Biomaterials Plenary (ALL-INVITED SESSION)
Room 317 - Session BP+BI-SuA

Biomaterials Plenary Session (ALL-INVITED)

Moderators: Dr. Christopher So, Naval Research Laboratory, **Prof. Rong Yang**, Cornell University

3:00pm **BP+BI-SuA-1 Bio-Inspired Design of Multifunctional Materials**, ***Kenan Fears,*** US Naval Research Laboratory **INVITED**

Biology serves as an inspiration for researchers due to the countless examples of nature evolving elegant solutions to complex problems humans have difficulty overcoming with engineered materials. For example, acorn barnacles, known for their ability to form a robust underwater cement that withstands harsh marine environments, have also evolved methods to compromise the attachment of the fouling organisms. We discovered barnacles secrete a phase-separating material at their basal interface that oxidizes and lifts off microbial biofilms ahead of growth and cement deposition. Proteomics analysis and confocal microscopy indicate haloperoxidases are present and active at the barnacle's adhesive interface.

Inspired by this approach to combating biofouling, we devised materials and coatings that mimic surface cleaning processes evolved by barnacles. These novel antifouling materials are comprised of surface-active glasses, that is, glasses that intentionally degrade in aqueous environments. We demonstrate the glasses deter marine biofouling by a combination of mechanisms: 1) deterring macrofouler settlement by elevating the concentration of potassium and magnesium ions, which are naturally abundant in seawater, and 2) compromising the adhesion of microbial foulers through the formation of reaction layers that generate reactive oxygen species.

3:30pm **BP+BI-SuA-3 Synthetic Brochosomes: From Biomimicry to Function**, ***Tak-Sing Wong,*** The Pennsylvania State University **INVITED**

Leafhopper-produced brochosomes are hollow, buckyball-like nanostructures with distributed nanoscale cavities, representing a unique class of biological optical materials. Inspired by these architectures, we develop synthetic brochosomes with demonstrated broadband, omnidirectional antireflective performance and optical camouflage capabilities [1-3]. This talk highlights recent advances in elucidating geometry-driven optical functionality of brochosomes, where hierarchical pore structures and particle size synergistically suppress reflection across ultraviolet–visible wavelengths [4]. We further discuss scalable manufacturing via droplet microfluidics and interfacial self-assembly, enabling high-throughput production of synthetic brochosomes with tunable architectures [5]. These results position synthetic brochosomes as a versatile platform for optical coatings, signature management, and photonic applications.

References:

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[4] L. Wang, Z. Li. S. Sheng, T.-S. Wong, *Proc. Natl. Acad. Sci. USA.* **121**, e2312700121 (2024).

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4:00pm **BP+BI-SuA-5 Gas Bubble-Encapsulating Microcapsules (GEMs): Pressure-Triggered Drug Delivery and AI-Enabled Fabrication**, ***Daeyeon Lee,*** University of Pennsylvania **INVITED**

Pressure-triggered drug delivery holds significant promise for treating pathologies characterized by sudden increases in localized hydrostatic pressure, such as traumatic brain injury and orthopedic injuries. Conventional microcapsules designed for compression-triggered release are liquid-filled, rendering them intrinsically insensitive to pressure. To address this limitation, we develop Gas Bubble-Encapsulating Microcapsules (GEMs), which incorporate gas bubbles via osmotic cavitation, endowing them with the compressibility necessary for pressure-sensitive mechanical response. To systematically optimize GEM structure, we develop an AI-empowered Automated Droplet Library (ADLib) generator that integrates convolutional neural network-based object detection with real-time microfluidic feedback control, autonomously generating 25 distinct monodisperse double-emulsion populations within 2–3 hours, compared to weeks of manual effort. Using ADLib, we identify two critical structural parameters governing the transition from non-destructive buckling to shell rupture: the shell thickness-to-diameter ratio and the gaseous volume fraction. We establish quantitative design principles that link GEM structure to pressure sensitivity and release kinetics, providing a generalizable platform for pressure-responsive microstructures in targeted drug delivery.

Biomaterial Interfaces

Room 321 - Session BI-MoM

Biofilms, Biofouling, and Biomolecules at Interfaces

Moderators: Prof. Sapun Parekh, University of Texas at Austin, **Prof. Rong Yang**, Cornell University

10:00am **BI-MoM-1 Peptide Based Liquid-Liquid Coacervates for Biosensing, Degradation Resistance, and as Biofoundries**, ***Sebastian Diaz***, US Naval Research Laboratory **INVITED**

Nature utilizes various materials such as peptides, nucleotides, and lipids to create order within complex environments such as cell interiors. Imitating nature, we combine DNA nanotechnology with peptide nanotechnology, specifically peptide based liquid-liquid phase separations, to access advanced functionalities. Peptide-based liquid-liquid phase separated domains, also known as coacervates, are neither pure homogenous liquid phase nor a heterogenous aggregate, displaying varying degrees of order. Coacervates are of keen interest in cell biology, where they function as membraneless organelles, dynamically colocalizing enzymes and other biomolecules (e.g. RNA) to enhance translation and other operations. We recently demonstrated that sequestration of DNA biosensors within coacervates allows for i) a greater than 20-fold reduction of the limit of detection within coacervates when compared to control buffer solutions; ii) an increase in the kinetics, equilibrium was reached more than 4-times faster in coacervates; and iii) enhancement in the dye fluorescent quantum yields within the coacervates, resulting in greater signal-to-noise. We have also found that coacervates protect DNA from nuclease degradation while subsequently allowing for release from the coacervate upon proper stimuli, which could have implications for nucleotide delivery applications. We hypothesize that the strong peptide-DNA interaction within the coacervates inhibits degradation and have preliminary evidence that this can be applied to other biological moieties, e.g. enzymes. In a third demonstration, enzymatic cascades are sequestered into coacervates improving product flux through the system by exploiting enzyme stabilization and intermediate channeling.

10:30am **BI-MoM-3 Tailoring the Inert Properties of Zwitterionic Coatings**, *Jana Karthäuser, Lisa Schardt, Katrin Ademmer,* Ruhr University Bochum, Germany*; Jasper Hansen, Andre Laschewsky,* Potsdam University, Germany*;* ***Axel Rosenhahn****,* Ruhr University Bochum, Germany

Manmade materials in contact with aqueous environments become rapidly colonized by living matter like proteins, macromolecules, bacteria, diatoms, and other fouling species. Frequently failure of devices and substantial maintenance costs are among the penalties associated with fouling processes. As the use of biocides is heavily restricted in many applications, environmentally friendly low-fouling materials are intensively explored [1]. In the recent years zwitterionic materials have emerged as highly promising building blocks with inherent inert properties. We synthesized different molecular architectures and studied the effect of structural variation on their inert properties [2]. The resistance to protein and microbe attachment was correlated with their anti-polyelectrolyte properties using several analytical in-situ methods including SPR, AFM, and spectroscopic ellipsometry [3,4,5]. Based on the obtained data, fundamental structure-property correlations and the implications for inert zwitterionic coatings will be discussed.

[1] M. Callow, J. Callow, Nature Communications 2011, 2, 244[2] A. Laschewsky, A. Rosenhahn, Langmuir 2018, 35, 1056[3] J.F. Karthäuser, D. Gruhn, A.M. Guajardo, R. Kopecz, N. Babel, U. Stervbo, A. Laschewsky, R. Viebahn, J. Salber, A. RosenhahnFrontiers in Bioengineering and Biotechnology 2024, 12, 1403654[4] L. Schardt, S. Da Vela, A. Martínez Guajardo, M. Jaugstetter, K. Tschulik, A. Laschewsky, A. RosenhahnAdvanced Materials Interfaces 2025, 12, 2400610[5] J. Karthäuser, J. Hansen, A. Smajlji, K.Z. Hunsucker, Y. Tenzin, C. Braga, T. Patschorke, G. Swain, A. Rosenhahn, A. LaschewskyLangmuir 2025, 41, 4545, 10.1021/acs.langmuir.4c04351

10:45am **BI-MoM-4 Graphene Oxide Coatings Enhance Biofilm Formation and Robustness in 3D-Printed Bioreactors**, ***Maryssa Beasley***, *Christopher Green, Megan Pitz,* US Naval Research Laboratory*; K.A. Shiral Fernando, Iman Eizadynejad, Oscar Ruiz,* Air Force Research Laboratory*; Rebecca Mickol,* US Naval Research Laboratory

