Georgia Tech
Institute for Matter and Systems

2026 NNCI

REU Convocation

Hosted by the Institute for Matter and Systems

Atlanta, GA

August 2-4, 2026

National Nanotechnology Coordinated Infrastructure

NSF

2026 NNCI REU Convocation Schedule

Hotel accommodations for REUs and education coordinators will be at the Home 2 Suites by Hilton Atlanta Midtown

Sunday August 2

6:00-8:30 PM, Pizza Party, Registration, and Get to Know You, Marcus Nanotechnology Building Rms 1116-1118

Monday August 3

7:00-9:00 AM, Breakfast Global Learning Center

9:00-9:15 AM, Director's Welcome, Institute for Matter and Systems Executive Director Eric Vogel, Global Learning Center, Auditorium 233

9:15-9:30 AM, I Know What You Did this Summer, Associate Director for Education and Outreach Mikkel Thomas, Global Learning Center, Auditorium 233

Session 1A, Global Learning Center, Auditorium 233 (Session Chair: Heather Rauser)

9:30-9:42 AM, A1 Katherine Kendrick, NNCI Site: RTNN
Synthesis of 2D Multilayer Chiral Perovskites

9:42-9:54 AM, A2 Michael Connolly, NNCI Site: MANTH
Ferroelectric Field-Effect Transistors with Ultrathin AlScN Gates and 2D MoS2 Channels

9:54-10:06 AM, A3 Mia Delja, NNCI Site: NNF
Exploring Ion-Conducting Polymer Membranes for Renewable Energy Technologies

10:06-10:18 AM, A4 Tara Martindale, NNCI Site: NNF
Wire electrical discharge machining of ultra-high temperature ceramics

10:18-10:30 AM, A5 Alexander Gaines, NNCI Site: RTNN
Synthesis of 2D Multilayer Chiral Perovskites

Session 1B, Global Learning Center, Rm. 330 (Session Chair: Ana Sanchez Galiano)

9:30-9:42 AM, B6 Luca Felicioli, NNCI Site: NCI-SW
The Potential of Carbon-Coated Perovskite Solar Devices

9:42-9:54 AM, B7 Jessica Wei, NNCI Site: SENIC
Macrophage-Targeted Nanomedicine in a Skin-on-a-Chip Model to Modulate Wound Inflammation and Reduce Fibrotic Scarring

9:54-10:06 AM, B8 Jalen White, NNCI Site: SENIC
Miniaturization of the Oscillating Heat Pipe

10:06-10:18 AM, B9 Jose Ocampo, NNCI Site: NCI-SW
Study of Perovskite Stability Under Ultraviolet Radiation Exposure

10:18-10:30 AM, B10 Matthew Francoer, NNCI Site: SENIC
Remediation of Microplastics Using Polymer Nanofibers

10:30-10:50 AM, BREAK

Session 2A, Global Learning Center, Auditorium 233 (Session Chair: Lee Orzier)

10:50-11:02 AM, A11 Violet Tice, NNCI Site: KY-Multiscale
Attaching Microdevices to Fibers for Flow Through Electronics

11:02-11:14 AM, A12 Joohwan Choe, NNCI Site: SENIC
Vertical Organic Electrochemical Transistors for physiologic sensors

11:14-11:26 AM, A13 Kathy Guo, NNCI Site: RTNN
ML Spectral Data Analysis of Perovskite Fabrication in Real Time

11:26-11:38 AM A14 April McLane, NNCI Site: RTNN
Nanoimprinted Laser Cavities on Silicon

11:38-11:50 AM, A15 Braden Shearer, NNCI Site: KY- Multiscale
Plasmon Field-Effect Transistors for Low-Concentration Gas Detection

Session 2B, Global Learning Center, Rm. 330 (Session Chair: Sequoia Raven Nichols)

10:50-11:02 AM, B16 Sean Freeland, NNCI Site: MONT
Fabrication of a Bilayer Wire-Grid

11:02-11:14 AM, B17 Adam Vanluvanee, NNCI Site: NCI-SW
Genetically Encoded Amphiphilic Polymers for Biomimetic Membrane-Based Nanotechnologies

11:14-11:26 AM, B18 Romindra Gokhul, NNCI Site: KY-Multiscale
Capacitive Characterization of MEMS Bistable Beam for Nonvolatile Computer Memory

11:26-11:38 AM, B19 Amanda Gutierrez, NNCI Site: NNF
Characterization and Fabrication of Isotropic Liquid Metal Composites for Soft Robotics

11:38-11:50 AM, B20 Lirio Delgado Diaz, NNCI Site: NCI-SW
Understanding Micro- and Nanoplastics Through Polymer Characterization

11:50-1:00 PM, Lunch

1:00-2:00 PM, Poster Session 1

Session 3A, Global Learning Center, Auditorium 233 (Session Chair: Jessica Hauer)

2:00-2:12 PM, A21 Heidi Thompson, NNCI Site: SENIC
Characterization of Thermosensitive Hydrogel for Lymphatic Drug Delivery

2:12-2:24 PM, A22 Dorothy Wong, NNCI Site: RTNN
Understanding Phase Transitions and Lattice Dynamics of Antimony-Doped Double Perovskites via Temperature Dependence

2:24-2:36 PM, A23 Audrey Cseh, NNCI Site: MONT
Design and Optimization of a Self-Monitored Photonic Wire Bond

2:36-2:48 PM, A24 Mason Kempf, NNCI Site: RTNN
Surface Functionalization for Hybrid Perovskite Growth

Session 3B, Global Learning Center, Rm. 330 (Session Chair: Jenna Huttenmaier)

2:00-2:12 PM, B25 Amaris Mbuagbaw, NNCI Site: MANTH
Optimization of Poly(Ethylene Glycol)-Vinyl Sulfone (PEG-VS) Hydrogels for Enhanced Extracellular Vesicle Biomarker Detection

2:12-2:24 PM, B26 Adam Bowman, NNCI Site: KY-Multiscale
Suborbital Flight Assessment of dRBC in Reduced Gravity: Advancing an Automated Control System with Dual-Wavelength Spectrophotometer

2:24-2:36 PM, B27 Nathan Pak, NNCI Site: SENIC
Advanced validation technology for 3D heterogeneous integration packaging in AI and HPC innovation

2:36-2:48 PM, B28 Hannah Hobbs, NNCI Site: SENIC
Embedded Electrochemical Impedance Spectroscopy for Autonomous Microfluidic Biofilm Experiments

2:48-3:08 PM, BREAK

Session 4A, Global Learning Center, Auditorium 233 (Session Chair: Ana Sanchez Galiano)

3:08-3:20 PM, A29 Mateo Aleksov Rodriguez, NNCI Site: NCI-SW
Open-Air Processing and Synthesis for ZnO Thin Film Transistors

3:20-3:32 PM, A30 Emanuel Rijo De La Rosa, NNCI Site: MANTH
Fabrication of Honeycomb-Structured Ultrathin Films

3:32-3:44 PM, A31 Simon Ignjatovic, NNCI Site: SENIC
Extracellular Vesicles as Drug Carriers: Establishing a Loading Protocol and Prototyping a Microfluidic Chip

3:44-3:56 PM, A32 Elaine Ngo, NNCI Site: NCI-SW
Determining Operating Sensitivities and Tolerances of a Rubidum-85 Magneto-Optical Trap

Session 4B, Global Learning Center, Rm. 330 (Session Chair: Heather Rauser)

3:08-3:20 PM, B33 Griffin Cook, NNCI Site: RTNN
Chiral/Achiral Spacer Mixing in Copper-Based Hybrid Halide Perovskites

3:20-3:32 PM, B34 Jacob Loos, NNCI Site: NNF
Development of 3D Printed Stamps for Extracellular Nitric Oxide Gradient Quantification via Single Walled Carbon Nanotubes

3:32-3:44 PM, B35 Catherine Puckett, NNCI Site: NNF
Thickness-Controlled Synthesis and Characterization of Wide-Bandgap Perovskite-Related Crystals for Nanophotonics

3:44-3:56 PM, B36 Fiona Wolfe-Roberts, NNCI Site: RTNN
Optimizing Target Solvent Composition for RIR-MAPLE Deposition of Hybrid Perovskites

4:00 PM Georgia Aquarium

Tuesday August 4

7:00-9:00 AM, Breakfast Global Learning Center

9:00-9:15 AM, NNCI Retrospective, NNCI Director David Gottfried, Global Learning Center, Auditorium 233

9:15-9:30 AM, Group Photo

Session 1C, Global Learning Center, Auditorium 233 (Session Chair: Sequoia Raven Nichols)

9:30-9:42 AM, C37 Jonathan Herold, NNCI Site: NNF
Engineering Sustainable Lignin-Functionalized Ionomer Separators for Energy Technologies.

9:42-9:54 AM, C38 David Nguyen, NNCI Site: KY-Multiscale
Fabrication and Characterization of Carbon-Polymer Piezoresistive Sensors using Aerosol Jet Printing

9:54-10:06 AM, C39 Ronan Tollefsen, NNCI Site: KY-Multiscale
Fog Harvesting Utilizing Electrospun Interwoven Membranes

10:06-10:18 AM, C40 Polly Naneva, NNCI Site: MONT
Characterizing and Modeling of Neural Population Activity in Bottom-up Engineered Neurite Networks

10:18-10:30 AM, C41 Nicolas Manning, NNCI Site: SENIC
Photopatterning Poly(propylene carbonate) Sacrificial Films with Photoacid Generator and 375 nm Sensitizer

Session 1D, Global Learning Center, Rm. 330 (Session Chair: Lee Orzier)

9:30-9:42 AM, D42 Jessen Carriveau, NNCI Site: NCI-SW
Raman Spectroscopy to Characterize Diamond Quantum Sensors

9:42-9:54 AM, D43 Isabella Palit, NNCI Site: RTNN
Determining Phonon Band Structures of Inorganic Lead Halide Perovskite Alloys Via First Principles Calculations

9:54-10:06 AM, D44 Andrew Fang, NNCI Site: RTNN
Design and Simulation of Opto-electronic Flash Memory

10:06-10:18 AM, D45 Jesu Zermeno, NNCI Site: NCI-SW
Development of a Fluorescence Imaging System for Data Acquisition and Analysis in a Magneto-Optical Trap

10:18-10:30 AM, D46 Madilyn Tran, NNCI Site: KY-Multiscale
Microfabricated gas sensor array for the detection of airborne toxic organic compounds

10:30-10:50 AM, BREAK

10:50-11:50 AM, Poster Session 2

11:50-1:00 PM, Lunch

1:00-2:00 PM, Entrepreneurship Panel, Global Learning Center, Auditorium 233

Session 2C, Global Learning Center, Auditorium 233 (Session Chair: Jenna Huttenmaier)

2:00-2:12 PM, C47 Heshy Nemer, NNCI Site: MONT
De Magnetic Field Gradient Effects on Mitochondrial Morphology in hNPCS and Using Microfluidic PDMS Scaffolding

