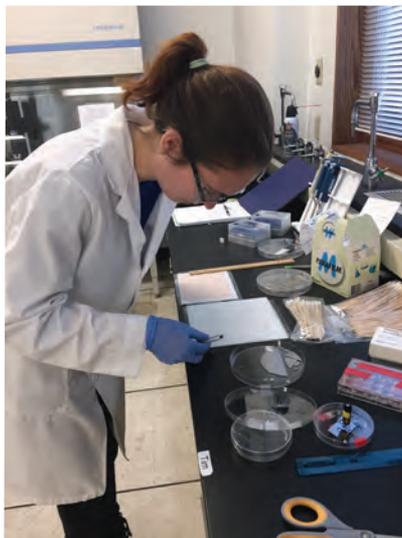
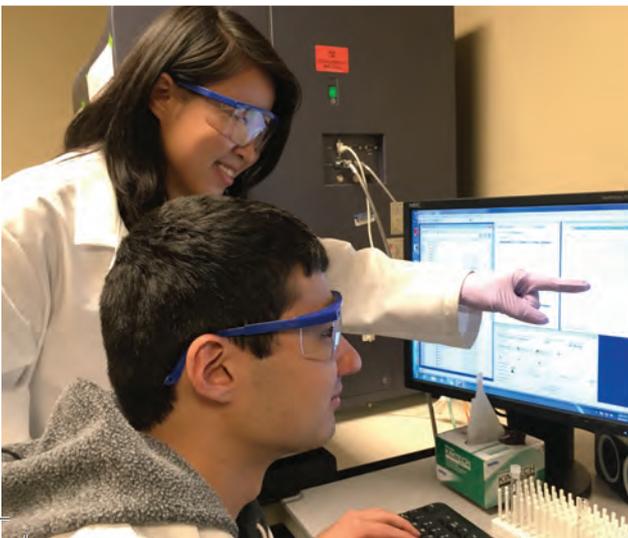
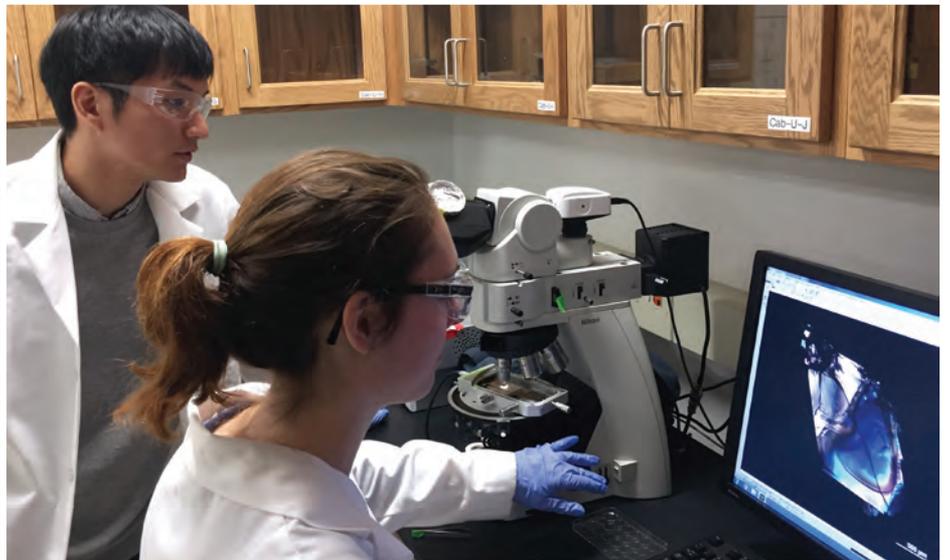
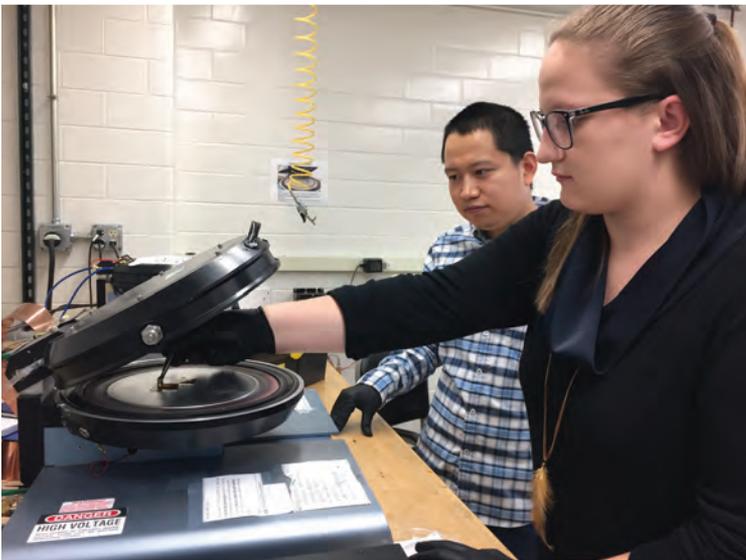