Here we demonstrate that both graphene oxide (GO)-coated and GO-impregnated bioreactors result in faster growth and more robust biofilm formation than uncoated bioreactors when inoculated with *Marinobacter atlanticus*. GO is a nanomaterial typically used as either an irreversible binding substrate to trap microbial cells or as an antimicrobial coating, often dependent on GO concentration. Here, GO was incorporated either prior to the final resin cure or as a coating to 3D-printed bioreactors in order to increase cellular adhesion, enhance biofilm formation, and ultimately, increase bioproduction capabilities. Initial assays showed dense biofilm formation on bioreactor segments coated 10x with 0.1 wt% GO-in-water, compared to other solutions. In contrast, crystal violet biofilm assays demonstrated maximum biofilm formation on segments coated only 1x, indicating that high GO concentrations transition from biofilm-promoting to antimicrobial. In bioreactor experiments, effluent oxygen concentrations and final protein concentrations demonstrated that *M. atlanticus* biofilms colonized and grew faster in GO-coated or GO-impregnated systems than in uncoated bioreactors. Recovery, defined as the highest effluent oxygen concentration measured immediately following inoculation, reached only 40.5±13.3% oxygen and 55.5±5.7% oxygen in GO-impregnated and GO-coated bioreactors, respectively, compared to uncoated bioreactors (89.6± 4.1% oxygen). Similarly, biofilms within GO-impregnated and GO-coated bioreactors grew to maximum biomass (here, measured as effluent oxygen concentration < 2%) in less time (3.5±0.8 h and 10.5±2.3 h, respectively) than biofilms within uncoated bioreactors (15.2±3.9 h). Additionally, the same total biomass (as measured by protein concentration) was achieved in half the time with GO-impregnated bioreactors than with uncoated bioreactors (50 h vs. 100 h). When *M. atlanticus* was inoculated into bioreactors with medium that did not contain trace minerals, biofilm growth was fastest in GO-coated bioreactors than in GO-impregnated or uncoated bioreactors, with maximum biomass achieved within 13.9±2.5 h. These results suggest that GO can promote microbial growth, potentially through electron transfer, as previously seen with GO-modified electrodes, although more research is necessary. These data indicate a complex relationship between GO concentration and microbial growth, which requires further investigation to improve and optimize GO coatings for enhanced microbial production.

11:00am **BI-MoM-5 Zwitterionic Polymers for Antifouling Surfaces in Soft Devices**, ***Abdon Pena-Francesch***, University of Michigan **INVITED**

Despite recent advances in medical device technology, seamless integration in biological environments remains a challenge. When interfacing with biological environments, devices are prone to the accumulation of fouling proteins, microorganisms, and biofilms that lead to inflammation, infections, foreign body response, and failure or rejection. Thus, there is an urgent need for long-lasting, highly-stable solutions to prevent biofouling to the wide range of materials, designs, and length scales that comprise medical devices. In this talk, we will present the design of zwitterionic polymer coatings as a bioinspired surface engineering approach to avoid the attachment of proteins, bacteria, and other microorganisms to soft devices. We have recently developed surface functionalization methods compatible with medical-grade silicones (which are typically inert and difficult to functionalize), as well as zwitterionic photoresin formulations compatible with 3D-printing technology, that we have implemented in soft anti-biofouling devices. We will demonstrate their application in two case studies: (i) zwitterionic polymer coatings in urinary catheters that reduce >99% bacterial attachment and the formation of biofilms, outperforming state-of-the-art commercial antimicrobial catheter devices, and (ii) 3D-printed microrobots that avoid immune recognition and clearance by macrophages, significantly prolonging the functional lifetime of medical microrobots.

11:30am **BI-MoM-7 Molecular Shape and Peeling-Stretching Mechanics of Collagen Adsorbed on Silicate Surfaces**, ***Bruno Zappone***, Consiglio Nazionale delle Ricerche - Istituto di Nanotechnology (CNR-Nanotec), Italy **INVITED**

Collagen is the most abundant protein in mammals and plays a critical role in tissue formation, stability, and mechanics, closely linked to its unique triple-helix structure. We used atomic force microscopy (AFM) and the surface forces apparatus (SFA) to study fibril-forming type I and III human collagen absorbed on atomically smooth mica surfaces. The two-dimensional contours of individual collagen molecules showed non-uniform curvature for both types, which persisted after drying the surface and dehydrating the molecules. This finding suggests that collagen either has an intrinsic three-dimensional curvature in solution, or it acquires a two-dimensional curvature due to a particularly strong interaction with the surface. The former case has direct relevance to the self-assembly and elasticity of collagen fibrils, whereas the latter has potential implications for biomaterial design and tissue engineering.

SFA measurements showed strong adhesion between a collagen-coated and an uncoated mica surface, and repulsion between equally coated

surfaces, suggesting that collagen-mica interaction is mainly electrostatic. Moreover, AFM force measurements showed a large adhesive force for a single collagen molecule being peeled by one end from the mica surface. Interestingly, a collagen molecule could be pulled and stretched without failing to a contour length of up to 900 nm—nearly three times its native length—over thousands of stretching cycles until the triple-helix started unravelling. During this process, the alpha-chains slipped progressively, irreversibly, and almost entirely past each other, before being caught by strong physical interactions between overlapping chain ends. These findings indicate that a controlled slippage mechanism at the molecular scale underpins the exceptional toughness of collagen fibrils and collagen-rich tissues such as tendons and skin.

Biomaterial Interfaces
Room 321 - Session BI-MoA

The Future of Biointerface Science

Moderator: Prof. Dr. Tobias Weidner, Aarhus University, Denmark

4:00pm **BI-MoA-11 Interactions Between Marinobacter atlanticus and Heavy Metals**, ***Sara Tuck,*** Naval Medical Research Command*; Maryssa Beasley, Rebecca Mickol,* U.S. Naval Research Laboratory*; Katherine Franz,* Duke University*; Kenan Fears,* U.S. Naval Research Laboratory

Marine bacteria have evolved mechanisms for the regulation of essential heavy metal ions (e.g., copper, zinc, cobalt). Understanding the interplay between these ions and marine bacteria is relevant to a variety of applications, including the development of antifouling coatings and materials and the capture and sensing of metal ions in seawater. Here we investigate the interactions between *Marinobacter atlanticus* and heavy metals commonly found in natural environments at trace levels. Further, *M. atlanticus* can produce small amounts of electricity and this ability is affected by labile metal ion concentration and can influence mineral cycling. We hypothesized that *M. atlanticus* may be a promising candidate for applications in heavy metal remediation or as a biosensor for heavy metal contamination. We utilized broth microdilution assays to expose *M. atlanticus* to a concentration range of essential and non-essential metal ions. *M. atlanticus* demonstrated a profound ability to grow in the presence of metal concentrations that significantly exceed those found in native environments. In metal depletion assays, where the ability of *M. atlanticus* to remove metal ions from solution was assessed, we found that this bacterium exhibited a marginal ability to reduce metal concentrations, with cadmium being the only heavy metal whose uptake significantly increased throughout a 72-hour evaluation period. Our results suggest *M. atlanticus* has limited use for bioremediation but could be used for biosensing.

4:15pm **BI-MoA-12 Addressing Agricultural Challenges Through Biomimetic Surfaces: Reframing Foliar Fungal Disease as a Biointerface Problem**, ***River Pachulicz,*** *Bryan Coad,* Adelaide University, Australia

Food security and agricultural economies depend on the continued production of grain crops, including barley, wheat and oats. Foliar fungal diseases pose a major threat to grains production worldwide, and solutions to reduce their incidence heavily rely on broadacre fungicide applications after disease occurs. This can be costly, environmentally harmful and eventually promote the emergence of chemically resistant pathogens. Prophylactic strategies to prevent fungal disease occurrence are scarce, but a shared bottleneck to fungal disease progression may a key target for intervention: the fungal pathogen must detect and successfully recognise the host's surface. This initial point of contact in plant-fungi interactions can hence be reframed as a biointerfaces problem that materials science can address.

The cuticle is a waxy bio-composite that coats the surface of leaves and is comprised of a cutin matrix that is embedded and/or coated with cuticular waxes, long chain aliphatic compounds that display an extensive range of carbon chain lengths and functional groups. Physiologically, the cuticle plays vital roles in water retention and physical defence against disease, however; increasing evidence has demonstrated that some cuticular waxes can signal recognition to pathogenic fungi to promote infection. The complexity of these plant-fungi interactions hence make them challenging to study and require model systems that can assess the effect of individual surface variables on fungal development.

To address this, we propose the development of a biomimetic model system using fabricated wax films to replicate native leaf chemistries on inert substrates. Using fabrication techniques including spin-coating to generate thin films that can be characterised using a suite of analytical techniques to assess their hydrophobicity, thickness, uniformity and morphology, precise tuning of surface physicochemical properties can be achieved. Individual surface parameters can then be disentangled and systematically assessed in the context of fungal development to identify key virulence traits at the leaf surface.