2:12-2:24 PM, C48 Caleb Sutton, NNCI Site: KY-Multiscale
Microfluidic Generation of Alginate Force Probes to Quantify Intra-Tumoral Compression

2:24-2:36 PM, C49 Sanya Braddy, NNCI Site: MANTH
Comparative Characterization of Extracellular Vesicles Released by Cell Lines from Distinct Tissue Origins

2:36-2:48 PM, C50 Alyssa Bauer, NNCI Site: SENIC
Selective Chemical Adsorption of Li+ from Brine Water

2:48-3:00 PM, C51 Nathan Bund, NNCI Site: Ky-Multiscale
Dielectric Consequences of Protein Tagging

Session 2D, Global Learning Center, Rm. 330 (Session Chair: Jessica Hauer)

2:00-2:12 PM, D53 Ava Foreman, NNCI Site: RTNN
MAPbI3 Thin Film Optimization for a Piezo-Acoustic Memristor

2:12-2:24 PM, D54 Grace Pavel, NNCI Site: SENIC
Silver Thione and Selone Complexes with Potential Antifungal Activity

2:24-2:36 PM, D55 Aashi Venkat. NNCI Site: SDNI
Kinetics of Nanotopography-Induced Transient Nuclear Membrane Poration and Repair

2:36-2:48 PM, D56 Rebecca Guan, NNCI Site: RTNN
Mixed-Cation Chiral 2D Perovskites Targeting Long Spin Lifetime

2:48-3:00 PM, D57 Carolyn Shi, NNCI Site: SENIC
Nanowire Characterization through Electrical and SEM Analysis

3:00-3:32 PM, BREAK

3.32-4:32 PM, Graduate Student Panel, Global Learning Center, Auditorium 233

4:32 PM Closing Remarks, Global Learning Center, Auditorium 233

Abstracts

Open-Air Processing and Synthesis for ZnO Thin Film Transistors

Mateo Aleksov, Arizona State University
REU Site: Arizona State University
REU PI: Nicholas Rolston *REU Mentor*: Nicholas Rolston

Thin film transistors are fundamental components found in nearly all electronics, and reducing their cost is at the forefront of transistor research. Due to the high cost of semiconductor manufacturing, there are many non-high performance applications where the cost of transistors is valued over the quality. Additionally, zinc oxide (ZnO) has emerged as a promising semiconductor for thin-film transistors due to its non-toxicity, abundance, low cost, and favorable optical and electrical properties. A key challenge is to find processing methods that can reduce manufacturing costs while also maintaining transistor performance and reliability. Open-air processing has emerged as a potential solution for this problem and an alternative to traditional vacuum-based fabrication by eliminating expensive vacuum equipment and prolonged high temperatures. Such open-air processing methods, including spin coating and plasma treatment, are utilized in order to develop an alumina (AlO_x)-based dielectric layer and a patterned ZnO semiconductor layer. The ZnO layer is patterned through the use of a shadow mask, and the resulting layers are added progressively on top of heavily p-doped silicon with aluminum electrodes deposited on the ZnO layer. The resulting AlO_x and ZnO layers are evaluated in terms of transistor performance, specifically analyzing the AlO_x layer's capacitive properties and leakage current along with both the layers' deposition thicknesses and uniformity. Several different spin-coated inks (aluminum nitrate and AlO_x nanoparticle based) and annealing methods (varying times and temperatures) are used to develop an AlO_x layer and are compared. Furthermore, the thicknesses and visual uniformity of all layers are analyzed with respect to the overall cleanliness of the samples. Ongoing work involves reducing leakage current in the AlO_x dielectric layer through improved annealing methods, controlling deposition thicknesses, and tuning the ZnO semiconductor layer for ideal resistances and carrier concentration.

Selective Chemical Adsorption of Li+ from Brine Water

Alyssa Bauer, University of Florida
REU Site: Georgia Institute of Technology
REU PI: Hailong Chen *REU Mentor*: Guangxing Zhang

With the rise of electric vehicles and energy storage technology, the global demand for lithium is rapidly increasing. Although lithium can be extracted through conventional methods such as hard-rock mining, which can be expensive and invasive to the environment, selective adsorption from naturally occurring brines offers an efficient and environmentally sustainable approach for lithium recovery. This project focuses on selectively adsorbing lithium ions (Li^+) from simulated brine water that contains competing ions such as sodium (Na^+) and magnesium (Mg^{2+}), using lithium containing battery materials as potential ion-sieve adsorbents.
Well known ion-sieve materials, such as lithium manganese oxide ($LiMn_2O_4$), were studied as a

reference for comparison, however this project primarily focuses on less-studied iron based materials such as lithium iron phosphate ($LiFePO_4$) and lithium iron oxide ($LiFeO_2$) due to the relatively low cost and natural abundance of iron. The battery materials undergo acid treatment to extract the lithium from their crystal structures which creates vacant sites where lithium can re-enter. XRD (X-ray Diffraction) characterization is used to evaluate phase change and structural change resulting from the acid treatment. Lithium adsorption tests are conducted by placing the materials in simulated brine containing lithium and competing ions to evaluate their ability to selectively adsorb Li^+ . Inductively coupled plasma mass spectroscopy (ICP-MS) is used to quantify lithium concentrations before and after adsorption. The results of this project will compare the stability and lithium adsorption behavior of each material to assess the potential of iron-based adsorbents for selective lithium recovery from brine.

Suborbital Flight Assessment of dRBC in Reduced Gravity: Advancing an Automated Control System with Dual-Wavelength Spectrophotometer

Adam Bowman, Centre College
REU Site: University of Louisville
REU PI: Kevin Walsh *REU Mentor*: Thomas Roussel

Dehydrated red blood cells (dRBC) have potential applications for long-term space voyages. By reducing mass by over 70% and eliminating the need for constant refrigeration, dRBCs serve as a novel solution to the problem of preserving blood for long-term space flight. A future, NASA-funded, sub-orbital flight experiment aims to test the efficiency of the rehydration process in zero gravity. The automated experiment will be controlled by a custom control circuit that provides tight sequence timing for the experiment (~190s), management of pressure and temperature sensors, as well as data acquisition and storage. The controller also includes a custom analog spectrophotometer circuit with a dual wavelength emitter and detector (574nm | 630nm) that will be used to quantify the O_2 binding of the hemoglobin (Hb) in the rehydrated RBCs.

This REU project has three main goals to support advancement of the experiment: design and fabrication of a custom enclosure for the control PCB and optical sensors, feasibility planning for the experiment design and layout, and final system built with initial validation. The custom enclosure design is a nested design including housing for the PCB and optical sensors. It provides feedthroughs for the fluid and electrical circuits of the experiment, and implements blackout conditions for the optical components. Through several fit-trials of the custom enclosure design, a basic layout for the experiment was performed, including the management of power distribution, and a thorough examination of the orientation of all electrical and fluid circuits. Five duplicates of the control circuit (four for flight and one for backup) have been completed and are ready for final validation of the experiment sequence and timing. An initial sensitivity calibration of the individual spectrophotometer wavelengths was performed using food coloring. Serial dilutions of Red 40 (574 nm) and Blue 1 (630 nm) food coloring were used to create four calibration curves, two for each color across two gain settings. While this data cannot be used to determine the O_2 binding capacity of Hb in rehydrated RBCs, the developed calibration procedure can be replicated to calibrate the system with rehydrated RBC samples.

Comparative Characterization of Extracellular Vesicles Released by Cell Lines from Distinct Tissue Origins

Sanya Braddy, North Carolina Agricultural and Technical State University
REU Site: University of Pennsylvania
REU PI: Jina Ko *REU Mentor*: Jenlu Pagnotta

Extracellular vesicles (EVs) are membrane-bound nanoparticles released by cells that facilitate intercellular communication by transporting proteins, lipids, and nucleic acids. Because EVs reflect the molecular characteristics of their parent cells, they have emerged as promising biomarkers for non-invasive cancer diagnosis and disease monitoring. This study compared EVs released by melanoma (A375), lung carcinoma (A549), and epidermoid carcinoma (A431) cell lines to evaluate differences in EV-associated CD9 detection. EVs were isolated from conditioned cell culture media using differential centrifugation followed by ultracentrifugation. Rolling circle amplification (RCA), a highly sensitive nucleic acid amplification technique, was employed with a CD9-targeted antibody-DNA probe to detect EVs through fluorescence microscopy. RCA-positive fluorescence signals were quantified and compared among the three cancer cell lines and a negative control.CD9-positive EVs were successfully detected in all three cancer cell lines. A549 exhibited the greatest RCA signal, followed by A431 and A375, while the negative control showed minimal background fluorescence. These findings demonstrate the ability of RCA to sensitively detect EV-associated biomarkers and reveal differences in CD9-associated signal among EVs released by distinct cancer cell lines. This work supports the continued investigation of extracellular vesicles as potential biomarkers for cancer detection and provides a foundation for future studies incorporating additional EV biomarkers, biological replicates, and patient-derived samples.

Dielectric Consequences of Protein Tagging

Nathan Bund, Texas A&M University
REU Site: University of Louisville
REU PI: Kevin Walsh *REU Mentor*: Stuart Williams

Dielectrophoresis (DEP) is a technique for trapping neutral particles using non-uniform electric fields. In protein DEP studies, fluorescent tags are often used as visual markers to aid in observation; however, these tags alter the chemical structure of the proteins, potentially impacting their polarizability. As a result, fluorescence-based measurements may not fully represent native protein behavior in biological applications.

In this project, we aim to design a system capable of integrating impedance analysis with fluorescent imaging of dielectrophoretic trapping. This system incorporates a silicon interdigitated microelectrode/microfluidic chip, an ADMX2001B impedance analyzer, fluorescence microscopy, and a relay to control the transition. Preliminary tests determined experimental parameters: impedance sweeps identified an ideal frequency range of 5-50 kHz, DEP trapping tests supported a voltage of 3.5 V_{rms}, and diffusion calculations confirmed that a 20 sec trapping period followed by a 60 ms measurement interval is feasible.

Future work can compare impedance spectra to particle luminosity and correlate both to protein concentration, ideally cementing impedance analysis as a label-free method of protein detection. DEP trapping rate, quantified using protein concentration, can then be used to compare the

polarizability of proteins with and without tags. Together, impedance analysis and standard fluorescent imaging can bridge the knowledge gap in dielectrophoretic protein research.