ENGINEERING AT ILLINOIS

ILLINOIS SCHOLARS  
UNDERGRADUATE RESEARCH  
**POSTER EXPO** APRIL 27, 2017  
ILLINI UNION **ABSTRACTS**



# ISUR Scholars 2016-2017



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BioE



Christopher Benson  
CS



Rebecca Boehning  
ChemE



Daniel Capua  
BioE



Andrew Douglas  
CompE



Elizabeth Gacek  
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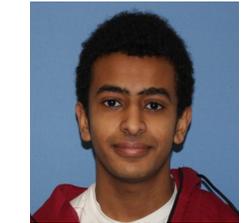
Indronil Ghosh  
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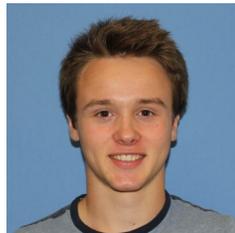
Allison Gibson  
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Pierce Hadley  
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Paulous Haile  
CompE



Dylan Harmon  
MechE



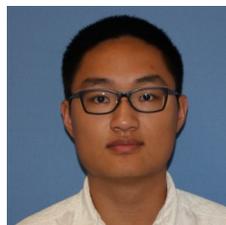
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## Illinois Scholars Undergraduate Research (ISUR) Program

The College of Engineering Illinois Scholars Undergraduate Research (ISUR) program is for students looking for a two-semester research experience with a research learning community. The program facilitates opportunities to expand students' academic experience beyond the walls of the traditional classroom. Through the learning-by-apprenticeship model, students become familiar with research methodologies, develop their research skills, are exposed to what graduate school entails, and gain experience needed for graduate school acceptance or research in industry.

The goals of the program are to

- Introduce students to university research,
- Engage students in the College of Engineering and the research community, particularly through the learning-by-apprenticeship model; and
- Expose students to engineering research with focus on agricultural biotechnology, chemical solutions, electronics, semiconductor, information technology, energy, and other research

As part of the research learning community, new ISUR scholars enroll in a semester-long research apprenticeship class (ENG 199 UGR) in addition to the time spent on research. In this class, students learn about the basic elements of research, including the logical framework of research, forms of technical communication, and training of researchers. Students also gain an understanding of the research pursued at the university and the skills needed by researchers. A mixture of lectures, panel discussions, guest speakers, and interactive class discussions are used to cover the topics.

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## Temporal Quantification of Angiogenic Receptor Levels and Heterogeneity in a 2D Endothelial-Fibroblast Co-Culture

Kareem Al-Qadi<sup>1</sup>, Si Chen<sup>2</sup>, Prof. Princess Imoukhuede<sup>3</sup>

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Illinois Scholars Undergraduate Research

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2D co-cultures involving endothelial cells (ECs) and mural cells have been widely used to model angiogenesis<sup>1-4</sup>. However, current co-culture models depend heavily on qualitative analysis and lack high-throughput single-cell quantification<sup>5</sup>. Here, we quantify membrane concentrations of several angiogenic receptors and their heterogeneity as endothelial-fibroblast co-culture matures using a standardized quantitative flow (qFlow) cytometry protocol<sup>6,7</sup>.