4:30pm **BI-MoA-13 Scaling Biomaterials Manufacturing: Lessons from the Paper Industry**, ***Sandro Zier,*** University of Maine

Biomaterials are increasingly being explored as sustainable alternatives to petroleum-derived materials, but many systems that perform well at laboratory scale remain difficult to manufacture reliably at industrial scale. One reason for this disconnect is that biomaterial structure and function are strongly influenced by the physical conditions present during assembly, including flow, transport, dewatering, and drying conditions that differ substantially between laboratory and industrial environments. This talk presents a framework for designing biomaterials with formation conditions and manufacturing environments considered from the outset instead of introducing process constraints only after laboratory optimization. Using papermaking and related large-scale bio-based manufacturing systems as examples, the presentation examines how process-dependent assembly governs interfacial structure development across systems including microfibrillated cellulose, protein-based materials, biofilms, and mycelium composites. Differences between benchtop and industrial processing are discussed in terms of flow behavior, transport limitations, shear history, and consolidation dynamics, demonstrating that scale-dependent physical regimes can produce fundamentally different structures and functional behavior. The talk further outlines a process-integrated framework in which material selection, structure formation, and manufacturing constraints are treated as interconnected design variables. Finally, future needs in process-relevant characterization, multiscale modeling, and experimental tools capable of probing biomaterial formation under realistic manufacturing conditions are discussed. Incorporating formation pathways into biomaterials research may improve reproducibility and help bridge the gap between laboratory discovery and industrial implementation.

4:45pm **BI-MoA-14 Extreme Copper Tolerance and Genomic Adaptation in Early-Stage Marine Biofilms**, ***Kailey Richard,*** U.S. Naval Research Laboratory*; Sara Tuck,* Naval Medical Research Command*; Sophie Colston, Marryssa Beasley, William Hervey,* U.S. Naval Research Laboratory*; Kevin Le,* NOVA Research, Inc.*; Sean Brown,* U.S. Naval Research Laboratory*; Katherine Franz,* Duke University*; Kenan Fears,* U.S. Naval Research Laboratory

Biofouling, the accumulation of unwanted organisms on submerged assets, presents an ongoing challenge within the maritime industry. Conventional methods to inhibit growth rely heavily on the application of copper-laden (≤75% copper compounds) antifouling coatings. However, the efficacy of these coatings is declining due to the broad emergence of copper-tolerant species. Here we investigated the mechanisms underlying this decline in antifouling performance. Polyvinyl chloride (PVC) panels coated with a commercial copper ablative paint were deployed in the Chesapeake Bay to collect early-stage biofilms; uncoated PVC panels were deployed as an inert control group. Community profiles of the harvested biofilms were obtained via 16S amplicon sequencing of the V4-V5 region. To elucidate genomics information about specific bacteria, primary bacterial colonizers were isolated on marine agar plates and identified through 16S amplicon sequencing and whole genome sequencing (WGS). The isolates were subsequently assessed for copper tolerance using copper sulfate ($CuSO_4$) in both marine agar and broth assays. While bacterial tolerance declined with increasing $CuSO_4$ concentrations on agar, tolerance was significantly greater in liquid media. We observed all isolates survived extreme concentrations, with minimum inhibitory concentrations (MIC) equal to or above 5 mM $CuSO_4$. Genomic annotation confirmed that this high phenotypic tolerance was driven by active genetic resistance mechanisms. Every isolate harbored at least three copper-related genes (e.g., *copA, cueO, copZ*), with highly adaptable species carrying a full spectrum of resistant genes. Ultimately, these findings highlight how the accumulation of metal resistance genes allows bacteria to colonize metal-rich surfaces, paving the way for subsequent macrofouling and coating failure.

Biomaterial Interfaces
Room 321 - Session BI1-TuM

Biomaterials and Nanomaterials Fabrication I

Moderators: Prof. Joe Baio, Oregon State University, **Prof. Sapun Parekh**, University of Texas at Austin

8:00am **BI1-TuM-1 Engineering the Human Sense of Touch as the Finger-Object Interface*, Charles Dhong,*** University of Delaware **INVITED**

The human sense of touch is a basic sensory experience, and for those who are visually impaired, a critical source of information. Technologies that interface with the sense of touch or "haptics" have seen progress over the years, but remain limited in the variety of sensations that these devices can reproduce and are nowhere near the the ability to recreate everyday sensations, especially when we compare these haptic technologies to vision or sound.

In this talk, we will show how the mechanical forces generated at the finger-object interface through adhesion and friction phenomena can be leveraged to control, or study, the human sense of touch. Mechanical forces generated at this interface give rise to tactile sensations and ultimately fine touch perception. Manipulating this mechanical interface through surface chemistry, polymer chemistry, and thin-film mechanics can give rise to new kinds of haptic devices while also enabling fundamental investigations into the perception of touch. We will end this talk by giving examples of how advances in the finger-object interface can enable widespread applications, from new insights into sensory neuroscience, to new accessibility technologies, and to medical diagnostics.

8:30am **BI1-TuM-3 Curvature-Programmed Polymer Interfaces via Condensed Droplet Polymerization*, Rong Yang,*** Cornell University

Polymer interfaces with micro- and nanoscale convex topographies offer powerful routes to control optical response, imaging, sensing, and biointerfacial interactions. However, conventional lithography and self-assembly approaches often face tradeoffs among scalability, geometric tunability, and fabrication complexity. Here, we introduce condensed droplet polymerization (CDP), a one-step, template-free strategy in which condensed monomer droplets serve as nanoscale reactors to generate polymeric micro- and nanodome arrays with programmable size, curvature, and surface coverage. To make CDP predictive rather than empirical, we develop a theoretical framework that integrates monomer condensation, polymerization kinetics, droplet evaporation, and geometric arguments. This model rationalizes dome height and radius through the measurable droplet base radius, enabling accurate prediction of final dome geometry from synthesis conditions and monomer reactivity despite the stochastic nature of condensation. The resulting curvature-programmed interfaces exhibit distinct optical functions, including light focusing and magnification, with potential utility for high-resolution visualization of subwavelength features and biological specimens. As a biointerface demonstration, biphilic microdome arrays fabricated from poly(2-hydroxyethyl methacrylate) reduce *Pseudomonas aeruginosa* colonization without changing macroscopic wettability, suggesting a curvature-driven antifouling mechanism. Early evidence further supports its capability to program immune cell functions. Together, CDP and the accompanying predictive model establish a scalable platform for designing polymer thin-film architectures with controlled curvature. This approach provides new opportunities for morphology-by-design in optical, sensing, and biointerfacial applications

8:45am **BI1-TuM-4 RF Pulsed Plasma Modified Composite Scaffold for Enhanced Anti-Microbial Activity and Accelerated Wound Healing*, Ajinkya Mahadev Trimukhe,*** University of Milan Bicocca, Italy*; Jose Savio Melo,* Bhabha Atomic Research Centre, India*; Deepa Chaturvedi, Ratnesh Jain, Prajakta Dandekar, Rajendrasing Deshmukh,* Institute of Chemical Technology, India

This study entails the successful synthesis of a biodegradable microporous agarose-chitosan composite scaffold and modifying its surface with diphenyldiselenide (DPDSe), by using low-pressure RF pulsed plasma for enhanced wound-healing applications. The scaffolds' synthesis composition was optimized at a 3:1 agarose-to-chitosan ratio and 4% polymer concentration. The optimized RF plasma treatment parameters for depositing DPDSe on the scaffold surface were at a pulse rate of $5_{ON}/15_{OFF}$ (ms) for 80 minutes. The plasma-modified scaffold surfaces demonstrated superior antibacterial activity against Gram-positive bacteria *S. aureus* and *S. epidermidis*, achieving inhibition zones up to 24 mm and 26 mm, respectively, while maintaining excellent biocompatibility, with 91.9% and 88.6% cell viability for HaCaT and HadF cells, respectively. Surface characterization revealed enhanced hydrophilicity, with contact angles decreasing from 89° to 33°, and from XPS analysis, it was observed that there was increased oxygen content from 19.82% to 21.87%, and successful selenium deposition at an atomic concentration of 1.01%. *In vivo* studies using albino Wistar rats demonstrated accelerated wound healing, with plasma-modified scaffolds achieving 100% wound closure by day 14, compared with 16 days for untreated scaffolds, accompanied by enhanced collagen synthesis, evidenced by a hydroxyproline content of 5.96 µg/mL. The selenium-modified scaffolds showed comparable efficacy to standard Betadine treatment while offering practical advantages as solid dressing materials, making them promising alternatives for treating challenging wounds.