Scaling up the fabrication of tri-layer corrugated plates for solar sails

Jenna Cain, Fordham University
REU Site: University of Pennsylvania
REU PI: Igor Bargatin *REU Mentor*: Matthew Campbell & Gulzhan Aldan

To achieve the high acceleration necessary for long-range missions, relativistic light sails require a large area of ultra-lightweight, reflective, and thermally stable material. To address the need for durable, thin sail materials, our research group has developed ceramic plates with a corrugated honeycomb pattern that can improve the bending stiffness of nanometer-thick films one hundred-fold. However, the existing methods of fabrication for these corrugated films involves photolithography, which is difficult to scale past the centimeter scale. Here, we present a modified, more scalable fabrication route for tri-layer honeycomb plates. Our plates comprise a reflective aluminum center flanked by hafnium oxide layers for thermal stability improvement. To fabricate these films, we laser engraved Mylar, a thin plastic film, to create a mold for corrugation onto which we then deposited conformal layers of hafnia and aluminum by atomic layer deposition (ALD) and magnetron sputtering, respectively. We then removed the Mylar substrate by oxygen plasma ashing. To model how changes in our final product resulting from our use of a more flexible substrate, namely sloped corrugation walls, would affect the bending stiffness of our design, we performed finite element analysis simulations, finding that sidewall sloping from 1° to 80° has very minimal effect on overall plate bending stiffness. While we could not fabricate a plate through completion of substrate removal within the course of our summer program, we identified that future work on this process would benefit from process-compatible mechanical supports for the film to prevent wrinkling and tearing throughout fabrication.

Raman Spectroscopy to Characterize Diamond Quantum Sensors

Jessen Carriveau, Arizona State University
REU Site: Arizona State University
REU PI: Robert Nemanich *REU Mentor*: Robert Nemanich

Diamonds have been shown to be utilized in quantum information and sensing through the exploitation of nitrogen vacancy centers. Raman spectroscopy has been used in studies to characterize diamond samples, specifically in uncovering the nitrogen vacancy center density of lab-grown diamonds. We grow several diamond wafers through different methods (high pressure high temperature and plasma-enhanced chemical vapor deposition) with varying amounts/types of dopants (nitrogen and phosphorus) in order to investigate variables that could influence nitrogen vacancy center density. We use a micro-Raman grating spectrometer with adjustable laser wavelengths and gratings to gather photoluminescence and Raman spectra for analysis. We also tested different spots on the samples as well as different depths within the wafers to understand how the nitrogen vacancy density changes throughout the diamonds. We hope that this work will help us learn the best methods for creating diamonds dense with quantum centers to be used in the development of quantum computing technology and quantum sensors.

Vertical Organic Electrochemical Transistors for physiologic sensors

Joohwan Choe, Texas A&M University
REU Site: Georgia Institute of Technology
REU PI: Antonio Facchetti *REU Mentor*: Ayush Dhande

Biosensors capable of detecting ions and charged biomarkers, including potassium ions (K^+), troponin, procalcitonin, and C-reactive protein, play an important role in monitoring physiological conditions. Devices that provide rapid, real-time, point-of-care diagnostics could improve outcomes for conditions such as myocardial infarction and sepsis, where timely detection and intervention are critical. Organic electrochemical transistors (OECTs) are promising candidates for these applications because they operate efficiently in aqueous environments, amplify small electrochemical signals, and can be fabricated as low-cost, flexible sensing platforms. Their integration with textiles could enable comfortable and continuous physiological monitoring. This project investigated the OECTs based on the n-type organic semiconductor HOMO-gDPPTz blended with a photopolymerizable component called PEGDMA. The vertical structure of the OECT shortens the charge-transport distance and enables higher performance. Different HOMO-gDPPTz to PEGDMA ratios were integrated into OECT architecture to identify the ideal composition with high transconductance and stretchability. The fabricated OECTs were tested in various K^+ and pH concentrations to ensure its functionality as an ion sensor. These measurements determined the ion selectivity of OECTs. Lastly, intrinsically and extrinsically engineered top and bottom electrodes were investigated and incorporated with HOMOgDPPTz to engineer a stretchable OECT capable of maintaining its performance at different levels of mechanical strain.

Ferroelectric Field-Effect Transistors with Ultrathin AlScN Gates and 2D MoS2 Channels

Michael Connolly, Georgetown University
REU Site: University of Pennsylvania
REU PI: Deep Jariwala *REU Mentor*: Zekun Hu & Chao-Chuan Chen

Ferroelectric field-effect transistors (FeFETs) allow for energy-efficient, non-volatile compute-in-memory architectures by replacing the standard transistor's dielectric gate with a ferroelectric material. Aluminum scandium nitride (AlScN) is a promising ferroelectric material due to its high remanent polarization and back-end-of-line (BEOL) compatibility. However, its large coercive field motivates the use of ultrathin films to allow for lower operating voltages. In this work, we fabricated and characterized a 20 nm AlScN-based FeDiode (Al/AlScN/Al) via DC J-V, AC J-V, and C-V measurements, all of which show behavior consistent with ferroelectric polarization switching. These results confirm switching in an ultrathin AlScN film, a necessary step toward realizing an AlScN-gated FeFET, though FeFET fabrication has not yet demonstrated successful channel switching.

Chiral/Achiral Spacer Mixing in Copper-Based Hybrid Halide Perovskites

Griffin Cook, North Carolina State University
REU Site: University of North Carolina – Chapel Hill
REU PI: Wei You *REU Mentor*: Liang Yan & Camryn Gloor

The mixing of chiral and achiral spacers within hybrid organic-inorganic perovskites (HOIPs) has been previously shown to enhance chiral characteristics of the system through chiral relay. Chiral copper-based HOIPs show promise in spintronic applications through the combination of inherent magnetism and chirality induced spin selectivity. This work seeks to study the effect of chiral/achiral spacer mixing within a copper-based HOIP system as a way of enhancing/changing chiral and spin selective properties.

Design and Optimization of a Self-Monitored Photonic Wire Bond

Audrey Cseh, University of Florida
REU Site: Montana State University
REU PI: Parvinder Gill *REU Mentor*: Parvinder Gill

Photonic wire bonds (PWBs) are adaptive optical interconnects fabricated in situ between photonic components, offering an alternative to inefficient active alignment processes during packaging. This work presents the design of a polymer PWB with dual functionality as an interconnect and an inline temperature sensor, realized through the incorporation of a first-order surface Bragg grating. The PWB was modeled as a tapered cylindrical bond adiabatically coupling a single-mode optical fiber and a silicon nitride strip waveguide; a periodic grating was subsequently integrated onto a uniform-diameter segment extended from this taper. Finite-difference eigenmode and eigenmode expansion simulations were used to evaluate the modal properties and spectral response of the structure, allowing the selection of design parameters such as grating length and corrugation depth to produce a resolvable Bragg reflection suitable for sensing while minimizing insertion loss. Temperature-dependent models further characterized Bragg wavelength shifts arising from the thermo-optic response and thermal expansion. This framework serves as a simulation-based proof of concept of Bragg grating temperature sensing in PWBs, providing a foundation for future experimental implementation and optimization.

Understanding Micro- and Nanoplastics Through Polymer Characterization

Lirio Delgado Diaz, Boston University
REU Site: Arizona State University
REU PI: Timothy Long *REU Mentor*: Kelly Nguyen

Micro- and nanoplastics are an increasing concern because microplastics have already been detected in several human tissues and fluids, while the behavior of even smaller nanoplastics remains less understood. This research investigates how polymer processing changes internal structure, particularly crystallinity, and how those structural changes influence thermal stability, friction, and wear. Using melt processing, differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), and tribology, the study aims to link material structure to micro- and nanoplastic generation and support the design of plastics that are more stable, durable, and less likely to release harmful particles during use.

Exploring Ion-Conducting Polymer Membranes for Renewable Energy Technologies

Mia Delja, University of Nebraska – Lincoln
REU Site: University of Nebraska – Lincoln
REU PI: Shudipto Dishari *REU Mentor*: Karen Acurio

Proton exchange membranes (PEMs) are essential for fuel cell operation, requiring high proton selectivity and mechanical durability. Initial efforts focused on Nafion-vesicle membrane composites to improve proton transport; however, these membranes suffered from poor mechanical stability failing primarily due to vesicle overloading which compromised the structural integrity of the polymer matrix. This instability hindered reliable characterization, prompting a research pivot to a comparative study of self-standing membranes cast from Nafion D2020 and 3M 825 EW PFSA ionomers. By employing solution casting and Electrochemical Impedance Spectroscopy (EIS), the study established key performance benchmarks for thickness and proton conductivity across both materials. The results provide critical insights into how membrane chemistry dictates the balance between fabrication feasibility and electrochemical efficiency, guiding the design of the next generation of polymer electrolytes for renewable energy applications.

Design and Simulation of Opto-electronic Flash Memory

Andrew Fang, Georgia Institute of Technology
REU Site: North Carolina State University
REU PI: Stan Cheung *REU Mentor*: Stan Cheung

Optical computing has been identified as a promising candidate to fulfill the surging demand for compute power driven by AI workloads, providing substantial improvements in speed, bandwidth, and energy efficiency over electronic computing. However, optical computing implementations have been limited by the lack of a suitable non-volatile memory technology with optical readout, requiring costly optical-to-electrical (O/E) and electrical-to-optical (E/O) conversions. Flash memory stands out as an attractive near-term solution due to its CMOS compatibility, high density, and established use for storage of neural network weights and training datasets. In this work, we use Technology Computer-Aided Design (TCAD) software to develop device models and to evaluate speed, retention, and optical characteristics in a Flash memory cell integrated within a silicon photonics platform with optical readout based on the plasma dispersion effect. We propose a novel device design employing a bandgap-engineered tunnel oxide to improve these characteristics.

The Potential of Carbon-Coated Perovskite Solar Devices

Luca Felicioli, Arizona State University
REU Site: Arizona State University
REU PI: Nicholas Rolston *REU Mentor*: Marco Casareto

Earth is currently experiencing a climate crisis, carbon emissions are on the rise, and the environment is at risk. This looming threat has created demand for sustainable energy solutions to mitigate the damage of climate change. Perovskite solar modules are seen as the next generation of solar modules, exceeding efficiencies of 25%. However, these devices typically consist of back-electrodes made up of rare and costly metals, such as silver, that limit the device's stability. Carbon is a worthy replacement for these metals as the back-electrode, being more abundant, cheaper, and allowing for better stability. Devices in this study were coated with carbon paste using open-air scalable methods such as blade coating for carbon deposition and UV laser marking for device isolation. Both methods can be upscaled to large-scale production. Carbon electrodes with lower thicknesses, not exceeding 5 micrometers, yielded the best efficiencies. However, these devices significantly fell short of the ideal efficiencies of silver coated devices. The carbon-coated devices

also displayed promising stability when undergoing heat and light exposure at 85° Celsius, with their efficiencies increasing in the first couple of days. When exposed to more extreme temperature aging at 100° Celsius, the devices showed similar stability. Although the carbon-coated devices showed lower efficiencies, they show economic promise due to their cost effectiveness when it comes to their stability, materials, and methods.