Human umbilical vein endothelial cells (HUVECs) and adult human dermal fibroblasts (HDFs) were seeded together upon confluency at a 1:1 ratio with a seeding density of  $1.6 \times 10^4$  cells/cm<sup>2</sup>. After 24 hours, 6, 11, or 17 days, the co-cultures were harvested and qFlow cytometry was performed.

We detect a significant ~2-fold increase ( $p < 0.05$ ) in PDGFR $\beta$  levels between single-cultured HDFs and Day 17 co-cultured HDFs. Interestingly, co-cultured HUVECs present ~3-7-fold higher PDGFR $\beta$  than single cultures. VEGFR2 levels on co-cultured HUVECs are upregulated in all timeframes. VEGFR1 levels do not change significantly in HUVECs. In addition, we show that both CD31 and CD34 antibodies are efficient for distinguishing HUVECs from fibroblasts. We observe increased heterogeneity in co-cultured HDFs for PDGFR $\alpha$  as opposed to the single cultured controls. We suspect that cells from early co-cultures possess higher receptor heterogeneity as the cells get situated in the new environment<sup>8</sup> and ECs start to sprout.

The present results suggest that VEGFs and PDGFs are critical for inducing tubule formation in fibroblast-endothelial co-culture. Quantitative examination of such co-culture models can offer insight into how growth factors regulate tissue microenvironment at the molecular-level, i.e. receptor levels and cellular heterogeneity, during angiogenesis.

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## **Detecting and Preventing Tracking Failure in ORB-SLAM**

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Autonomous robots can use Visual Simultaneous Localization and Mapping (SLAM) algorithms to navigate in the unknown environment. These algorithms use visual data to track the movement of a robot as it travels through an environment while simultaneously creating a three dimensional mapping of the environment. Unfortunately, many of the state of the art SLAM algorithms struggle with maintaining tracking through severe motion of the robot. The aim of this study is to improve the robustness of SLAM algorithms on datasets with significant motion.

ORB-SLAM is a novel and state of the art Visual SLAM system that uses a keyframe based approach for tracking motion. Keyframes are reference images, selected from the set of all images, which are used to build the map. Part of the research examined the failure modes of ORB-SLAM on datasets that contained significant motion. Loss of tracking typically occurred because too few points were matched in the local map or the in the reference keyframe. Additionally, we examined the effects of keyframe selection on tracking motion. The data was not completely conclusive, but adding additional keyframes when the camera is moving quickly appears to increase robustness of tracking.

Future work will focus on attempting to detect when tracking will be lost and prevent this from occurring. We will use machine learning techniques to predict loss of tracking and more precisely select keyframes.

## **Beating the Coffee Ring Effect: Understanding Crystal Growth Mechanisms**

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Research Sponsor: Shell Corporation

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Single crystals have played a central role in the development of modern electronics and energy materials. In recent years, organic semiconductors (OSCs) have emerged as an alternative to traditional semiconductor materials. Similar to the inorganic counterpart, OSCs perform best as single crystals. Although methods exist for fabricating single crystals of OSCs, most require complicated processing or large sample volumes. This work proposes dropcasting of a sessile drop in ambient conditions as a simple and low volume method of producing OSC single crystals.

In this study, a solution of 6,13-Bis(triisopropylsilylethynyl)pentacene (TIPS pentacene) in decane is deposited on two substrates: bare silicon wafer (bare) and octyltrichlorosilane coated silicon wafer (OTS). By manipulating the surface chemistry of the substrate, the crystal growth regime can be controlled. For this system, TIPS pentacene on bare exhibited contact line pinning and formed crystal rings and thin films, due to the coffee ring effect. The same solution on OTS did not exhibit pinning, resulting in bulk nucleation and single crystal growth. The differences in growth regimes is attributed to the different surface energies, causing the domination of capillary forces or Marangoni forces within the drop. By understanding this growth mechanism and utilizing the simple dropcasting method, OSC single crystals can be viably made for several applications, such as samples for phase transition studies or to make transistors.