9:00am **BI1-TuM-5 Engineering Curvature-Controlled Polymer Dome Biointerfaces via Condensed Droplet Polymerization*, Haobo Xu, Rong Yang,*** Cornell University

Surface-attached dome morphologies are ubiquitous in nature but remain difficult to reproduce synthetically due to limited control over geometric parameters such as curvature. Here we introduce condensed droplet polymerization (CDP), a synthesis strategy that leverages condensed monomer microdroplets as discrete microreactors to produce surface-attached polymer dome arrays with precisely tunable geometry. The potential of CDP for functional interface design is demonstrated in two contexts. Inspired by dome-shaped morphologies on crustacean shells, we investigate antifouling behavior and identify an optimal intermediate dome size (~10 µm) with targeted curvature that significantly suppresses *Pseudomonas aeruginosa* attachment despite a globally hydrophobic surface. In addition, sub-micron dome arrays significantly increase extracellular vesicle yield from M1-polarized murine macrophages (J774A.1), suggesting that curvature-defined biointerfaces can regulate plasma membrane dynamics, particularly the inward budding process associated with the endocytic pathway, thereby promoting the subsequent production and release of extracellular vesicles. These results establish CDP as a versatile platform for engineering curvature-controlled interfaces for antifouling materials and cell-regulating biomaterials.

Biomaterial Interfaces
Room 321 - Session BI2-TuM

Biomaterials and Nanomaterials Fabrication II

Moderators: Ali Rafati, Medtronic, Inc., **Dr. Christopher So**, Naval Research Laboratory

9:15am **BI2-TuM-6 Tuning Biopolymer Surface Wettability through Plasma Copolymerization*, Morgan Hawker,*** *Alexzandria Kubik, Mackenzie Jackson, Kristina Closser,* California State University, Fresno

Plasma, the fourth state of matter, is a partially ionized gaseous mixture and versatile tool for controlling interactions at biointerfaces. Polymers are ubiquitous biomaterials and tailoring how the polymer device interfaces with the biological environment is paramount to controlling its function. For example, promoting favorable cell-surface interactions is needed for tissue engineering devices, whereas preventing bacterial attachment is favorable to prevent infection at the device surface. Plasma-enhanced chemical vapor deposition is a versatile technology to control interactions at the biomaterial/biological environment interface through adding a conformal protective film that encases the polymeric device below. The film is obtained through interfacing a polymer substrate with the plasma (partially ionized gas mixture). Plasma species such as radicals and cations undergo gas-phase reactions, and products from those reactions form the conformal film. Plasma copolymerization is a related strategy that utilizes a mixed feedgas of two or more plasma precursors, whereby conformal coating surface properties can be controlled by simply varying the feedgas composition.

This study reports a previously unexplored combination of plasma precursors – pentane and acrylic acid – to deposit coatings with tunable chemistry and wettability on silk fibroin constructs. Five pentane/acrylic acid feedgas compositions were utilized, ranging from 100%, 75%, 50%, 25%, and 0% pentane by pressure. Plasma deposited coating properties were evaluated through water contact angle goniometry and x-ray photoelectron spectroscopy. Coating static water contact angle values were tunable between >90 degrees to <55 degrees depending on the feedgas

composition, which correlated to surface chemical composition. Plasma diagnostics and density functional theory were used to evaluate plasma precursor fragmentation, providing further insights into plasma/surface interactions. This library of plasma-modified silk-based materials can be used to design biomaterial surfaces that are optimally situated for the intended biomedical setting.

9:30am **BI2-TuM-7 Capture of Rare Earth Metals Using Bio-Inspired Polymeric Materials**, ***Gillian Kropp***, *Kailey Richard, Kenan Fears, Okhil Nag,* U.S. Naval Research Laboratory

Rare earth metals, largely comprised of lanthanides, are essential materials for a wide range of applications, including electronics, imaging and diagnostic technology, and energy systems. However, in nature these metals are found dispersed at low concentrations and mixed with other metals, making them challenging to locate, extract, and chemically isolate. Therefore, developing materials with high selectivity and tuneability is crucial to the separation and extraction of these lanthanides. Peptoids are a class of biomimetic molecules that are expanding the landscape of materials used for therapeutics, diagnostics, and metal chelation. In fact, with the development of new synthetic and automated strategies, peptoid-based materials are highly versatile and tunable. Our goal is to leverage this tuneability to design, synthesize, and characterize materials for selective rare earth metal extraction.

9:45am **BI2-TuM-8 Materials Science / Properties of Transformational Uncoated and Multifunctional/Best Biocompatible Ultrananocrystalline Diamond (Uncd) Coated-Bioactive Bovine Nanohydroxyapatite Scaffolds for Transformational Bone Tissue Engineering**, ***Orlando Auciello***, Texas State University and Original Biomedical Implants*; Angelica Castillo-Paza,* Centro de Investigación y Estudios Avanzados, Mexico*; Leon Bernal-Alvarez,* Universidad Nacional Autónoma de México*; Dorian Cañon-Davila,* Centro de Investigación y Estudios Avanzados, Mexico*; Lerma Chan-Chanc,* Universidad Nacional Autónoma de México, Campus Juriquillalerma@, Mexico*; Rafael Ramírez-Bona,* Centro de Investigación y Estudios Avanzados, Mexico*; Mario Rodriguez-Garciad,* Universidad Nacional Autónoma de México, Campus Juriquilla, Mexico

Abstract

This Talk will be focused on describing materials science and characterization ofphysicochemical properties of hydroxyapatite (HAp) scaffolds and HAp scaffolds coated with a unique transformational best biocompatible (because made of Carbon atoms /element of life in human DNA, cells, molecules) Utrananocrystalline Diamond (UNCD) coating (HAp-UNCD) produced by a patented microwave plasma chemical vapor deposition (MPCVD) and Hot filament Chemical Vapor Deposition (HFCVD) process. The studies involved complementary analytical techniques and biological assays, namely:

1. Scanning Electron Microscopy (SEM) revealed scaffolds' pore structure, critical for bone regeneration / formation and associated EDS chemical analysis showing Ca, P and C atoms.
2. High Resolution Transmission Electron Microscopy (HRTEM) revealed nanoscale structures of HAp and HAp-UNCD scaffolds; and Energy Dispersive Spectroscopy (EDS) analysis confirmed the presence of P on HAp and C atoms in the UNCD coating on HAp scaffolds.
3. X-ray Diffraction (XRD) analysis revealed HAp-UNCD crystalline structure before/after immersion in HBSS, revealing excellent inertness of the UNCD-coated HAp.
4. Raman spectroscopy provided chemical analysis of original HAp and UNCD-coated HAp, before and after immersion in Hanks' Balanced Salt Solution (HBSS).
5. Infrared (IR) analysis revealed carbonate ions on scaffolds' surfaces.
6. X-ray Photoelectron Spectroscopy (XPS) analysis revealed transformational chemical interactions between atoms in HAp scaffolds and in UNCD coated HAp scaffolds.
7. *In vitro* cytotoxicity assays showed NO-cytotoxicity in HAp and HAp-UNCD scaffolds.
8. N_2 adsorption-desorption analysis showed mesoporosity in both scaffolds.
9. Mineral content analysis showed Na / Mg atoms, important elements for bone cells' growth.
10. .
11. Application of Integrated UNCD-coated commercial Ti-alloy dental implants in HAp in maxillary bones demonstrated a new transformational UNCD-coated DIs-maxillary bone integration

Biomaterial Interfaces
Room 321 - Session BI3-TuM
Characterization of Biological and Biomaterials Surfaces

Moderators: Dr. Sebastian Diaz, Naval Research Laboratory, **Prof. Roberto Eguiluz**, University of California Merced

11:15am **BI3-TuM-14 ToF-SIMS Analysis of Tissue Microenvironments and Tumor Growth Progression**, ***Lara Gamble***, *Daniel Graham,* University of Washington

Tissue microenvironments are a complex ecosystem of cell and non-cellular (e.g. chemical signaling molecules). The regulation of cell growth, metastatic potential, and drug resistances are associated with the microenvironments around solid tumors. Time-of-flight secondary ion mass spectrometry (TOF-SIMS) is a sub-micron spatial resolution imaging mass spectrometry technique used for chemical imaging. Here a combination of ToF-SIMS and H&E staining are used to analyze mouse pancreatic tissue slices by imaging tumors in a *pIns-MycER^{TAM}/p53$^{-/-}$* mouse model. TOF-SIMS was performed with an ION-TOF TOF.SIMS 5-100 instrument (ION-TOF GmbH, Münster, Germany) equipped with a liquid metal ion gun (LMIG) for analysis and an electron flood gun for charge neutralization. Analyses of the *pIns-MycER^{TAM};p53$^{-/-}$* tumor microenvironment has identified and mapped molecules that play key roles in tumor metabolism and growth including nucleic acids, organic acids and lipids, as well as inorganic ions. Evidence is provided of significant metabolic change occurring within *Myc*-driven *β* cell tumors and surrounding stromal region over a 12-day period and demonstrate that TOF-SIMS imaging is a useful tool for spatial characterization of metabolite changes in the *Myc* model. Analyses provide evidence that significant metabolic changes occur in the tumor microenvironment in response to *Myc* activation and that the metabolic profiles of the tumor and the stroma differ dramatically.