MAPbI3 Thin Film Optimization for a Piezo-Acoustic Memristor

Ava Foreman, University of North Carolina – Asheville
REU Site: Duke University
REU PI: David Mitzi & Tania Roy *REU Mentor*: Yi Xie, Hintsa Fisseha Hishe & Arijit Sarkar

Memristors and other neuromorphic devices represent a significant advancement in computing hardware, offering a solution to many of the inherent problems of the traditional von Neumann architecture including latency and massive energy consumption. Within this field, piezo acoustic memristors are a distinct class of devices in which resistive switching between conductance states can be modulated by acoustic stimuli, enabling the devices to sense and process signals without the need for electrical input. With a general structure of electrode/active layer/electrode, many materials including chalcogenides, polymers, and metal oxides have been employed as the active layer in memristors, however complex structures and synthetic procedures of these materials have largely hindered efficiency in production and widespread implementation. Methylammonium lead iodide ($MAPbI_3$) is a halide perovskite material that possesses beneficial properties for a memristor including high defect tolerance, long electron hole diffusion, and piezotronic potential. While $MAPbI_3$ is a well-studied material, its application largely lies in solar cells, leaving optimization for a memristive device relatively unexplored. For the present study, uniform and reproducible $MAPbI_3$ thin films were deposited on a glass substrate using a onestep antisolvent spincoating method, followed by annealing. Characterization was done with X-ray diffraction (XRD) to determine the crystallinity and phase, optical microscopy to examine defects and determine uniformity, and scanning electron microscopy (SEM) to examine thickness of the films. The $MAPbI_3$ memristor was assembled on a glass substrate with the structure: bottom electrode (Au)/$MAPbI_3$/top electrode(Ag), in which the electrodes were evaporated in a crossbar array to allow for scalability. High quality $MAPbI_3$ films were obtained by modulating precursor concentrations to eliminate PbI_2 impurities and maintain the targeted tetragonal phase, using a mixed DMF and DMSO solvent for the precursor solution to evade pinholes in films, and using diethyl ether as an antisolvent to promote uniform nucleation over the substrate. For the structure of the device itself, it was found that bottom electrodes should be less than ¼ of the thickness of the $MAPbI_3$ layer, to avoid defects at contact points. Preliminary testing of a piezoacoustic $MAPbI_3$ memristor through I-t measurement found the conductance states to be modulated by sound waves with a frequency of 1 kHz. These results will allow for further development of piezoacoustic $MAPbI_3$ memristors with a wider array of frequency sensitivities and applications.

Remediation of Microplastics Using Polymer Nanofibers

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Microplastic (MP) pollution is a key concern for public health and environmental protection, but current methods of removal used in water treatment plants often struggle with smaller particles

(<50μm) that can more easily pass through filter pores. Nanofiber filtration is a promising method for removing these smaller MPs, with the high surface area and small pore size of nanofiber filters allowing for improved adsorption and size exclusion. In this work, a range of electrospun nanofibers, including environmentally friendly biopolymers, were fabricated and their ability to remove MP pollution from water was evaluated. Polyacrylonitrile, Cellulose Acetate, Cellulose, and Chitosan-based membranes were evaluated, formed via electrospinning followed by surface functionalization. Aerogels of Polyacrylonitrile and Cellulose were also fabricated through ultrasonication and freeze drying. Performance was evaluated through the filtration of a model MP solution of 1μm Polystyrene spheres, using UV-Vis Spectroscopy to quantify MP removal. Results from this testing identified Cellulose Nanofiber as a promising material for microplastic removal and demonstrated successful filtration using aerogels despite their loose and porous structure.

Fabrication of a Bilayer Wire-Grid

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This work investigated the practical resolution limits of photolithographic fabrication in the Montana Microfabrication Facility clean room by creating a bilayer wire-grid. Periodic wire-grid structures were fabricated using negative-tone NR9-1500PY photoresist. Silicon wafers were cleaned, spin-coated, softbaked, exposed through a resolution-testing photomask via contact, post-exposure baked, and developed. Aluminum was then deposited onto the wafer by nonconformal evaporation to create a two-level aluminum grating. Optical microscopy and Dektak stylus profilometry were used to characterize the fabricated structure. Optical images were analyzed in FIJI and with python scripts to determine wire widths, gap widths, periods, and fill factors in the same wafer and to compare across different wafers. Profilometry measurements were used to determine the photoresist height, full width at half maximum, and feature period for larger structures. The smallest feature size that was fabricated reliably was 1.5um. Measured fill factor differed from the nominal value of 50% by about 5%. Variations in measurements from nominal values can be attributed to wafer-to-mask contact, contamination, and measurement limitations. These results demonstrate the fabrication resolution of the available MSU process and identify specific improvements needed for more repeatable sub-micrometer wire-grid fabrication.

Synthesis of 2D Multilayer Chiral Perovskites

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An ensemble of closely spaced two-level systems under certain conditions can demonstrate an increased emission rate proportional to their density. In 1954, R. Dicke predicted this phenomenon as a consequence of coupling to the shared photonic field during the spontaneous radiation process. In solid-state materials, photoexcited dipoles can be approximated effectively as two-level objects. However, their short electronic coherence limits them to act as independent, uncoupled entities. This research presents the recent spectroscopic results obtained for CsPbBr3 perovskite that exhibits unconventional solitonic superfluorescence. A custom built Homodyne detection setup is detailed and employed to study the photon statistics of this solitonic

superfluorescence. Additionally low-temperature second-order correlation studies confirm the higher coherence degree of the emission as it transitions from a random to an ordered configuration above a critical density, with the second order coherence being measured by the custom built homodyne detection setup. These findings could pave the way towards the development of new materials that exhibit macroscopic quantum phenomena at elevated temperatures and further our understanding of unconventional solitonic superfluorescence.

Capacitive Characterization of MEMS Bistable Beam for Nonvolatile Computer Memory

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Modern computing relies on two memories that are both hitting walls: DRAM is volatile, wastes power on constant refresh, and is radiation-sensitive, while flash suffers limited write endurance and slow, high-voltage writes. This project aims to characterize a memory cell that stores the bit as physical position rather than charge: a Ti-W beam, fabricated under compressive stress at the University of Louisville, buckles into one of two stable states after release, and electrostatic force from a top or bottom electrode switches the state with no power required to hold it — offering zero standby power, low-voltage writes, and inherent radiation hardness. These chips were fabricated in Spring 2026, and this project is their first electrical characterization. Device capacitance was measured with an Agilent 4284A LCR meter at a probe station and an AD7746 capacitance evaluation board controlled through LabVIEW. Because the ~150 attofarad switching signal is far smaller than typical probe-station noise, a noise budget was built piece by piece — instrument alone, then each cable and probe — to isolate each component's contribution. Key results include confirmation of device geometry through agreement between electrical and optical measurements, probe-station configurations that reduce noise by nearly an order of magnitude, and capacitance-voltage sweeps on working devices, establishing the measurement foundation needed to definitively verify bistable switching.

Mixed-Cation Chiral 2D Perovskites Targeting Long Spin Lifetime

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Materials with long spin lifetimes are desired for spintronic applications; however, spin relaxation mechanisms limit spin lifetime. Chiral 2D halide perovskites are a group of materials being studied for their spin dynamics. The inclusion of a hydroxyl group in the perovskite structure can potentially increase the spin lifetime of the material. In this work, we attempt to use a mixed-cation system to incorporate both the hydroxyl group and chirality into a 2D perovskite to lengthen the spin lifetime.

ML Spectral Data Analysis of Perovskite Fabrication in Real Time

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Hybrid metal halide perovskites are cutting-edge photovoltaic materials due to their tunable properties, high efficiency, and inexpensive synthesis. However, achieving these properties in thin film devices requires precise control over antisolvent drip conditions during the spin coating process. Antisolvent drip controls the exact time of nucleation which can be monitored using optical spectroscopy. We utilize an automated spin coater equipped with in situ spectroscopic measurements, computer vision, and Bayesian Optimization to find optimal drip conditions. Current vision-based classification is helpful but it is limited to classifying films into discrete ranks without any physics-based data. We present a hybrid way to classify perovskite thin films using vision and spectroscopy to provide more detailed ranking. This approach can further help predict the film quality before completed fabrication using in-situ spectral data. Through this research, we hope to better assess film quality autonomously by using multiple data sources, including imaging, spectroscopy, and time-resolved traces.

Characterization and Fabrication of Isotropic Liquid Metal Composites for Soft Robotics

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Soft robotics and thermoregulatory garments rely on thermally conductive, liquid metal (LM)-embedded composites to maintain stable electrical pathways during extreme mechanical movement. However, the standard spherical morphology of LM droplets inherently limits both composite flexibility and conductivity. To overcome this bottleneck, this study systematically evaluated the coupled effects of droplet elongation and spatial orientation within a 50% LM volume-fraction solid-liquid composite. Extensive characterization revealed that while uncontrolled droplet elongation reduced conductivity in off-axis directions, controlled directional alignment substantially optimized transport properties along the primary conductive axis. Furthermore, integrating this tailored composite into an additive manufacturing process enabled the fabrication of complex 3D shapes, confirming the practical viability of this approach. Together, these characterization and fabrication insights offer a robust framework for next-generation flexible electronics and wearable technology.

Engineering Sustainable Lignin-Functionalized Ionomer Separators for Energy Technologies.

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Ion-conducting membranes play a critical role in electrochemical energy technologies, where they regulate ion transport and influence overall device efficiency and durability. Efficient ion transport is, therefore, essential for improving the performance and long-term stability of electrochemical devices. Nafion represents a widely used perfluorosulfonic acid ionomer, whereas SPSf provides a potentially lower-cost and more environmentally sustainable hydrocarbon-based alternative. In this work, pristine Nafion and sulfonated polysulfone (SPSf) membranes were fabricated, and in some other variants, sulfonated lignin (LS) was incorporated into Nafion and SPSf membrane matrices. Lignin, a renewable biopolymer, was chosen to potentially improve the performance and

sustainability of the membrane separators. Electrochemical impedance spectroscopy and ion-permeability measurements demonstrated that LS-incorporation enhanced proton conductivity in both membrane systems. Among the investigated membranes, Nafion-LS exhibited the highest ionic conductivity, while SPSf-LS showed promising performance as a cost-effective and environmentally sustainable alternative to fluorinated ionomers. These findings highlight the potential of lignin-functionalized ionomer membranes as advanced separation materials for next-generation energy technologies.