### **Soft, Conformal Sensor for Thermal Characterization of Human Skin**

Dr. Kaitlyn E. Crawford<sup>2</sup>, Yinji Ma, Daniel B. Capua<sup>1</sup>, Siddharth Krishnan, Xiufeng Wang, Yajing Li, Limei Tan, Yonggang Huang, and Prof. John A. Rogers<sup>3</sup>

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Skin health plays a major role in many prevalent conditions such as diabetes and atherosclerosis. Depending on the condition, local blood flow to certain areas of the body is altered. Blood flow rates and the extent of vascularization within the dermis are thus important indicators of tissue health.

We present an epidermal sensor that conforms to the surface of skin and may allow for the continuous, non-invasive monitoring of vascularization through minimal heating of a resistor and subsequent analysis of the relative temperature changes as underlying blood vessels distribute the heat. We focus on optimizing the sensor to measure the relative thermal properties of skin and then comparing these values with simulation results to determine properties such as the thermal conductivity and thermal diffusivity of skin.

The device was fabricated using traditional microfabrication techniques in Rogers group (originally pioneered by Webb et al.) and its ohmic properties were validated by comparing its measured temperatures versus both its measured resistances and heat flux densities. To optimize thermal measurements, the device was heated atop multiple different polymeric materials for different lengths of time. The data was fitted using Finite Element Analysis and compared to simulation data ran at Northwestern University and to literature.

The resulting data shows that larger sensors (with a diameter greater than 3 mm) with shorter heating times yield comparable thermal conductivity values to that of the simulation and to literature. These results suggest the device could be used in a clinical setting for monitoring skin health.

## **Improving Visual-Inertial Odometry Testing**

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For robots relying upon sensor measurements to estimate their pose, it is vital that the time associated with each sensor measurement be as accurate as possible. Any error in time synchronization is directly translated to an error in the robot's pose estimate. Robotic systems can employ any number of different sensors that all need to be synchronized to a common time, as well as multiple computers which collect data from the sensors. The ability to synchronize sensor data streams is dependent on the motion of the robot, of particular importance is the observability strength of the time delay between sensor data streams. Time synchronization techniques should thus take into consideration the observability strength of the system and adjust themselves as the observability strength changes.

In this paper, we describe a synchronization method that changes based on the observability strength of the dynamic system. This method employs existing synchronization algorithms, but reduces the load on the operating system and network whenever possible in order to alleviate problems introduced by dropped packets on real-time operating system delay.

## **An Investigation of the Effect of Gear Ratio on Manual Wheelchair Kinetics**

Elizabeth Gacek<sup>1</sup>, Alan Gaglio<sup>2</sup>, Nick Thompson<sup>2</sup>, Omid Jahanian<sup>3</sup>, Scott Daigle<sup>4</sup>, Ian Rice<sup>5</sup>, Brooke Slavens<sup>3</sup>, and Prof. Elizabeth T. Hsiao-Weckler<sup>6</sup>

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Manual wheelchair users (MWUs) commonly report upper extremity joint pain, most notably in the shoulders and wrists, due to excessive loading. Approximately 58.5% of users report shoulder pain, which is most commonly attributed to manual wheelchair mobility.

IntelliWheels, Inc. has developed geared wheels that incorporate a planetary gear train between the hand rim and the wheel for different gear ratios. Although geared manual wheelchairs have the potential to reduce biomechanical demands and pain in upper-extremity joints of MWUs, their kinetic effects on propulsion biomechanics remain untested.

To investigate the effects of lower gear ratio on wheelchair biomechanics, an instrumented wheelchair hand rim was developed. The applied forces and torques during direct drive

(DD, 1:1) and a low gear ratio (G, 1:1.5) were examined for two conditions (over level ground and up a short ramp). Preliminary data were from an able-bodied adult male (24 yr) propelling at a self-selected speed. The total force,  $F_{tot}$ , was larger for DD than G, during propulsion on a level floor and on an incline. The force applied in the x-axis,  $F_x$ , was notably lower for G than DD during overground (30%) and ramp (19%) propulsion. The presented preliminary results demonstrate that reducing the gear ratio on a manual wheelchair wheel can reduce hand rim forces, suggesting that geared manual wheelchair wheels may be used as an interventional tool. Geared manual wheelchairs with lower gear ratios offer an alternative to assistive technologies aimed at reducing excessive joint loads experienced by MWUs.

