conventional two-terminal graphene photodetectors (e.g., photodiodes or photoconductors), our device employs an advanced configuration that enhances carrier-injection efficiency and carrier multiplication, thereby increasing responsivity. Further optimization of drain/gate biases and device channel length yields a high responsivity of 157 A/W at 1550 nm, with a -3dB bandwidth of 90 kHz. This work demonstrates advanced, monolithically integrated graphene/germanium photodetectors on traditional semiconductor wafers and highlights their promising applications in optical integration circuits.

Towards a comprehensive multi-technique characterization of GaN HEMTs through correlated TEM-EDX, nano-Auger, and XPS analyses

Kirene Gaffar*[1], Solène Béchu[2], Arnaud Etcheberry[2], Gilles Patriarche[3], Farid Medjdoub[4] and Muriel Bouttemy[2]

[1]*Laboratoire Albert Fert, CNRS, Thales, Université Paris-Saclay, Palaiseau, France*
[2]*Institut Lavoisier de Versailles, UVSQ, Université Paris-Saclay, CNRS, UMR 8180, Versailles, France*
[3]*C2N, Université Paris-Saclay, CNRS, Palaiseau, France*
[4]*CNRS-IEMN, 59652 Villeneuve-d'Ascq, France*

Abstract:

Over the last decade, major improvements have been achieved in GaN technology, especially in GaN-based HEMTs. Despite this progress, these electronic devices still need substantial refinement, as issues like strong trapping effects continue to impair their dynamic behavior. While these mechanisms are not yet completely understood, numerous studies have shown that interface states play a major role in shaping the electrical performance of GaN HEMTs and their long-term reliability, which seriously restricts their large-scale applications. Moreover, the miniaturization of certain features such as the gate length demands the use of appropriate analytical techniques to more effectively identify and characterize nanoscale defects. However, reaching buried interfaces and accessing critical areas remains challenging. In the microelectronic field, the most common chemical and structural characterization techniques employed for HEMT devices, such as SIMS[1*], XPS[2*], or TEM-EDX[3*] have demonstrated their effectiveness across a widerange of semiconductor systems. Nevertheless, most reported studies focus on simplified layer stacks rather than fully fabricated devices. This limitation arises from the complex architecture of the final HEMT structure, which consists of nanometer-scale layers of semiconductors, nitrides, and metals deposited on insulating substrates. Consequently, only a limited set of characterization methods is suitable for analyzing such demanding structures. This study aims to establish a robust multi-technique characterization approach combining nano-probe Auger spectroscopy with TEM-EDX analyses on cross-sections to access buried HEMT interfaces and correlate their structural and chemical features with the resulting electrical behavior. Since accurate Auger quantification requires precise reference data, the study begins with a dedicated XPS investigation specifically for GaN devices, addressing the critical overlap between the Ga $L_2M_{4,5}M_{4,5}$ Auger transition and the N 1s photopeak. An innovative decomposition strategy is thus developed using III–V Ga based Auger transitions references to extract the nitrogen content and enable a reliable XPS analysis of GaN materials.

**GaN: Gallium Nitride*
**SIMS: Secondary Ion Mass Spectrometry*
**XPS: X-ray Photoemission Spectroscopy*
**TEM-EDX: Transmission Electron Microscopy - Energy-Dispersive X-ray Spectroscopy*

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Ultrasensitive Electrochemical Detection of PFOA via Magnetically Enriched Poly(p-Phenylenediamine) Nanoparticles

Wonjun Jo[1]*, Kyunghwan Chai[1], Gayoung Kim[1], Daeil Park[1], Chaeyeong Kang[1], Dayoung Chang[1], Doeun Choi[1], Subeen Kim[1], Chihyun Kim[1], Hyunjun Park[1], Woochang Kim[1], Joohyung Park[1], Jinsung Park[1]

[1]*Sungkyunkwan University, Suwon, Gyeonggi, South Korea*

Abstract:

Perfluorooctanoic acid (PFOA), a representative per- and polyfluoroalkyl substance (PFAS), is a persistent and bioaccumulative contaminant associated with severe health and environmental risks. To address the demand for highly sensitive and selective monitoring, we developed a portable electrochemical sensor based on poly(p-phenylenediamine)-coated magnetic nanoparticles (p-MNPs).

The sensing principle relies on two synergistic mechanisms: (i) poly(p-PD)-mediated redox disruption caused by electrostatic–hydrophobic interaction with PFOA, and (ii) magnetic localization of p-MNPs, which preconcentrates analytes at the electrode interface. This dual mechanism amplifies current suppression while preserving molecular selectivity against structurally similar PFAS.

The platform achieved a femtomolar detection limit (0.242 pM) with excellent reproducibility (RSD < 4.2%). Validation with real samples demonstrated detection limits of 4.795 pM in tap water and 132.26 pM in diluted human serum, values meeting or surpassing international water quality standards. In consumer-product extracts such as nonstick frying pans and paper straws, the results closely matched liquid chromatography–mass spectrometry (LC–MS) within 5%.