11:30am **BI3-TuM-15 Molecular Analysis of Small Extracellular Vesicles by Nanoprojectile Secondary Ion Mass Spectrometry**, ***Pierre Hirchenhahn***, *Stanislav Verkhoturov, Victoria Cura, Ravi Jada,* Texas A&M University*; Thanh Qui Nguyen, Daheui Choi,* Mayo Clinic*; Michael J. Eller,* University of Mississippi*; Alexander Revzin,* Mayo Clinic*; Emile A. Schweikert,* Texas A&M University

Small extracellular vesicles (SEVs) are biological objects of 30 to 150 nm. They serve as communication line between cells and their environment through the transport of lipids, proteins and genetic material. Because they carry tissue- and health-status-specific biomarkers, SEVs are highly promising candidates for disease diagnosis and monitoring. However, their strong chemical heterogeneity makes their characterization particularly challenging. Current analytical techniques generally provide only partial or averaged information, preventing a comprehensive understanding of SEVs molecular diversity. In this context, Nanoprojectile Secondary Ion Mass Spectrometry (NP-SIMS) appears as a powerful solution. Unlike conventional SIMS approaches, NP-SIMS operates in an event-by-event mode, where the analyte is impacted by a single nanoprojectile at a time. The nanoprojectiles used are Au_{400}^{4+} clusters accelerated to 100 kV, generating craters of only 10–20 nm in diameter. The secondary ions emitted from each individual impact are mass analyzed and recorded separately, providing unprecedented molecular lateral resolution and sensitivity. A critical challenge for NP-SIMS investigations is the preparation of suitable capture surfaces ensuring both high EV density and minimal aggregation, so that each nanoprojectile impacts only a single vesicle. To address this issue, plasma-cleaned silicon wafers were functionalized with successive layers of (3-Aminopropyl)triethoxysilane (APTES) and glutaraldehyde prior to EV incubation. The different preparation steps and resulting surface chemistry were assessed through a combination of NP-SIMS, X-ray photoelectron spectroscopy (XPS), and scanning electron microscopy (SEM). Finally, the validity of the developed preparation protocol was demonstrated using hepatic extracellular vesicles.

This work was supported by NIH grant number 5R01DK134661.

11:45am **BI3-TuM-16 Nanoscale Characterization of Bio-Nanomaterials Using Nano-Projectile Secondary Ion Mass Spectrometry**, ***Christelle Guillermier***, Bienne Technology*; Michael Eller,* University of Mississippi*; Stanislav Verkhoturov,* Texas A&M University*; Richard Rickman,* Bienne Technology*; Emile Schweikert,* Texas A&M University

Advances in nanoparticle biomaterial engineering have made accurate characterization of these systems increasingly important. Many modern nanoparticle designs are multifunctional, resulting in complex and often heterogeneous composition, including hybrid and core/shell architectures, particles functionalized with multiple ligands, asymmetric particles, sensing

platforms, and targeted therapeutic carriers each presenting distinct analytical challenges.

To address these challenges, we present Nano Projectile Secondary Ion Mass Spectrometry (NP-SIMS), a variant of conventional SIMS that enables nanoscale molecular analysis of individual nanoassemblies. In contrast to conventional SIMS, which relies on continuous ion beams with spatial resolutions typically limited to ~30 nm, NP-SIMS employs ~2 nm gold nanoprojectiles delivered as isolated impacts separated in both time and space. A time-of-flight (ToF) mass spectrum is acquired from each individual impact event. Each nanoprojectile probes a nanovolume approximately 10 nm in diameter, allowing nanoassemblies to be analyzed one-by-one rather than as ensemble averages. This event-by-event acquisition approach enables the direct identification of colocalized molecular species within complex nanoassemblies.

Here, we present several examples illustrating the application of NP-SIMS to the characterization of complex biomaterial nanoassemblies. First, NP-SIMS was used to analyze extracellular vesicle (EV) population heterogeneity at single-EV resolution and to distinguish hepatocyte-derived EVs from liver cancer EVs based on differences in surface marker expression. Second, we demonstrate the determination of DNA ligand loading and ligand density on DNA functionalized metal nanoparticles, specifically anisotropic gold nanostars and isotropic gold nanospheres with comparable surface areas. Third, NP-SIMS was applied to the analysis of a mixture of nanoparticles containing identical metal cores (3–5 nm in diameter) but functionalized with ligands of different chain lengths (decanethiol, tetradecanethiol, and hexadecanethiol). Using NP-SIMS, we determined the relative abundance of the three nanoparticle populations on the surface.

These examples demonstrate the capability of NP-SIMS to characterize molecular composition, heterogeneity, and surface functionalization within complex nanoscale biomaterial systems at the level of individual nanoassemblies, providing analytical information inaccessible through ensemble-averaged measurements.

12:00pm **BI3-TuM-17 Interactions of Divalent Metal Cations with Phosphate Headgroups in Monolayers at the Air/Water Interface***, **Sadia Afroz**, Paul S. Cremer,* Pennsylvania State University

The binding of divalent metal cations to negatively charged monolayers in aqueous solutions is a complex process that depends on the supramolecular arrangement and spacing of the headgroups at the air/water interface. Previous literature showed that binding of Mg^{2+} and Ca^{2+} to the PIP(4,5)P_2 head groups has significant impact on interactions between PIP(4,5)P_2 and protein by changing the orientation of the head group and ordering of the acyl chain. Moreover, Ca^{2+}forms contact ion pairs with PIP(4,5)P_2 head groups, whereas Mg^{2+}preferentially forms solvent-shared ion pairs. Herein, Sum Frequency Generation (SFG) vibrational spectroscopy was employed to probe the water structure and mode of ion binding with two different PA species, 1,2-dilauroyl-sn-glycero-3-phosphate (DLPA) and 1-stearoyl-2-hydroxy-sn-glycero-3-phosphate (LPA). It was found that increasing the PA charge density and fraction deprotonation increased the binding affinity in both cases, but LPA showed stronger sensitivity than DLPA. These data also suggested that differences in the binding behaviour between $Ca^{2+}$and Mg^{2+}arose from the molecular-level details of the binding mechanism. The spacing of the headgroup was important and the phosphate moieties could be closer together with LPA (1 tail) compared to DLPA (2 tail). This study provides important insights into the mechanisms underlying the binding of divalent cations to PA, which may have implications for understanding cellular signaling.

Biomaterial Interfaces
Room 321 - Session BI-TuA

Functional Materials and Biosensing

Moderators: Dr. Kenan Fears, U.S. Naval Research Laboratory, **Prof. Morgan Hawker**, California State University, Fresno

2:15pm **BI-TuA-1 Fibronectin and ECM-Mediated Regulation of Synovial Fluid Film Formation and Nanomechanics**, ***Roberto Andresen Eguiluz***, University of California Merced **INVITED**

Film formation is critical during locomotion to lubricate and protect the surface of articulated joints. The molecular components of the cartilage extracellular matrix (ECM) provide anchoring sites for lubricating molecules, thus serving as a platform for the assembly of the load/energy-dissipative films. The role of the collagen family in mediating the adsorption of lubricating and wear-protecting molecules, such as lubricin or hyaluronan, has been studied. However, the role of fibronectin (Fn) and its various conformations in regulating the adsorption of synovial fluid (SF) components and the wear-protecting properties of SF has been overlooked. During this talk, I will present our research efforts to understand the roles of various ECM components in controlling the supramolecular assembly of SF-derived films and SF components, and to gain insights into the synergies that regulate synovial joint surface nanomechanics. For this end, we employ experimental tools that include the surface forces apparatus (SFA), quartz crystal microbalance with dissipation (QCM-D), and atomic force microscopy, which I will briefly introduce.

2:45pm **BI-TuA-3 Magnetic Microparticle Biointerfaces for Fluorescence-Based Detection of C-Reactive Protein in Biological Fluids**, *Pegah Jamali, Zia Syed,* ***Umer Hassan,*** Rutgers, The State University of New Jersey

Biofunctionalized particle surfaces are useful model interfaces for studying biomolecular recognition while also enabling compact biosensing formats. In this work, we developed an antibody-presenting magnetic microparticle interface for fluorescence-based detection of C-reactive protein (CRP), an inflammatory biomarker associated with infection. The study focuses on the design and characterization of the bead–biomolecule interface, including antibody immobilization, target capture, fluorescence signal generation, and matrix-dependent assay response in biological fluids.

Carboxylated magnetic microparticles were chemically activated using EDC/NHS chemistry to create reactive surface groups for covalent antibody attachment. Anti-human CRP antibodies were then immobilized on the particle surface to form a biomolecular capture interface. The functionalized particles were incubated with FITC-labeled recombinant human CRP prepared across a concentration range of 0.5–100 µg/mL. After magnetic washing, bead-associated fluorescence was measured by optical microscopy, and image-based quantification was performed using background-corrected mean intensity analysis. This workflow links the surface density and stability of antibody-functionalized microparticles with the resulting optical response from captured protein.