### **Optimization of Anisotropic Photonic Density of States for Raman Cooling**

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Optical refrigeration of solids can be achieved using anti-Stokes photoluminescence or inelastic anti-Stokes Brillouin and Raman scattering. Between these methods, inelastic light scattering imposes fewer constraints on material properties and remains relatively unexplored. The main challenge in using inelastic light scattering for laser cooling lies in the natural imbalance in transition rates for Stokes and anti-Stokes scattering. Previously, we proposed a method that encompasses engineering the photonic density of states and Raman selection rules to reverse the Stokes-to-anti-Stokes ratio and can potentially lead to net Raman cooling of the system. However, the complete optimization of this method that accounts for the anisotropy of the photonic density of states has not yet been performed. In this study we present for the first time an explicit expression for calculating the influence of the anisotropic photonic density of states on Raman scattering. Using this tool, we perform a complete optimization of anti-Stokes Raman cooling considering many possible orientations for a selected material crystal and photonic crystal with respect to a fixed incident direction/polarization. Our calculations show that the optimized Raman net cooling efficiency can be 60% greater than that of an unoptimized arrangement. These results suggest an approach to engineering the photonic density of states that can better facilitate the experimental demonstration of net Raman cooling in solids. Further, this general method can be applied not only to the Raman cooling process, but also help consider anisotropy in other laser cooling methods.

## **2D and 3D Measurements of the Vortical Structures Formed in the Wake of Vortex Generating Tabs**

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The vortical structures and turbulence statistics in the near-wake of rectangular, trapezoidal, triangular, and ellipsoidal tabs were experimentally studied in a refractive-index matching channel. The tabs share the same bulk dimensions and inclination angle. Measurements were performed at Reynolds numbers  $Re_h = 2000$  and  $Re_h = 13000$  based on the tab height. Three-dimensional, three-component particle image velocimetry (PIV) was used to study the mean flow distribution and dominant large-scale vortices. Additionally, high spatial resolution planar PIV measurements were used to quantify high-order statistics. Instantaneous 3D fields revealed that a coherent counter-rotating vortex pair (CVP) coexist with hairpin vortices. The CVP and hairpin vortices exhibit distinctive characteristics and strength across Reynolds Numbers and tab geometries. The CVP is coherently present in the mean flow field and grows in strength over a significantly longer distance at the low  $Re_h$  due to the lower turbulence levels and the delayed shedding of the hairpin vortices. These features at the low  $Re_h$  are associated with the presence of Kelvin-Helmholtz instability that develops downstream of the tabs. A secondary CVP with an opposite sense of rotation appears below the primary one at low  $Re_h$  for each tab. The interaction between the hairpin structures and the primary CVP is experimentally measured in 3D and shows complex coexistence. Although the CVP undergoes deformation and splitting, it maintains its coherence and leads to significant mean spanwise and wall-normal flows, which leads to enhanced turbulent mixing.

## **Detection of Biochemical Changes Related to Breast Cancer Progression Using Raman Spectroscopy**

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Investigating the metabolic changes related to cancer metastasis has been limited due to the use of genetically dissimilar cell lines. These cells attempt to represent the transition from benign breast tissue to metastasized tumors, but they may come from varying sources. By using the MCF-10A breast epithelial cell line, and its metastatic derivatives (termed the M-line), it is possible to analyze the biochemical shifts related to the progression from healthy to malignant tissue while minimizing the confounding factor of genetic variation. Using Raman spectroscopy, chemical information pertaining to metabolic changes in molecules such as

proteins, nucleic acids, and lipids can be extracted without the use of chemical stains. Due to increased cell stress and replication rates, characteristics of malignant cell behavior, increased absorbance for lipids, nucleic acids, and proteins was observed. In addition, we applied partial least-squares discriminant analysis (PLS-DA) to classify and predict the cells based off of their spectral features and to identify the spectral changes between cell types. The classification model demonstrates a high degree of specificity and precision, allowing for accurate cell identification. Our method enables us to analyze and classify cells based off of their metastatic potential without the use of chemical staining procedures.