Embedded Electrochemical Impedance Spectroscopy for Autonomous Microfluidic Biofilm Experiments

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Rapid detection and characterization of bacterial biofilms remain longstanding challenges in point-of-care diagnostics. Conventional approaches, including culture-based assays and microscopy, are labor-intensive, often destructive, and provide limited continuous information about biofilm development or responses to environmental perturbations. Electrochemical impedance spectroscopy (EIS) offers a non-destructive alternative by measuring the frequency-dependent electrical impedance of electrochemical systems. Unlike endpoint imaging methods, EIS enables continuous monitoring of biological processes while capturing changes in electrochemical properties, such as resistance and capacitance, that reflect the evolving biological microenvironment. BioLoop is an embedded platform for autonomous electrochemical impedance spectroscopy in microfluidic systems. It integrates a Raspberry Pi controller, automated fluid routing, and an EmStat4X potentiostat to perform continuous impedance measurements during biological experiments. A conductivity-based analysis framework estimates apparent ionic strength while tracking electrochemical signatures associated with biofilm development. We demonstrated platform functionality through automated salinity monitoring, electrode quality control, biofilm monitoring, and preliminary viability assessment. By unifying automated sensing, environmental perturbation, and data analysis in a single workflow, BioLoop provides a foundation for closed-loop microfluidic systems that can adapt experimental conditions in response to electrochemical feedback. Potential applications include biofilm monitoring, environmental sensing, and autonomous laboratory experimentation.

Extracellular Vesicles as Drug Carriers: Establishing a Loading Protocol and Prototyping a Microfluidic Chip

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The development of extracellular vesicles (EV) research, from isolation and characterization to loading and drug delivery, has created a need for delivery method standardization. Much of the literature surrounding EV loading relies on the comparison of loading methods with differing cell lines, ratios of drug to EV, and loading drugs. This project aimed to compare passive incubation and electroporation EV loading using calcein, a small, hydrophilic fluorescent molecule, similar in size and charge to many chemotherapeutic drugs. This study successfully produced a procedure for

passive loading of EVs with calcein for 24 h at 37℃ resulting in a small increase in EV size, minimal changes in concentration, and a maximum encapsulation efficiency (EE%) of 0.0069%. This project additionally developed a microfluidic chip to add a microfluidic loading component to the broader research project. A design was adapted and modified to allow the shear stress applied to EVs during mixing to form transient pores for loading cargo to diffuse through without posing threat to the viability of EVs membranes. Several prototypes were created using 3D resin-printed molds, polydimethylsiloxane (PDMS) casts, and plasma bonding to glass slides.

Surface Functionalization for Hybrid Perovskite Growth

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Hybrid perovskites (HP) are a class of semiconductors composed of an organic cation, a divalent metal cation, and a halide within a hybrid crystal structure. The wide variety of combinations of perovskite components results in materials with tunable optoelectrical properties, valuable for various applications in the semiconductor industry, such as photovoltaic cells. While most perovskite thin-film fabrication is solution based, metal-organic chemical vapor deposition, in which precursor gases are flowed through two temperature zones using organometallic precursors has been shown to produce compact uniform HP films. Depending on the substrate on which they are grown, resultant films exhibit different properties. I have investigated this behavior and the control that can be offered by functionalizing the substrate surface using various aminopropyl precursors, including 3-aminopropyl methoxysilane (APTMS), ethoxysilane (APTES), and phosphonic acid (APPA). X-ray photoelectron spectroscopy (XPS) was used to verify the success of surface functionalization. Perovskites were then grown on the various functionalized services. X-ray diffraction (XRD) was used to determine the preferred orientation of perovskite crystals, while scanning electron microscopy (SEM) was used to determine the surface morphology of the perovskite films. We found that all surface functionalizations resulted in a more uniform layer of perovskite compared to a bare silicon surface. Furthermore, functionalization resulted in a pronounced (202) crystal plane peak in the XRD spectra that is absent in that of the bare silicon substrate spectrum. Further investigation into other types of functionalization precursor and perovskite formulations could prove valuable in improving perovskite film growth and interfaces for photovoltaic devices.

Synthesis of 2D Multilayer Chiral Perovskites

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This research explores the synthesis and characterization of amino acid-based hybrid perovskitoids. Hybrid perovskitoids combine organic and inorganic components, with the organic species typically acting as spacers. Amino acids are natural, abundant, and chiral, making them ideal spacer candidates for introducing chirality into perovskitoid frameworks. Their ester derivatives were used to minimize incorporation through hydrogen bonding. Crystals were synthesized using slow cooling and layer diffusion methods, and they were characterized by powder X-ray diffraction (PXRD), optical microscopy, and UV–Vis spectroscopy. D-enantiomer perovskitoids of leucinate, valinate, and 2-aminobutanoate were successfully synthesized and

characterized. Synthesis of a piperidine-based perovskitoid was also optimized, and PXRD and UV–Vis measurements provide strong evidence for the formation of a hybrid material with structural features similar to other amino acid ester perovskitoids.

Development of 3D Printed Stamps for Extracellular Nitric Oxide Gradient Quantification via Single Walled Carbon Nanotubes

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Nitric oxide (NO) is a critical intercellular signaling molecule with varying effects. Elevated or deficient NO levels have been linked to apoptosis, reduced transcription of growth factors, and inhibition of the S phase of the cell cycle. In cancer cells, NO concentration is linked to altering tumor adhesion, growth, and proliferation. Understanding NO concentrations and gradients could help with cancer diagnosis and treatment. NO can be monitored via changes in Single Walled Carbon Nanotube (SWNT) fluorescence, but a system to make reproducible measurements must first be developed to enable reliable analysis of NO gradients. In addition, this system must preserve the integrity of the SWNT platforms. This study investigates NO concentration generated by MDA-MB-231, triple negative breast cancer cells. Stamps are designed to allow for multiple spatial arrangements, modeled in Fusion 360, 3D printed, and used to mold polydimethylsiloxane (PDMS) substrates. Once cured, the PDMS is used for patterned cell seeding. Designs consist of thin (<1 mm) PDMS substrates with small wells, while variations in well spacing and number are used to establish a library of gradients and cell interactions. The stamps provide a reproducible approach for investigating the relationship between cell spacing, NO signaling, and cancer cell proliferation.

Photopatterning Poly(propylene carbonate) Sacrificial Films with Photoacid Generator and 375 nm Sensitizer

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Direct photopatterning of poly(propylene carbonate) (PPC) sacrificial films can be used to create templates for embedded channels and air gaps. However, established positive-tone PPC processes rely on photoacid generators (PAGs) activated at 248 nm. Here, 1-chloro-4-propoxythioxanthone (CPTX) was evaluated as a near-ultraviolet sensitizer for the 248 nm Rhodorsil-FABA (FABA) photoacid generator to enable maskless patterning at 375 nm. Neither FABA nor CPTX alone produced PPC removal at 375 nm, whereas their combination produced dose-dependent film removal, supporting CPTX sensitization. Increased additive loadings shifted the response toward lower dose but increased non-volatile residue. A formulation containing 5 wt% FABA and 1.5 wt% CPTX relative to PPC was selected for applied studies. 1 µm-thick films were dry-developed in 5 min at 110 °C ($D0$ = 30 mJ/cm^2, $D100$ = 300 mJ/cm^2, γ = 1.97), whereas thicker films required extended development that produced widening consistent with lateral acid-mediated transport. For 10 µm thick films exposed at 400 mJ/cm2, the dimensional bias was only ±6 µm per side across 250 to 1000 µm features. Fully developed 36 µm-thick films were achieved after 30 min at 110 °C, with D0 = 50 mJ/cm^2, D100 = 330 mJ/cm^2, and γ = 2.76. At 1000 mJ/cm^2, the 500 and 1000 µm features

showed bottom-width biases of +4.4 and +22.1 μm per side, respectively. These results establish a quantitative basis for near-ultraviolet photopatterning of PPC sacrificial polymers.

Wire electrical discharge machining of ultra-high temperature ceramics

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Aerospace and nuclear applications require materials resistant to extreme temperatures, oxidation, and irradiation. Ultra-high temperature ceramics (UHTCs) are well suited to this task; being transition metals that are bonded with diborides, carbides, and/or nitrides that can withstand temperatures above 3000°C. Due to their extreme hardness and brittleness they are extremely difficult to machine via traditional means as they are prone to fracture and excessive tool wear; therefore, to manufacture UHTCs parts, thermal processes such as wire electrical discharge machining (WEDM) are used to form complex shapes. While this is a well-known process, not much work has been done in characterizing the machinability of certain materials via WEDM. This project aimed to analyze the physical characteristics of zirconium carbide (ZrC), silicon carbide (SiC), and their composite ZrC-SiC before and after machining with WEDM. These materials were formed into solid parts from commercial powder, underwent wire EDM, and had their physical and chemical properties analyzed to indicate potential difficulties with machining for future work.

Optimization of Poly(Ethylene Glycol)-Vinyl Sulfone (PEG-VS) Hydrogels for Enhanced Extracellular Vesicle Biomarker Detection

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Extracellular vesicles (EVs) are membrane-bound particles, typically 20–200 nm in diameter,(exosomes) that carry molecular cargo, including proteins and microRNAs, reflective of the physiological state of their parent cells. Their small size and low abundance make detection using traditional nucleic acid assays challenging. Although rolling circle amplification (RCA) enables highly sensitive nucleic acid detection, its performance relies on efficient pre-amplification steps, including target hybridization, and ligation. Optimizing these steps is therefore critical for improving downstream RCA performance.
In this study, poly(ethylene glycol)-vinyl sulfone (PEG-VS) hydrogels were used as a platform for pre-amplification optimization. PEG-VS hydrogels contain vinyl sulfone groups that covalently bind with thiolated DNA probes through thiol-vinyl sulfone addition, enabling stable probe immobilization and providing a hydrated matrix for localized reactions.
Uniform hydrogel (~60 μm) were fabricated using a flow-focusing droplet microfluidic device with a PEG-VS precursor solution, HFE-7500 fluorinated oil, and triethanolamine (TEA) to initiate crosslinking. Thiolated miR-21 probes, selected because miR-21 is a widely studied extracellular vesicle biomarker associated with multiple cancers, were reduced with tris(2-carboxyethyl)phosphine (TCEP) before immobilization within the hydrogel matrix. Following functionalization and an 8hour crosslinking, target capture efficiency was evaluated by varying probe concentration, after which ligation was optimized by varying reaction temperature and incubation time using a fluorescent target.

Uniform PEG-VS hydrogels provided a reproducible platform for optimization studies. A 1 μM probe concentration produced the highest target capture, room-temperature ligation generated greater fluorescence than 37°C, and extending ligation beyond 30 minutes did not improve post ligation signal. These optimized pre-amplification conditions establish a foundation for integrating PEG-VS hydrogels with RCA for extracellular vesicle biomarker detection.

Nanoimprinted Laser Cavities on Silicon

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Hybrid organic-inorganic metal halide perovskites are attractive for laser applications due to their long charge carrier lifetimes, high charge carrier mobility, and high absorption coefficients. Fabricating a perovskite laser requires patterning the material into an optical cavity that provides feedback for stimulated emission. However, conventional patterning techniques such as photolithography and electron-beam lithography use polar solvents that degrade perovskites. Nanoimprint lithography (NIL) offers an alternative that patterns the material using only heat and pressure. In this work, we verify the compatibility of $MAPbBr_3$ perovskite thin films with the NIL process as an initial step toward fabricating patterned laser cavities on silicon. We confirmed that a flat, FDTS-coated silicon stamp met the hydrophobicity threshold (>100°) for clean release, and that the NIL system could reliably reach established processing conditions (100°C and 70 bar). $MAPbBr_3$ thin films on glass and silicon substrates were then imprinted under these conditions for 20 minutes. The samples on glass substrates showed no visible changes after imprinting, while the samples on silicon substrates showed a visible outline of the imprint pattern along with slight transfer of the FDTS coating from the stamp.