The particle biointerface produced a concentration-dependent fluorescence signal in PBS buffer, human serum, and human urine. Calibration curves showed strong analytical linearity in all three matrices, with regression fits of $y = 54.10 + 1.12x$, $R^2 = 0.98$ in PBS; $y = 58.95 + 1.35x$, $R^2 = 0.98$ in serum; and $y = 13.0 + 0.32x$, $R^2 = 0.95$ in urine. The assay achieved a limit of detection of 0.5 µg/mL across all matrices. Serum produced the strongest optical response, while urine showed reduced sensitivity, highlighting the role of fluid composition, ionic environment, and nonspecific matrix effects on antibody–antigen recognition at the bead surface. Surface-conjugation stability was also evaluated over 28 days at 4°C and room temperature, with approximately 90% of the initial fluorescence signal retained, supporting the robustness of the covalent antibody–particle interface.

These results demonstrate a functional magnetic microparticle biointerface for CRP capture and fluorescence microscopy readout in complex biological environments. The platform is relevant to biomaterial-interface engineering, optical characterization of biofunctional surfaces, and particle-based biosensing, with future potential for integration into microfluidic workflows for rapid inflammatory biomarker testing.

3:00pm **BI-TuA-4 Potassium-Selective Nanoelectrode Arrays for Single-Cell Profiling of human iPSC-Derived Cardiomyocytes**, ***Dhivya Pushpa Meganathan***, *Joseph Wang,* University of California San Diego*; Zeinab Jahed Zeinab Jahed,* University of California at San Diego

Potassium ion (K^+) dynamics are central to cardiac electrophysiology, with early disruptions in K^+ flux often preceding arrhythmia and contractile dysfunction. However, current sensing technologies, such as patch-clamp, Microelectrode arrays (MEAs), and fluorescent indicators, either lack chemical specificity for K^+ or are unsuitable for long-term, single-cell analysis. Conventional ion-selective electrodes (ISEs), while more selective, are limited by bulk-phase design and poor spatial resolution. To address these limitations, we present KINESIS (K^+-Ion Nano-Electrode Selective Interface System), a nanofabricated, cell-compliant platform that enables direct, label-free potentiometric measurement of K^+ gradients with subcellular precision. KINESIS features high-aspect-ratio nanopillars coated with a valinomycin-based K^+ recognition membrane, forming a stable, non-invasive interface with human induced pluripotent stem cell-derived cardiomyocytes (hiPSC-CMs). This architecture allows localized, Nernstian sensing of K^+ efflux or depletion without disrupting cell membranes. Pharmacological validation shows distinct potential shifts in response to caffeine and ouabain. KINESIS thus offers a highly selective, spatially resolved approach for studying K^+ handling in cardiotoxicity screening and patient-specific disease modeling.

3:15pm **BI-TuA-5 Peptide Biosensor for Pathological Tau Detection in Neurodegenerative Disease**, ***Megan Pitz***, *Rebecca Mickol, Hugo Miranda Quijada, Sean Brown, Kenan Fears, Maryssa Beasley,* US Naval Research Laboratory

Tauopathies are a class of neurodegenerative diseases that are characterized by an abnormal aggregation and accumulation of the tau protein. Included in this class are Alzheimer's disease (AD), chronic traumatic encephalopathy (CTE), corticobasal degeneration (CBD), and Pick's disease (PiD), among others. Definitive diagnosis of many of these diseases is limited to post-mortem analysis of brain tissue, due to a lack of medical technologies allowing diagnosis during the patient's lifetime. However, diagnosis of these diseases ante-mortem would allow for much more targeted care and treatment for these patients. Therefore, there is a compelling need for technologies that can identify tau accumulations ante-mortem with high specificity. Here, we present a peptide-based biosensor system with the goal of detecting pathological tau aggregations in biological samples ante-mortem. One limitation in developing tau biosensors is the difficulty in producing the tau protein in laboratory settings. Consequently, in this project, we first explored recombinant expression of dGAE, a truncated form of tau which is responsible for protein aggregation. This protein segment has been historically difficult to express due to its high propensity for aggregation, interfering with efficient recombinant expression and purification. We explored three different purification tags to decrease aggregation after protein expression and compared total protein yields across expression and purification conditions. The second aim of this project explored a detector peptide system for identifying tau aggregations. A de novo peptide sequence was designed and evaluated via molecular dynamic simulations for its ability to selectively identify tau aggregates using a molecular probe. Preliminary results show the detector peptide aligning and changing conformation in the presence of tau aggregates, suggesting a peptide system capable of acting as a biomolecular probe for identifying pathological tau accumulation.

Biomaterial Interfaces
Room Ballroom A - Session BI-ThP
Biomaterial Interfaces Poster Session

BI-ThP-1 Interactions of KSCN with Phospholipid Monolayers Studied by Sum Frequency Generation and X-Ray Fluorescence, ***Sadia Afroz***, Pennsylvania State University; *Bastian Mueller, Emanuel Schneck,* TU Darmstadt, Germany; *Paul S. Cremer,* Pennsylvania State University

Thiocyanate (SCN^-) is a weakly hydrated anion that can interact relatively strongly with lipid membranes compared to other anions in the Hofmeister series. To date, the specific mechanisms governing this processes remain poorly characterized. To shed light on ion-lipid membrane interactions, we introduced KSCN into the subphase below 1,2-dilauroyl-sn-glycero-3-phosphocholine (DLPC) monolayers. This saturated lipid was chosen because it remains in the fluid phase at room temperature. Both the two-dimensional pressure of the monolayer and the salt concentration were varied. SFG was used to follow vibrational signals associated with the interfacial water structure, the lipid headgroups, the ordering of the alkyl chains, as well as the SCN^- anions. Such data are vital for characterizing the system, but the concentration of interfacial ions is not directly quantifiable. As such, we also employed total reflection X-ray fluorescence which can monitor the interfacial concentration of both K^+ and SCN^- concentrations. Details of these interactions as well as their implications for Hofmeister chemistry will be discussed.

BI-ThP-2 The Neurotoxin Vipoxin Induces Changes in Mechanical Properties of Breast Epithelial Cells, *William Linthicum,* Oxford Instruments; *Qi Wen,* ***Nancy Burnham***, Worcester Polytechnic Institute; *Svetla Petrova, Konstantin Balashev,* Sofia University, Bulgaria

The investigation of how drugs or toxins alter cell mechanics is gaining significant traction in biomedical science, driven by the dual objectives of elucidating their mechanisms of action and enhancing drug screening processes. In this study, Atomic Force Microscopy (AFM) was employed to examine and analyze the mechanical responses of cells exposed to the neurotoxin Vipoxin. This method enables the precise measurement of key mechanical parameters such as cell stiffness and viscoelasticity before and after toxin introduction in the cell culture. It was demonstrated that the cells' stiffness and viscosity decreased with increasing Vipoxin concentration. Additionally, Total Internal Reflection Fluorescence Microscopy (TIRFM) was utilized to monitor morphological changes in the cells over time. These morphological changes were quantitatively analyzed using fractal analysis of the acquired images. The observed changes in cell shapes implied the reorganization of the cell cytoskeleton, thus providing insight into the cell mechanics under the influence of Vipoxin.

BI-ThP-3 Sustainable Bioinspired Polymer–Mineral Composites for Adaptable Repair in Conservation Applications, ***Zoe Weber-Porter***, *Rishima Agnihotri, Ashwin Marichetty, Marco Rolandi,* UC Santa Cruz

Every year, tens of thousands of tons of plaster-based materials are used in restoration and conservation applications, many of which are derived from non-renewable sources and discarded at the end of their service life. Here, we introduce a biodegradable, bio-derived composite based on chitosan and calcium carbonate that is composed of simple, widely available constituents and designed for adaptable repair applications. By varying polymer molecular weight, concentration, and mineral content, the composite can be formulated to span injectable, paste-like, and putty-like behaviors, enabling accommodation of diverse structural filling and stabilization needs. We examine relationships between composition, flow behavior, and mechanical performance through rheological characterization of the wet composite and measurements of bulk density, porosity, and compressive strength in the hardened state. Rather than targeting a single optimized formulation, this work demonstrates a tunable material platform in which relationships between composition, flow behavior and mechanical performance guide selection of material behavior based on application requirements. Future applications of this approach include sustainable repair and conservation materials for exhibits, architectural restoration, and other contexts where adaptable handling, mechanical integrity, and biodegradability are desired.