Overall, this p-MNP-based sensor provides a portable, regulation-ready solution for environmental and biomedical monitoring of PFOA, demonstrating strong potential for field deployment and future PFAS detection strategies.

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Ultra-Sensitive Manganese Ion Detection via a Vibration-Assisted Portable Sensor

Daeil Park[1]*, Joohyung Park[2], Woochang Kim[2], Chihyun Kim[2], Hyunjoon Park[2], Kyunghwan Chai[1], Gayoung Kim[1], Wonjun jo[3], Chaeyeong Kang[3], Dayoung Chang[3], Doeun Choi[2], Subeen Kim[3] and Jinsung Park[2,3]

[1]*Department of Biopharmaceutical Convergence, Sungkyunkwan University, Suwon, Gyeonggido, Republic of Korea*

[2]*Department of Biomechatronic Engineering, Sungkyunkwan University, Suwon, Gyeonggi-do, Republic of Korea*

[3]*Department of MetaBioHealth, Sungkyunkwan University, Suwon, Gyeonggi-do, Republic of Korea*

Abstract:

This study reports a vibration-assisted electrochemical sensor for ultra-sensitive and selective detection of manganese (Mn^{2+}) ions in complex aqueous environments. Mn^{2+}, widely used in industries such as batteries and fertilizers, can accumulate in aquatic systems through industrial discharge. Chronic exposure causes bioaccumulation and neurological disorders, while excess Mn^{2+} also leads to water discoloration and ecological damage, highlighting the need for rapid, field-deployable monitoring tools. Conventional methods such as ICP-MS and AAS offer high accuracy but require bulky, expensive equipment and trained operators, limiting their use for in-field analysis. Electrochemical approaches are simpler and portable but often depend on aptamers or chelating agents, which are costly and unstable. To overcome these limitations, we designed a sensor based on a screen-printed carbon electrode (SPCE) modified with graphite, electrochemically reduced graphene oxide (ErGO), and Nafion. A miniature vibration motor was integrated beneath the electrode to enhance mass transport during cathodic stripping voltammetry (CSV). The vibration-generated vertical oscillations thin the diffusion layer and increase ion flux, resulting in faster manganese deposition and significantly amplified stripping signals. This mechanism was validated experimentally and supported by COMSOL simulations, confirming the physical basis of the enhancement. The optimized sensor achieved a broad detection range of 10 nM to 250 μM with a detection limit of 489 pM. It exhibited strong selectivity against coexisting ions and organic interferents, and reproducibility with an RSD of 2.88% at 1 μM Mn^{2+}. Real-sample analyses in tap water, effluent, and river water confirmed reliable performance at nanomolar levels. With its simple design, batch fabrication compatibility, and scalability, this vibration-assisted sensor offers a practical platform for real-time manganese monitoring and can be extended to other heavy metal ions for environmental surveillance. Acknowledgement This work was supported by the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (grant numbers: RS-2023-NR077066, RS-2024-00460957, RS-2024- 00438542, RS-2025-00561260, and RS-2025-00554830). Additional support was provided by the SMC-SKKU Future Convergence Research Program.

Ultrasensitive mercury detection via DNA-engineered SERS with coffee-ring signal amplification

Kyunghwan Chai[1]*, Juneseok You[2], Joohyung Park[3], Woochang Kim[3], Chihyun Kim[3], Hyunjun Park[3], Gayoung Kim[1], Daeil Park[1], Wonjun Jo[4], Dayoung Chang[4], Chaeyoung Kang[4], Subeen Kim[4], Doeun Choi[3], Sungsoo Na[5] and Jinsung Park[3,4]

[1]*Department of Biopharmaceutical Convergence, Sungkyunkwan University, Suwon, Gyeonggi-do, Republic of Korea*
[2] *Department of Mechanical Engineering, Kumoh National Institute of Technology, Gumi, Gyeongsangbuk-do, Republic of Korea*

[3]*Department of Biomechatronics Engineering, Sungkyunkwan University, Suwon, Gyeonggi-do, Republic of Korea*

[4]*Department of MetaBioHealth, Sungkyunkwan University, Suwon, Gyeonggi-do, Republic of Korea*

[5]*Department of Mechanical Engineering, Korea University, Seoul, Republic of Korea*

Abstract:

Mercury ions (Hg^{2+}) released from industrial processes, batteries, and natural sources accumulate in the food chain and pose severe risks to human health, including neurotoxicity and Minamata disease. Thus, rapid and accurate detection of Hg^{2+} in food and water is crucial. Here, we present a surface-enhanced Raman scattering (SERS) sensor that enables sensitive and quantitative detection of mercury ions.