Characterizing and Modeling of Neural Population Activity in Bottom-up Engineered Neurite Networks

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Understanding how neurons communicate within geometrically defined circuits is central to uncovering how network architecture shapes neuronal function. This is commonly studied using patterned dissociated neuronal cultures, in which microfluidic or microembossed hydrogel techniques constrain neurons into defined topologies whose activity can be observed through calcium imaging. Recently, it has been shown that topological patterning can reintroduce structured ensemble dynamics otherwise absent in dissociated cultures. Building on this, we aim to develop a computational model that incorporates these topological constraints to better understand how circuit architecture influences the formation of synchronous calcium spiking. We constructed a pipeline integrating the Auryn spiking neural network simulator with the Lütcke calcium reconstruction model, allowing us to control circuit connectivity, replicate each topology, and generate the resulting synthetic calcium signals. The model reproduced key features of the experimentally observed activity and indicated that circuit topology modulates the rate of synchronous calcium events.

De Magnetic Field Gradient Effects on Mitochondrial Morphology in hNPCS and Using Microfluidic PDMS Scaffolding

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Mitochondrial morphology is a key indicator of cellular health with dysfunction related to neurodegenerative diseases. Research on mitochondrial dynamics in living cells offers a mechanism to better understand how external factors, such as magnetic fields, impact cellular health. Magnetic fields are three-dimensional vector fields with heterogeneous properties stemming from their bipolar nature with gradients that vary across space. The gradient of a magnetic field has the ability to alter the mitochondrial morphology and thus function. Human neural progenitor cells (hNPCS) were exposed to varying magnetic field gradients, with mitochondrial morphological changes noted across conditions. However, with cell culturing, a persistent issue arose; currently, the cells are positioned with surface tension, which introduces additional risk of displacement during transport, as the surface tension can be disturbed easily, limiting the statistical robustness of morphological variations across gradient conditions. To address this problem, polydimethylsiloxane (PDMS) molds were created for cell culturing with mechanically fixed boundaries. PDMS, an easily molded silicon-based polymer device, overlays the petri dish without shifting during transportation and can be removed with ease. As of now, PDMS molds have been fabricated, cell culturing and analysis on mitochondrial morphology across gradient conditions are ongoing, and the addition of the PDMS molds into the experimental procedure will be implemented in future experiments.

Determining Operating Sensitivities and Tolerances of a Rubidum-85 Magneto-Optical Trap

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A magneto-optical trap (MOT) uses six circularly polarized, red-detuned lasers and a magnetic field gradient to cool and trap neutral atoms. As the atoms within the MOT absorb and emit photons during laser cooling, the resulting fluorescence can be captured by an infrared-sensitive camera and used as a visual indicator for successful atom trapping. However, atom trapping is a sensitive process with little tolerance for variations in the MOT's operating parameters. In this work, we show how we can use fluorescence imaging to explore how individual parameters affect the MOT's ability to trap. In particular, we present our efforts to determine operating sensitivities and tolerances of the MOT by correlating changes in fluorescence images with controlled variations in operating parameters (e.g. laser power, polarization, magnetic field, and laser detuning). This work lays the foundation for future studies on MOT-based quantum sensing.

Fabrication and Characterization of Carbon-Polymer Piezoresistive Sensors using Aerosol Jet Printing

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Carbon-polymer piezoresistive strain sensors change their electrical resistance upon physical deformation. Near the percolation threshold — the region where an insulating polymer network becomes conductive — these sensors are typically more sensitive than conventional metal foil strain gauges. While traditionally fabricated using complex cleanroom micro-electromechanical systems (MEMS) techniques, these sensors can be produced significantly faster using Aerosol Jet Printing (AJP). However, identifying the optimal ratio of carbon and polymer that is compatible with AJP and near the percolation threshold remains a critical concern for sensor design. In this project, we aim to fabricate and characterize flexible carbon-polymer piezoresistive sensors using AJP and determine the optimal ratio of carbon black (CB) and polyvinyl alcohol (PVA). The fabrication process starts by depositing silver onto Kapton film to print interdigitated electrodes (IDEs). Then, layers of CB and PVA are deposited over the silver IDEs to form the carbon-polymer sensing layer. Sensors with seven different ratios of CB and PVA were successfully fabricated with AJP and tested for their initial resistance to model the percolation curve. A cantilever displacement apparatus was used to characterize the sensors under tensile and compressive loading to determine their sensitivity, or gauge factor (GF). The results show that all sensors were equally sensitive under tensile and compressive loading, and the sensor printed with the 1.25 wt% CB ratio has the highest GF of 7.70. This research confirms AJP as a valid methodology for printing high-resolution, flexible carbon-polymer piezoresistive strain sensors.

Study of Perovskite Stability Under Ultraviolet Radiation Exposure

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Solar energy has many practical uses in an established space solar industry. Current Space Solar Cells are dominated by Group III-V semiconductors, which use multi-junction architectures to achieve high performance. Recently, a new ABX_3 crystal structure, called perovskite, has been found to match and even surpass the previously mentioned multi-junction cells in a simple single-junction configuration. Despite their tremendous potential as highly efficient photovoltaic materials, perovskites are unstable under atmospheric conditions, which is not a problem for space applications but requires further study of the impact of space radiation exposure on them. Among different radiation energies, low-energy long-wave radiation fails to excite the perovskite bandgap, whereas high-energy short-wave radiation largely passes through the crystal structure. However, mid-range ultraviolet (UV) radiation is directly absorbed, potentially driving material changes that require further investigation. For this reason, the study focused on exposing the Perovskite films and devices to UVA radiation in accordance with industry performance standard IEC 61215, which requires 15 kWh/m^2 UV exposure. During this study, both Nitrogen and ambient Oxygen conditions were tested at 45℃ to exposures up to 6.29 kWh/m^2. Photoluminescence (PL) data showed that UVA was not a major factor in the degradation of the perovskite layer in films. PL loss was observed when samples were aged in oxygen, with PL signals becoming absent after 1.05

kWh/m^2 of exposure. Predictably, nitrogen was found to preserve the Perovskite layer, with PL signals being recovered after an exposure of 6.29 kWh/m^2. Devices tested under the same nitrogen conditions remained stable after 1.05 kWh/m^2 of exposure following an initial drop in efficiency. The conclusions from this study are that UVA exposure up to 6.29kWh/m2 at 45℃ does not affect the Perovskite layer in films, and that devices are shown to be stable. Therefore, future work will focus on continued aging to meet the IEC industry standard of 15 kWh/m2 UV at 60℃.

Advanced validation technology for 3D heterogeneous integration packaging in AI and HPC innovation

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The rapid growth of AI and High Performance Computing (HPC) has made advanced semiconductor packaging one of the most strategically important technologies in the industry. Major companies such as TSMC have doubled their Chip-on-Wafer-on-Substrate (CoWoS) packaging production capacity to meet demand from NVIDIA. The U.S. government is investing heavily in packaging capabilities as a core pillar of semiconductor leadership. Integrating multifunctional chips within a substrate through advanced packaging requires significant effort to overcome technology obstacles such as miniaturization, power efficiency, cost reduction, and standardization. This project aims to develop reliable, cost-effective, transferable, and producible verification technologies for advanced packaging. The process will include substrate fabrication for simplified test vehicle preparation and evaluation studies for process verification and reliability assessment. Fabrication includes conventional semiconductor packaging processes and advanced die-to-wafer and wafer-to-wafer integration technologies. Evaluation and characterization of the test vehicles will be practiced by detecting and identifying defects such as voids, delamination, and misalignment generated during the advanced packaging process. Project goals are to evaluate how these defects arise during the packaging process and how non-destructive imaging tools such as X-ray tomography and acoustic microscopy are used to detect and understand these failure mechanisms. This project is aimed to deepen the understanding of how modern AI hardware is developed and how its reliability is ensured through a comprehensive study on advanced validation technologies.

Determining Phonon Band Structures of Inorganic Lead Halide Perovskite Alloys Via First Principles Calculations

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When many excited quantum states in a crystal lattice spontaneously align, they emit a coherent burst of light — a phenomenon called superfluorescence. Understanding superfluorescence could lead to further discoveries of quantum phenomena and, ultimately, advance quantum technologies. However, superfluorescence has largely only been observed near 0K and its underlying mechanisms remain under debate. Recently, room-temperature superfluorescence has been observed in $CsPbBr_3$. Fluctuations in its superfluorescence emission are in the same

frequency range as longitudinal optical rocking phonon modes, suggesting phonons may play a role. As such, this project computationally (1) determines the structures for mixed $CsPbBr_iX_{3-i}$ (X = Cl, I, i = 0, 1, 2, 3) perovskites and (2) calculates their phonon band structures. For each alloy, we find every possible atomic arrangement and determine the lowest energy structure. Alloys with more of the heavier halide ($CsPbBr_2Cl$ and $CsPbBrI_2$) are the Pnma space group at their lowest energy, matching the pure halide perovskites. Alloys with more of the lighter halide ($CsPbBrCl_2$ and $CsPbBr_2I$) form lower symmetry structures. Phonon band structures contain only real modes after the application of nonanalytical corrections, confirming structural stability. These results can be used to identify the particular modes hypothesized to underlie superfluorescence.

Silver Thione and Selone Complexes with Potential Antifungal Activity

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Silver has many medicinal applications due to its antimicrobial, antiseptic, anti-inflammatory, and anticancer properties. Silver was used in ancient times to store food and water to prevent their spoilage, in World War I as a disinfectant, and is now being researched as a potential drug against cancer and infectious diseases. N-heterocyclic thione (NHT) and selone (NHSe) ligands are used in this project due to their ability to stabilize silver and provide a degree of synthetic tuneability to the metal complex. The complexes synthesized are homoleptic two-coordinate silver(I) complexes such as [Ag(NHT)2]X and [Ag(NHSe)2]X, where X is a weakly coordinating anion (NO3, BF4, ClO4), which display antifungal activity. These new compounds have been characterized by a combination of analytical and spectroscopic methods, including elemental analysis, NMR and IR spectroscopies, and (if possible) X-ray crystallography. The physical and chemical properties of these compounds will be compared with those of previously prepared species that have 1:3 and 1:4 stoichiometries, i.e. [Ag(NHT)3]X and [Ag(NHT)4]X. Selected compounds have been evaluated for antifungal activity against the opportunistic fungal pathogen Candida albicans. The goal of biological testing is to assess the influence of ligand structure (e.g., nature of the donor atom, substituent effects), coordination number, and the presence of different counterions on biological activity. These studies aim to establish structure–activity relationships between ligand design and antifungal activity while providing insight into the development of biologically active silver(I) complexes.