BI-ThP-5 Pulsed Plasma Surface Functionalized Nanosilver for Gene Delivery, ***Ajinkya Trimukhe***, University of Milan Bicocca, Italy; *Prasad Pofali,* Pravara Institute of Medical Sciences, India; *Amogh Vaidya,* University of Texas Southwestern Medical Center; *Uday Koli, Prajakta Dandekar, Rajendrasing Deshmukh, Ratnesh Jain,* Institute of Chemical Technology, India

The efficient intracellular delivery of nucleic acids remains limited by the lack of vectors that are both effective and biocompatible. In this study, we synthesized silver nanoparticles, that were surface-engineered using low-pressure pulsed RF plasma polymerization with acrylic acid in vapor phase to introduce carboxylic functionalities, followed by covalent coupling to chitosan oligosaccharide (COS) through EDC chemistry, yielding metallo-polymeric nanocarriers (MPNCs). Surface functionalization characterization confirmed successful functionalization: FTIR and XPS evidenced carboxylation and amide bond formation, while DLS showed an increase in hydrodynamic size from AgNPs to AgNPs/COOH (166.3±23.04 nm) and then to MPNCs with attached DNA (276.0±17.75 nm). Zeta potential shifted from negative values for AgNPs (-13.4±1.39 mV) to strongly positive values for MPNCs, supporting electrostatic complexation with plasmid DNA (27.0±1.1 mV). Gel retardation assays demonstrated stable nanoplex formation at a plasmid:MPNC ratio of 1:6, and the complexes remained stable across a broad pH range. Importantly, the MPNCs protected plasmid DNA against both DNase I degradation and sequence-specific restriction digestion. Cell viability assay demonstrated that the COS used to encapsulate the modified nanosilver using EDC (92.05±9.46% and 102.79±2.85%), was substantially less cytotoxic than bare AgNPs (0% and 0%), and AgNPs/COOH (0% and 0%) equivalent to Triton X-100 (positive control); MPNCs at 0.5 mg/ml (87.06±3.98% and 93.55±1.65%) maintained high viability in A549 and HeLa cells respectively. Cellular uptake studies (in-vitro) further showed that MPNC-bound plasmid-DNA was internalized efficiently, with GFP expression detected in A549 cells and quantified by flow cytometry, reaching about 10% transfection efficiency at 24 h. Overall, the work demonstrates that pulsed plasma surface functionalization, combined with COS conjugation, can transform silver nanoparticles into a stable, biocompatible, positively charged non-viral vector with meaningful gene delivery performance.

BI-ThP-6 UVC Surface Sterilization Comparative Study via a New, Rapid Handheld Bio-Sensor for Pathogens, InnovaBug™, using Macroscopic DNA/RNA Epi-Fluorescence On Calibrated *E.Coli* Cultures Vs Standard Plating, *Nicole Herbots,* Arizona State University Department of Physics/SiO2 Innovates LLC/InnovaBug LLC; *Archana Suresh, Adith Shankar,* SiO2 Innovates LLC/BacteroBug LLC/FungiBug LLC; *Ananya Suresh,* SiO2 Innovates LLC/BacteroBug LLC/InnovaBug LLC; *Manassa Suresh,* SiO2 Innovates LLC/BacteroBug LLC/FungiBug LLC; ***Viraj Amin***, *Zaid Abu-Salah, Nachiket Rajinikhant,* University of Missouri-Kansas City School of Medicine/SiO2 Innovates LLC/InnovaBug LLC; *Cara Jacobs,* University of Missouri-Kansas City/SiO2 Innovates LLC/InnovaBug LLC; *Eric J. Culbertson,* SiO2 Innovates LLC/InnovaBug LLC; *Robert J. Culbertson,* Arizona State University Department of Physics

Anti-Microbial Resistance kills 50,000 patients/y in the US, 1.3 Mil /y globally. Meanwhile, since 2009, new pathogens, epidemics, pandemics and global outbreaks occur about every 2.5 years, not every 8-year as measured since the 1800s. H1N1 (2009), MERS (2012), Ebola (2014), Zika (2015), Covid-19 (2019), mpox (2022), Ebola-causing Bundibugyo virus disease (BVD) (2026) – occurred in the last 17 years.

Two key strategies to address such crisis are prevention and detection, in other words, sanitation and sterilization as prevention, especially of surfaces, and rapid triage of infected patients as detection.

Standard sterilization methods such as autoclaving at 121 °C under high water steam pressure and gamma irradiation are not usable in public and hospital spaces. But an - as of yet unestablished - sterilization method, UVC, potentially is.

In this work, a methodology for sterilization via UVC irradiation, is investigated on two different model bacteria to establish which combinations of UVC irradiation dose can meet sterilization criteria.

Sterilization criteria require reducing the probability for a single viable microorganism to remain, to less than 10^{-6}, which is also defined as a Sterility Assurance Level (SAL) of 6.

UVC irradiation can eradicate pathogens by breaking bonds in nucleic acid pairs in DNA/RNA and is used in disinfection (SAL = 3). The present study investigates 260-280 nm LEDs to sterilize surfaces beyond disinfection (SAL=3) using as model bacteria *Lactobacillus Acidophilus* and *E.Coli*. to achieve full sterilization, or SAL 6.

The LEDs deliver a power density of 80 ± 0.04 μW/cm^2, at a distance of 1 cm. For reproducibility and accuracy, six identical sets of 10 cultures are tested, three of which are used for control and three of which are irradiated.

*E. Coli*CFU counts were calibrated to yield 20 ± 5 × 10^{9}typical for microbial cultures reproducibility. After serial dilution, A and B are inoculated. The three control sets are compared to three sets irradiated for 180 second at 1 cm on one half of the plate, while the other half is shielded to remain unirradiated. This is to verify that absence or limits on bacterial growth in the UVC irradiated area is indeed due to irradiation, not failed culturing.

Irradiation for 180 s. yields a total of 144 ± 7 mJ/cm^{2}on a 4 cm^{2}square area, and an average kill rate of 99.9999% on surfaces, with reproducibility achieved over 9 different plates.

In conclusion, UVC LEDs can consistently achieve sterilization with a SAL of 6. However, the timeframe for final sterilization may not be immediate, as measured within minutes with a new sensor, InnovaBug™, instead of after 48 hours culturing.

BI-ThP-7 Physics–Driven Mechanisms Governing the Pharmacokinetics and Immune Fate of Gold Nanoparticles: The ADIE Framework Perspective*,* ***Bashiru Sodipo****,* Kaduna State University, Nigeria*; Hafsah Oyedokun,* Kaduna University, Nigeria

The clinical translation of gold nanoparticles (GNPs) in nanomedicine hinges on a mechanistic understanding of their pharmacokinetics (PK) at the nano–bio interface. Traditional ADME (Absorption, Distribution, Metabolism, Elimination) model is effective for small molecules and biodegradable polymers. But it fails to capture the unique behaviour of inorganic GNPs, which are non-biodegradable, and not subject to enzymatic metabolism. Also, the interactions of GNPs in-vivo are not random biochemical processes. This Perspective introduces the ADIE (Absorption, Distribution, Immune interaction, and Elimination) framework. Immune interaction replaces metabolism as the pivotal phase. The journey of GNPs in-vivo is governed by transport physics and interfacial energetics. Convection and diffusion dictate distribution of the GNPs. While the collision of the nanoparticles with blood biomolecules and protein corona (PC) formation is governed by stochastic Brownian motion. The PC dictates immune recognition through competitive adsorption and thermodynamic binding energies. Also, it determines opsonization and clearance pathways. The elimination of GNPs is mainly via renal elimination. This is governed by size-exclusion physics and stealth coating (surface chemistry) property of the inorganic nanoparticles. While hepatic sequestration results from immune recognition. ADIE model offers a predictive foundation for designing GNPs with optimized biodistribution and clearance. Also, it advances the rational development of nanomedicines by integrating principles of transport physics, interfacial thermodynamics, and immune interaction.

BI-ThP-8 Rapid Solidification of Blood Drops Into Homogeneous Thin Films via Hyper-Hydrophilic Coatings: Electrolytes and Blood Iron Comparative Analysis by EXAFS, XRF and RBS*, Nicole Herbots, Yash Pershad,* ***Thilina Balassoriya****, Nikhil Suresh, Wesley Peng, Saaketh Narayan, Rianna Rane, Harshini Thinakaran, Ashwin Suresh,* Arizona State University Department of Physics/SiO2 Innovates LLC/MicroDrop Diagnostics LLC*; Arjun Sekar,* Arizona State University Department of Physics/SiO2 Innovates LLC/MicroDrop Diagnostics*; Aarush Thinakaran, Arya Saravanan,* Arizona State University Department of Physics/SiO2 Innovates LLC/MicroDrop Diagnostics LLC*; Robert J. Culbertson,* Arizona State University Department of Physics

The most common, initial test to diagnose a plethora of conditions – especially in ERs- is to test electrolytes and blood iron quickly so that the most common causes conditions such dehydration, hyponatremia, anemia, de-nutrition, etc can be assessed .. In 2026, 4 to 10 milliliters (mL) of blood are the standard Blood Volume (BV) required per test, with 10 mL being the most commonly sampled BV.