The sensing principle relies on the thymine–thymine (T–T) mismatch stabilized by Hg^{2+}. Unlike previous approaches that mainly used poly-thymine DNA, which suffers from strong electrostatic repulsion and reduced hybridization efficiency, we identified optimized DNA sequences through PCR melting curve analysis to improve binding affinity.

To amplify sensitivity, we exploited the coffee-ring effect, which concentrates DNA–Hg^{2+} complexes at the droplet edge, thereby enhancing hybridization probability. By selectively mapping this “pizza-crust” region, we achieved intuitive and rapid SERS visualization of Hg^{2+}.

The developed platform showed high sensitivity in various matrices, including drinking water, tap water, canned tuna, and raw tuna, with detection limits surpassing the safety threshold set by the U.S. Environmental Protection Agency (EPA). These results demonstrate the sensor’s strong potential for real-world applications.

In conclusion, our approach combines DNA sequence engineering with coffee-ring–based signal amplification, providing a simple yet powerful tool for sensitive mercury detection. We expect this method to contribute to food safety, environmental monitoring, and public health protection.

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Enabling High Performance Tellurium p-FET through Interface Electrostatic Engineering

Sung-Tsun Wang[1,2]* and Der-Hsien Lien[1]

[1] *Institute of Electronics, National Yang Ming Chiao Tung University, Hsinchu 30010, Taiwan*
[2] *Institute of Pioneer Semiconductor Innovation, National Yang Ming Chiao Tung University, Hsinchu 30010, Taiwan*

Abstract:

Tellurium (Te) has emerged as a compelling low-dimensional semiconductor for future electronics owing to its unique one-dimensional crystal framework, intrinsically high hole mobility, and compatibility with scaled device geometries. These attributes position Te as a promising channel material for next-generation transistors and integrated systems beyond conventional silicon. Nevertheless, the practical adoption of Te has been constrained by instability in electrical characteristics, which obscures its intrinsic transport advantages. In this work, we investigate the origin of this instability from a materials–device perspective and establish a viable pathway toward stable Te-based electronics. Systematic electrical measurements reveal that the threshold voltage of Te transistors is highly sensitive to electrostatic modulation and surface conditions, rather than being governed by irreversible bulk defects. Environmental control experiments demonstrate that stabilizing the surface electrostatic environment is essential for unlocking reproducible device behavior. Guided by this understanding, we implement conformal encapsulation using atomic-layer-deposited Al_2O_3 to engineer the interface surrounding the Te channel. This approach effectively suppresses unwanted electrostatic perturbations and enables stable transistor operation. As a result, the encapsulated Te devices exhibit nearly invariant transfer characteristics, on/off current ratios exceeding 10^4, and hole mobilities above 80 $cm^2 V^{-1} s^{-1}$. These findings highlight the critical role of interface and surface electrostatics in governing the performance of low-dimensional materials and position tellurium as a viable and competitive channel material for future high-performance, scalable electronic applications.

Solid Electrolyte for High-Mobility Proton-driven Oxide Transistors

Yu-Cheng Chang,[1,2*], Sheng-Lun Cheng[1], Hui-Hsin Lu[1], Der-Hsien Lien[1]

[1]*Institute of Electronics, National Yang-Ming Chiao Tung University, Hsinchu, Taiwan*
[2]*Taiwan Instrument Research Institute, National Applied Research Laboratories, Hsinchu, Taiwan*

Abstract:

CMOS-compatible PVD-grown SiO_2 provides an attractive solid-state alternative to liquid electrolytes for low-voltage oxide transistors. When incorporated into In_2O_3 back-gate transistor structures, the PVD-SiO_2 layer introduces pronounced ionic effects, leading to counterclockwise hysteretic transfer characteristics with a clear memory window. Capacitance–voltage measurements show a strong frequency dependence, with an area capacitance of approximately 5 μF cm^{-2} at 20 Hz.

Electrical measurements under vacuum, thermal annealing experiments, and secondary ion mass spectrometry (SIMS) analyses were carried out to identify the physical origin of the observed ionic response. The results indicate that the electric double-layer behavior arises from proton migration within the PVD-grown SiO_2 network. The intrinsically porous structure of the film promotes moisture absorption, supplying mobile protons that hop through Si–OH bonds under an applied electric field and accumulate at the oxide/ SiO_2 interface.

Beyond its role as a solid electrolyte, PVD-grown SiO_2 also serves as a channel passivation layer for oxide transistors. By employing PVD- SiO_2 as the passivation layer in In_2O_3 back-gate devices, enhancement-mode operation ($V_T > 0$) is achieved together with a high field-effect mobility exceeding 100 $cm^2 V^{-1} s^{-1}$. These results demonstrate that high-mobility proton-gated oxide transistors can be achieved by PVD-grown SiO_2 passivation, highlighting its dual functionality and potential for future low-voltage and high-performance oxide electronics.