Thickness-Controlled Synthesis and Characterization of Wide-Bandgap Perovskite-Related Crystals for Nanophotonics

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Lead halide perovskites are a class of crystalline semiconductors commonly described by the chemical formula ABX_3, with a representative example in which the A-site cation is Cs^+, the B-site cation is Pb^{2+}, and the X-site anion is Br^-. These perovskites, initially explored in photovoltaic applications, have also emerged as promising nanophotonic materials due to their unique excitonic emission and tunable optoelectronic properties via stoichiometry and phase engineering. In this work, we present a synthesis protocol to create high-quality, wide-bandgap, perovskite-related

$CsPb_2Br_5$ crystals with controlled nanometer-scale thicknesses. Precise thickness control is important for nanophotonic applications because it plays a key role in determining optical confinement and the resulting device response. Moreover, we developed a thickness estimation methodology based on optical contrast and reflection measurements, without using the time-consuming and potentially invasive atomic force microscopy (AFM). This work also lays the foundation for developing a machine learning (ML)-based model that can automatically assign thickness directly from reflection spectra, thereby advancing optical characterization and facilitating the development of perovskite-based nanophotonic devices.

Fabrication of Honeycomb-Structured Ultrathin Films

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Solar sails use radiation pressure from sunlight to propel spacecraft without carrying propellant, but their performance depends on materials that are lightweight, reflective, thermally stable, and mechanically robust. This project investigates the fabrication and scale-up of honeycomb-structured ultrathin films designed to improve mechanical stability while maintaining low areal density. A Mylar substrate was laser-patterned with a honeycomb geometry, followed by deposition of a hafnium oxide/aluminum/hafnium oxide multilayer and oxygen plasma removal of the substrate. Preliminary fabrication results showed that the honeycomb pattern remained visible after deposition, although localized deformation and cracking occurred. SEM imaging did not clearly reveal the expected trench and rib features, and plasma ashing did not remove the Mylar uniformly, indicating that the patterning and release processes require further optimization. Optical modeling in MATLAB and COMSOL was also used to compare multilayer designs containing HfO_2, TiO_2, or SiO_2 with Al, Mo, or W. Among the evaluated designs, SiO_2–Al provided the best balance of high solar-weighted reflectance and low areal density. Future work will focus on improving substrate patterning, film release, and mechanical and thermal characterization.

Plasmon Field-Effect Transistors for Low-Concentration Gas Detection

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Hazardous gases are widely used in industrial, environmental, and biomedical applications, but reliable detection at low concentrations remains challenging due to limitations in sensor sensitivity, response time, and device size. Plasmon field-effect transistors (PFETs) offer a platform for compact and highly sensitive gas sensing by combining the electrical control of a field-effect transistor with the optical properties of localized surface plasmon resonance. In this project, we designed, fabricated, and characterized ZnO-based PFET structures with gold nanoparticle sensing regions. Device layouts were created using Layout Editor with channel lengths ranging from 5–100 μm and fabricated using photolithography, image reversal, electron beam evaporation, lift-off, and gold nanoparticle formation. Electrical characterization using a probe station and Keithley SourceMeters confirmed FET operation prior to nanoparticle-based testing. Optical characterization methods were also established for Au PFET devices and Au/Pd nanoparticle films using wavelength-selected illumination and absorbance measurements. Preliminary Au/Pd absorbance spectra showed a broad LSPR peak near 566 nm, but no clear hydrogen-induced peak

shift was observed under the tested conditions. Future work will focus on optimizing palladium thickness, annealing conditions, and gas exposure parameters before integrating Au/Pd nanoparticles into PFET devices for low-concentration gas detection.

Nanowire Characterization through Electrical and SEM Analysis

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GaAsSb nanowires (NWs) are a promising platform for near-infrared photodetectors due to their tunable bandgap and their ability to grow on substrates with reduced the lattice-matching limitations compared with planar epitaxy. In our lab, NWs are grown via molecular beam epitaxy (MBE) following an established recipe, producing samples with varying structural configurations, including axial and core-shell geometries. To assess how these variations affect device performance, we characterize samples using several techniques: inspecting currentvoltage (I-V) curves, extracting activation energies via Arrhenius plots, and evaluating NWs morphology through scanning electron microscope (SEM) imaging. I-V characteristics reveal how much leakage current is present for a given bias. The Arrhenius-type relationship between current and temperature reveals which mechanism dominates the current at a specific temperature regime. Since manual analysis on a multitude of samples can be tedious, we built a Python pipeline to read datasheets, plot I-V and Arrhenius curves across a range of voltages, extract activation energies for different temperature regimes, and compare how the dominant mechanism shifts with bias by superimposing Arrhenius graphs. NWs morphology is also examined for growth quality. We are extracting quantitative SEM features using ImageJ and applying unsupervised learning to identify different morphology and growth quality groups. The long term goal is to develop a CNN that can directly analyze and classify SEM images.

Microfluidic Generation of Alginate Force Probes to Quantify Intra-Tumoral Compression

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Glioblastoma is a type of brain cancer with a very low survival rate due to the lack of effective therapeutic treatments. Historically, cancer research has focused on the genetic and molecular drivers of disease; however, recent work has suggested that mechanical states of tumors such as intra-tumoral compressive stress may regulate cancer progression. Investigations into this relationship are challenging as the magnitude and dynamic growth of compressive stress are currently unknown. Given this gap in understanding, we aim to develop a cell-sized, deformable, measurable force probe to quantify intra-tumoral compressive stress. To address this objective, we fabricated alginate force probes (beads) using a flow-focused microfluidics device. Bead size was quantified using ImageJ and was verified to be on the same scale as a cell with an average bead diameter of ~ 30 μm. After size verification, beads were subject to fluorescence microscopy to confirm measurable fluorescent signals. To determine whether beads could be successfully embedded within tumor spheres, we mixed beads in with U87-line Glioblastoma cells in a Biofloat plate, and monitored tumorsphere formation over 3 days. Imaging of the tumor sphere confirmed

successful integration of the beads within tumor spheres. The results of the project include a detailed bead-creation procedure, a basic statistical analysis of bead diameter, and images of bead-embedded tumor spheres. Future work will focus on improving the sterility of the beads for long-term tumor sphere growth and measuring the resulting deformations to determine the magnitude and dynamic progression of compressive stress using finite element analysis.

Characterization of Thermosensitive Hydrogel for Lymphatic Drug Delivery

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The lymphatic system plays a critical role in immune function and fluid balance, making it an important target for hydrogel-based drug delivery systems that enable localized and sustained drug release. The purpose of the hydrogel is to formulate a drug delivery system capable of controlled micelle release into the lymphatic system. This project investigates the composition and performance of a hydrogel made from two FDA-approved biocompatible copolymers: Polymers A and B. The degradation of the hydrogel was examined using Phosphate Buffered Saline at 37° C. The hydrogel underwent a heat/cool cycle, where the samples were placed in the fridge and then warmed to room temperature three times. It was determined that the hydrogels that underwent a heat/cool cycle had a degradation time of five days, compared to seven days for hydrogels used straight out of the fridge. In addition, the composition of micelles was analyzed from collected supernatant of the degraded samples using SDS-PAGE and gel staining, as well as iodine and BCA assays. The degradation micelles included both Polymers A and B, with the release of 65% Polymer A and 40% Polymer B from the original hydrogel samples.

Attaching Microdevices to Fibers for Flow Through Electronics

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Integrating electronic circuits into textiles has the potential to change the wearable electronics and soft robotics industries because of their ability to move like traditional fabrics while performing complex functions. Our lab has developed a MEMS device composed of cantilevers that grasp onto wires when a current releases them, creating a large-scale porous circuit board. However, attaching sensors to the device has a low success rate due to excess soldering flux sticking the cantilevers to the wafer. To address this problem, we used a film applicator to spread uniform layers of tacky flux to find an optimal flux depth. Next, a micro assembly station was used to dip chips into the tacky flux and adhere them to a prepared MEMS device. The results suggested that flux depths of 125 microns were enough to attach to the MEMS device without gluing the cantilevers down. This knowledge is crucial for the further development of these MEMS devices and making progress in the field of large-scale circuits on fabrics, meshes, and other fibrous materials.

Fog Harvesting Utilizing Electrospun Interwoven Membranes

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In 2024, the World Health Organization and United Nations Children's Fund reported that 1 in 4 people lack safely managed drinking water. To provide a potential low-cost water source in arid regions, fog collection has been examined as a possible method. Current fog collection methods, which utilize large nets, suffer from low efficiency largely due to a high evaporation rate. To reduce evaporation, Janus membranes composed of a hydrophobic and a hydrophilic layer have been studied. These membranes collect water on the hydrophobic layer and transport it inward to the hydrophilic layer. However, transport is slow, so efficiency still suffers from evaporation occurring before transport is complete. Using electrospinning, this work created "interwoven" Janus membranes, in which hydrophilic fibers are woven throughout the hydrophobic membrane to form pathways that facilitate faster transport. Interwoven Janus membranes were electrospun from PVA and PVDF and evaluated against traditional Janus membranes using a custom fog collection testing setup. The manufacturing and testing methods require further refinement, but initial results show that the average collection efficiency of the interwoven membranes was 0.15 $mL/cm^2/hr$, 30.7% higher than the average for the traditional Janus membranes. These results suggest that interwoven Janus membranes are a promising configuration for fog collection devices and support the use of fog as an alternative water source.

Microfabricated gas sensor array for the detection of airborne toxic organic compounds

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The usage of nanoparticle gas sensor arrays for the detection of airborne toxic organic compounds (TOCs) remains an ongoing development in the biomedical industry. Exposure to TOCs, including carbonyl compounds and benzene, toluene, ethylbenzene, and xylene (BTEX), can cause adverse effects on human health, ranging from acute irritation to chronic diseases. Attempts to fabricate sensors for applications in medical breath analysis and environmental monitoring aim to discern these contaminants from the air with high selectivity and sensitivity. These devices address a growing need to introduce a reliable, low-cost, and portable technique for detecting and identifying TOCs with heightened accuracy.
Microfabricated gas sensor arrays equipped with thiol-functionalized gold nanoparticles (AuNPs) as chemiresistive sensing materials show considerable potential and serve as a viable option to identify analytes within gas samples by the characteristic features of their response curves. This project synthesized two contrasting thiol ligands: 16-mercaptohexadecanoic acid (16-MHA) and N-(3-chlorophenyl)-N'-(5-Mercapto-1,3,4-Thiadiazol-2-YL) urea (2-YL). The structural variances between the aliphatic 16-MHA and the urea-functionalized, aromatic 2-YL presented distinct binding affinities towards different toxic organic compounds. These AuNPs were individually deposited onto the sensor chips and exposed to increasing concentrations of gas analyte samples of benzene, acetone, hexane, and ethanol ranging from 10 ppb to 10,000 ppb. Significant progress was made to establish connections between the chosen thiolate ligand and its capabilities when interacting with various TOCs. While one sensor can be employed to identify an analyte, another can demonstrate a relationship between sensor response and sample concentration. This work contributes to developing thiol-functionalized AuNP sensor profiles and supports the advancement of gas detection technology.