Drawing 3 to 8 vials is the norm, for a total of 30 to 80 mL blood per test. In hospitals, such tests are conducted **daily**. Iron anemia occurs when 10% of BV has been removed. It takes only 5 to 10 days to cause 75% of patients to incur Hospital-Acquired Anemia (HAA) In infants, it is standard practice to replace their ***entire*** blood volumes by continuous transfusion every 10 days.

Reducing BV can improve healthcare practices and outcomes.

HemaDrop™ is a ***Hyper-Hydrophilic*** coating that can rapidly solidify microliters (μL) sized blood droplets in minutes.

Hyper-Hydrophilicity (HH) can flatten droplets into flat films by rapidly absorbing H_2O, transforming liquid drops into Homogeneous Thin Solid Films (HTSF) without phase separation or segregation. Solidification via HH occurs no matter the temperature and relative humidity. By instantly flattening drops into thin liquid films with large areas of contact, HemaDrop™ does not rely on surface evaporation, unlike coagulation.

Inhibiting coagulation yields HTSF with smooth, glistening surfaces and uniform thickness unlike the rough surfaces and uneven thickness of conventional Dried Blood Spots (DBS). 0.05 mL or 50 μL of blood yields HTSF of uniform composition to ±10% over ~0.25 cm^2, or 5 mm diameter blood disks.

Rapid solidification of blood drops via HH allows for solid state analysis in minutes via hand-held X-ray Fluorescence (XRF) while the BV drawn is reduced to 0.1 mL

Three independent methods were used to test this proposition.

Rutherford Backscattering Spectrometry (RBS) is used to study lateral uniformity, absolute elemental composition. compositional depth profile, and comparison to DBS.

X-ray Fluorescence (XRF) measured relative elemental composition of the blood HTSF

Extended X-ray Absorption Fine Structures (EXAFS) was used to detect blood iron to p.p.b.. EXAFS spectra show consistent, reproducible detection iron in multiple HTSFs of the same blood.

Accuracy and reproducibility of Solid State Analysis of Blood HTSFs via RBS, XRF, and EXAFS were tested by measuring electrolytes (Na, K, Mg, Ca, Cl) and Fe from single 50- μL droplets. Relative error analysis for XRF, RBS and EXAFS measured on multiple HTSFs shows reproducibility within 10%, the medically accepted standard.

BI-ThP-9 Rapid Differential Detection & Triage of Bacterial, Viral & Fungal Infection Triage for Early Outbreak Containment via Differential Macroscopic DNA/RNA Epi-Fluorescence (DMEF) in a Small Fluid Volume Diagnostic (SFVD) handheld Device: MicrobeD™**, Nicole Herbots,* Arizona State University Department of Physics/SiO2 Innovates LLC/InnovaBug LLC*; David Guo,* Drexel University School of Medicine/SiO2 Innovates LLC/InnovaBug LLC/ViroBug LLC*; Arya Saravanan,* Arizona State University School of Health Sciences/SiO2 Innovates LLC/BacteroBug LLC/MicrobeD LLC*; Nithish Prakash,* University of Pennsylvania School of Medicine/SiO2 Innovates LLC/InnovaBug LLC/ViroBug LLC/MicrobeD LLC/*; Manassa Suresh,* SiO2 Innovates LLC/InnovaBug LLC/MicrobeD LLC*; Jonathan Guo,* SiO2 Innovates LLC/InnovaBug LLC/ViroBug LL/MicrobeD LLC*; Nila Kathivaran,* Arizona State University Department of Physics/SiO2 Innovates LLC/BacteroBug LLC/MicrobeD LLC*; Sudharshini (Sudhi) Ram,* Arizona State University Department of Physics/InnovaBug LLC/ViroBug LLC/MicrobeD LLC/AID-TRIAGE LLC*; Ananya Suresh,* Arizona State University Department of Physics/SIO2 Innovates LLC/BacteroBug™/MicrobeD LLC*; Archana Suresh,* Arizona State University Department of Physics/SiO2 Innovates LLC/BacteroBug LLC/MicrobeD LLC*; Adith Shankar,* Arizona State University Department of Physics/SiO2 Innovates LLC/innovaBug LLC/MicrobeD LLC*; Esther Guo,* Arizona State University Department of Physics/SiO2 Innovates LLC/Innovabug LLC/ViroBug LLC/MicrobeD LLC*; Sriram Rajesh, Edawrd Kelemen,* Arizona State University Department of Physics/SiO2 Innovates LLC/InnovaBug LLC/BacteroBug LLC/MicrobeD LLC

In the years 2000-2026, **ten** viraloutbreaks have arisen, **four from new viruses**: West Nile (2003), **SARS-Cov-1 (2002-04),H1N1/Swine flu (2009-10), MERS-CoV (2012)**, Zaire Ebola virus (2013-2016), Zika (2015-2016), **COVID-19 (2019-21),**mpox (2022), Ebola-causing Bundibugyo Virus (BVD) (4/24/2026-), Andes Hantavirus, (5/9/2026-), thus one outbreak per 2.6 years, in contrast to an average of 1 per 8.5 years between 1800 and 2000.

Current diagnostics for viral infections use polymerase chain reaction (PCR) and virus-specific antigens. Covid-19 PCR swabs yield 40 % False Negatives (FN), 50% False Positives (FP) in the first 7 days of infection and need 3 days and advanced lab equipment for results. Covid-19 Rapid Antigen tests yield 66% FN and 40% FP in asymptomatic individuals.

Rapid, reliable detection of viruses is needed early in outbreaks until virus-specific tests are available. Two months into the 2026 Ebola BVD outbreak, **no** BVD tests exist. OTC COVID-19 became widely available only on Dec. 15, 2020, 12 months on.

Here, a new approach for detection and triage, *Differential Macroscopic DNA/RNA epi-fluorescence (DMEF),* uses test strips inserted a single hand-held, 'Small Fluid Volume Diagnostic' (SFVD) device, MicrobeD™*, akin to a blood glucose meter, but designed as an accessory to attached to a Smartphone camera. Test strips - called InnovaBug™*, with design subcategories specified as BacteroBug™*for bacteria , ViroBug™* for

viruses, and FungiBug™ for fungi, are optimized to detect and differentiate in minutes viral infections and loads from bacterial ones, use pairs of 0.015 mL drops, and aim for an accuracy ≤ 10% for FN and FP, 10% being the medical gold standard.

Strips combine DMEF from different dyes.

Micro-filters integrated to the strips impregnate blood serum, urine, sputum, etc .. with safe DNA/RNA fluorophores.

The strips are inserted into MicrobeD™, where the smartphone camera captures irradiances: $I_B$of LEDs inducing fluorescence, and fluorescence irradiances, $I_F$from DNA and RNA. Net $I_F$are analyzed via an AI App, AID-TRIAGE™*, which normalizes $I_{F\ with} I_B$, as a $R_{F/B}$ratio. AID-TRAIGE™ matches $R_{F/B}$to pathogen type and load via calibration tables from plating and assays databases. Sensitivity spans $10^5$to 10^9CFUs/mL, test duration ~ 5 -20 min. DMEF was collected on 500 InnovaBug™ strips, in 4 labs disseminated in Phoenix Metro, via 12 studies over 2 years with 4 MicrobeD™ prototypes. Manual analysis and AID-Triage™ established proof-of-concept, accuracy & reproducibility of DMEF to detect and differentiate pathogen types and loads via*in vitro*diagnostic device, MicrobeD™, InnovaBug™* test strips and the AID-Triage™ App.

* Patents Pending (2026)

BI-ThP-10 Decoding Antifouling Failure: How Primary Microfouling Communities Compromise Biocide Release*, **Kailey Richard,*** National Research Council Research Associateship Program at US Naval Research Laboratory*; Kenan Fears,* Naval Research Laboratory

For decades, copper-based marine coatings have been the primary defense against biofouling. However, their failure, suspected to be caused by microbial copper tolerance, is a growing concern. Primary colonizers, like bacteria and diatoms, can develop resistance, forming biofilms that may slow biocide release and accelerate macrofouling. This study investigates the role of key fouling species in this process, with a focus on diatoms. To achieve this, we exposed *Navicula incerta* and the green alga *Enteromorpha* sp. to copper biocides, copper (II) ions and copper (II) pyrithione, to assess their level of tolerance, their influence on the biocides chemical state, and their impact on copper release rates. Furthermore, this study investigates the interactions between bacterial and diatom communities, by establishing bacterial biofilms on coatings prior to the introduction of diatoms to observe the effects on subsequent diatom adhesion and growth.

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