Genetically Encoded Amphiphilic Polymers for Biomimetic Membrane-Based Nanotechnologies

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Biomimetic membrane-based nanotechnology has broad applications across medicine, environmental remediation, and energy-based applications. Lipids and amphiphilic block copolymers are two commonly employed platforms for such applications. However, current synthetic membrane systems face limitations. Synthetic lipid membranes are labile, static, and prone to fluctuation, while amphiphilic block copolymers are costly, require caustic synthesis approaches, and low-yielding. Genetically encoded polymers (GEPs) offer a promising alternative providing potential paths to large libraries of membrane materials and the potential to embrace the desired qualities of both lipids and polymers while negating their negatives. In the current study, amphiphilic GEPs based upon the chemical structure of elastin (one of the most abundant proteins in the human body) with precise, sequence-level genetic control are synthesized. Specifically, a genetically encoded amphiphilic elastin-like polypeptide (ELP) construct with a 20:10 hydrophobic-to-hydrophilic repeat ratio was designed, expressed in *E. coli,* and purified via inverse transition cycling. SDS-PAGE and UV-Vis spectroscopy confirm successful synthesis, purification and quantify protein yield. To investigate complex structure formation (e.g. micelles/coacervates) temperature cycling was performed and demonstrated a reversible phase transition via DLS. Further, generation of membrane architectures and characterization will also be demonstrated. The presented results demonstrate the feasibility of creating a library of tunable GEP-based materials for membrane nanotechnology applications.

Kinetics of Nanotopography-Induced Transient Nuclear Membrane Poration and Repair

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The nuclear envelope functions as a permeable barrier that maintains nucleo-cytoplasmic compartmentalization. Engineered nanopillar substrates induce localized curvature at the nuclear envelope, resulting in transient nanoscale poration while maintaining plasma membrane integrity. However, the kinetics associated with the initiation, duration, and resolution of these curvature-induced porations remain insufficiently characterized. In this study, we use live-cell imaging of an NLS-GFP reporter to quantitatively monitor nuclear envelope poration and repair in real time. Under baseline conditions, NLS-GFP is actively imported and retained within the nucleus; following nanopillar-induced nuclear membrane poration, NLS-GFP mislocalizes to the cytoplasm, which provides a direct and dynamic indicator of nuclear envelope poration. As the nuclear membrane repairs, NLS-GFP is reimported into the nucleus, and this process of mislocalization and reimportation allows us to define discrete kinetic phases of poration and repair. We aim to quantitatively determine the relationship between induced membrane curvature and nuclear envelope poration by controlling nanopillar spacing and studying how this correlates with the frequency and duration of NLS-GFP mislocalization. This approach establishes a single-cell framework for understanding how nanotopography-driven curvature initiates poration and how

intrinsic repair mechanisms restore nuclear integrity over time, independent of monitoring specific repair-protein dynamics. The results are expected to provide a rational design of nanotopographic platforms for applications such as direct nuclear delivery of gene editing tools, where controlled and transient nuclear envelope access is essential.

Macrophage-Targeted Nanomedicine in a Skin-on-a-Chip Model to Modulate Wound Inflammation and Reduce Fibrotic Scarring

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Excessive or prolonged inflammation during wound healing can drive fibroblasts to overproduce collagen, resulting in fibrotic, poor-quality scars. This dysregulation is closely tied to macrophage behavior: a timely shift from the pro-inflammatory M1 phenotype to the pro-healing M2 phenotype supports normal tissue repair, while macrophages that remain in the M1 state for too long promote excessive fibrosis. Current scar treatments, such as silicone gel, steroid injections, and laser therapy, are applied only after a scar has formed and do not address this underlying immune mechanism. This project aims to develop and test a macrophage-targeted nanomedicine designed to promote appropriate M1-to-M2 transition and reduce fibrotic scarring at its source.
To evaluate this strategy, we developed a skin-on-a-chip platform consisting of a polydimethylsiloxane (PDMS) device cast from a 3D-printed mold, housing a co-culture of THP-1-derived macrophages and human dermal fibroblasts (HDF) across a membrane insert. Lipopolysaccharide (LPS) was used to induce an inflammatory state, modeling early-stage wound inflammation, and cells were treated with our nanomedicine to assess its effect on macrophage polarization. Gene expression was quantified via RT-qPCR.
We found that our nanomedicine induced increased interleukin-10 (IL-10) expression, a key anti-inflammatory cytokine and marker of M2 macrophage polarization, in THP-1 cells stimulated with LPS. In a wound-healing assay, we also confirmed that our nanomedicine promoted keratinocyte migration and wound closure, suggesting a pro-healing role. These findings support our hypothesis that targeted nanomedicine delivery can promote healthier macrophage polarization during inflammation, and establish a reusable,
physiologically relevant in vitro platform for evaluating anti-scarring nanotherapeutics. Future work will expand this analysis to additional M1, M2, and fibrosis-associated markers, and integrate the platform with 3D bioprinted skin tissue to further improve model realism

Miniaturization of the Oscillating Heat Pipe

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Efficient thermal management has become increasingly important with the continued miniaturization of modern electronic devices. Traditional heat pipes are commonly used for heat transfer in electronic systems by circulating a working fluid through evaporation and condensation processes. Heat absorbed at the evaporator section is transferred along the pipe and dissipated at the condenser section. However, conventional heat pipes face several limitations, including

susceptibility to high heat flux failure, gravitational constraints, and manufacturing challenges. Oscillating heat pipes (OHPs) offer a promising alternative due to their simple structure and enhanced thermal performance. An OHP consists of a capillary tube bent into multiple interconnected turns, allowing liquid and vapor slugs to oscillate naturally within the device. Heat applied at one end causes the working fluid to evaporate, generating pressure that drives the fluid toward the cooler section. Upon reaching the condenser region, the vapor condenses back into liquid and returns to the heated section, creating a continuous oscillatory flow that transports heat efficiently. The objective of this study was to develop and evaluate a microscale oscillating heat pipe for applications in small electronic devices. The fabricated device measured 26 mm in width and 96 mm in length and contained 38 microchannels. Water was used as the working fluid, with the evaporator maintained at 100°C and the condenser at 25°C. The performance and operational behavior of the miniaturized oscillating heat pipe were monitored to assess its effectiveness as a thermal management solution. The results of this work contribute to the advancement of compact cooling technologies. As electronic devices continue to decrease in size while increasing in power density, microscale oscillating heat pipes may provide an effective and reliable means of dissipating heat, thereby supporting the development of next-generation electronic systems.

Optimizing Target Solvent Composition for RIR-MAPLE Deposition of Hybrid Perovskites

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Hybrid perovskite materials show promise as high-performance and low-cost photovoltaics. Their unique properties, such as high absorption coefficients, high carrier mobility, and tunability, make them particularly favorable for use in devices such as solar cells, LEDs, and batteries. Traditional solution-processing and vapor-processing techniques of hybrid perovskites face challenges such as solvent contamination, insufficient control of film morphology and stoichiometry, and high-energy degradation of precursors. Mixed-processing techniques such as resonant infrared, matrix-assisted pulsed laser evaporation (RIR-MAPLE) show promise for eliminating degradation of precursors, production of high-quality films, and scalability. In RIR-MAPLE, precursors dissolved in a primary solvent are combined with a matrix solvent which is frozen to form the target. The target is irradiated by a pulsed infrared laser and the energy is resonantly absorbed by the matrix solvent, intentionally chosen for the purpose of avoiding energy absorption by the precursors and subsequent degradation. The heated volume explodes in a plume of the vaporized matrix solvent and precursor droplets, which are deposited onto a substrate where the thin film grows. One limitation on throughput of RIR-MAPLE deposition is the target lifetime, which in certain solvent mixtures is drastically reduced by the instability of the frozen solid phase after being subjected to the pulsed laser. In this work, we aim to understand how the solvent ratios and freezing procedure affect the solid phase and stability of the target. By optimizing these parameters, we seek to extend the lifetime of the target. It has been found that when the solvents used are strong glass-formers it is necessary to control the target composition and cooling rate to avoid the formation of a vitrified target, which is more sensitive to thermal fluctuations than a crystalline target. For the particular combination of primary solvent, dimethyl sulfoxide (DMSO), and matrix solvent, monoethylene glycol (MEG), differential scanning calorimetry (DSC) measurements were used to find the critical cooling rates for a range of ratios, and an optimal ratio was identified for cooling rates of 10-20K/min. The identified solvent ratio was tested in the target with the deposition of a two-

dimensional hybrid perovskite, phenethylammonium lead iodide. The target successfully crystallized upon freezing and remained solid throughout deposition. This work resulted in enhanced understanding of the target phase behavior based on solvent composition, yielding a relatively simple approach to significantly increase the target lifetime, thereby allowing for the target to be reused for multiple depositions and increasing the overall efficiency of the RIR-MAPLE technique

Understanding Phase Transitions and Lattice Dynamics of Antimony-Doped Double Perovskites via Temperature Dependence

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Phase transitions and vibrational dynamics of metal-halide double perovskites have a strong influence on their optoelectronic properties, including bandgap, charge carrier transport, light absorption, and more. Here, we present a thorough study of the lattice dynamics and phase transitions of $Cs_2NaBiCl_6$ and the effects of degrees) by added Sb content, though an exact quantification was not possible. Sb-doping has a mild effect on the lattice parameters. However, it seemingly has little or no effect on the thermal expansion and phase transition temperature of $Cs_2NaBiCl_6$. In all compositions, there is an unusual softening of the internal T_{2g} octahedral mode with temperature decrease, contrasting with the more expected hardening which can be seen in other modes. This strange phenomenon, while not yet understood, points to the strongly anharmonic character of these materials, which is crucial to their desirable macroscale properties.

Development of a Fluorescence Imaging System for Data Acquisition and Analysis in a Magneto-Optical Trap

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Using laser cooling and magnetic fields, the Magneto-Optical Trap (MOT) is a foundational tool for cooling and trapping neutral atoms across a wide range of applications, including applications in quantum science and technology. However, achieving and maintaining a stable MOT is challenging due to its sensitivity to multiple operating parameters, and reliable data acquisition and analysis are needed to characterize its behavior and performance. In this work, we discuss our efforts to develop a dedicated infrared imaging system to capture consistent, high-resolution images of rubidium-85 cloud fluorescence. In particular, we show how we utilize fluorescence imaging data to establish the data acquisition and analysis framework needed to systematically characterize the MOT and provide the foundation for studies of MOT sensitivity, performance, and optimization.