### **Autonomous Visual-Inertial Navigation for Ground Robot**

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Visual-inertial Odometry (VIO) system provides fast and accurate state estimation for autonomous robot navigation. A VIO system exploits the measurements from two sensors - a camera as well as an Inertial measurement unit, both of which are commonly used in robotics. OKVIS is a tightly coupled VIO system which can provide better robustness and accuracy than loosely coupled or vision only VIO systems. In order to perform autonomous robot navigation, we converted our system so that it would be able to run in real time with ROS. This involved changing the OKVIS ROS software so that it could run on real time data, as it previously was only able to run against datasets, as well as developing a ROS driver for a visual inertial module. We gathered data and compared our results with ground truth using a motion capture system to have a reference to ground truth to see if we could replicate the results from ETH Autonomous Systems Lab. We also compared our results with other SLAM systems. We hope to install the visual inertial module on the JACKAL ground robot in the lab and see if we can use OKVIS to provide real time state estimation for robot path planning and control.

## **Structure of the Turbulent Boundary Layer Over Irregular Terrains**

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This study examines the effects of complex large-scale topographies on atmospheric and river boundary layers by experimentally analyzing the flow over a superposition of two topographical modes. This superposition consists of a large-scale topography of a sinusoidal wave in the streamwise direction ( $x$ ) with a wavelength  $\lambda_x = 100$  mm and an amplitude to wavelength ratio  $a/\lambda_x = 0.05$ . The small-scale topography is a similar wave with 1/13 the amplitude and wavelength of the large-scale topography. The flow over smooth and complex models was studied in a refractive-index matching flow channel using particle image velocimetry at Reynolds number  $Re = 40,000$  based on the channel half height and the bulk velocity. The fluid was seeded with small particles (14 microns in diameter) that follow the flow. A plane in the flow was then illuminated using a laser sheet allowing the motion of the particles to be captured using high-speed cameras operated in sync with the laser. The results show that the superimposed mode on the two-dimensional model had a minimal effect on the mean flow over the surface. However, the turbulent kinetic energy was significantly reduced in the region near the wall.

## **Sensor Calibration of a Visual-Inertial System**

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A proper calibration of visual-inertial system is crucial in visual-inertial navigation for mobile robots. The calibration accuracy must be verified before implementation.

Using Kalibr, a calibration toolkit from the Autonomous Systems Lab at ETH-Zurich, camera and IMU parameters were determined. These included intrinsic and extrinsic parameters for the camera as well as spatial and temporal parameters to describe the relationship between the IMU and camera. While Kalibr provides an indication to the validity of the calibration through metrics such as reprojection error, the calibration cannot be assessed until it is used in conjunction with the OKVIS. Additionally, the IMU noise levels are determined using Kalibr's IMU Noise Model procedure to determine noise and bias from Allan variance plots.

Once a calibration result has been determined, it must be validated using a reference. This is done by tracking the VI-sensor in a motion capture system while simultaneously running a

visual inertial odometry (VIO) system OKVIS. By computing the Relative Pose Error (RPE), the accuracy of calibration result can be qualitatively accessed.

Data is preliminary and the calibration will be refined until the performance is suitable. Future work will focus on mounting the VI-sensor to a ground robot and using it as the primary sensor for path planning once a robust calibration is established.

### **Small Animal Neurodegenerative Phantom Toolkit for Semiconductor PET**

Jazz Kroeger<sup>1</sup>, Andrew Groll<sup>2</sup>, Prof. Ling Jian Meng<sup>3</sup>

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**Purpose:** Nuclear instrumentation such as positron emission tomography (PET) requires acute attention to the obtainable spatial resolution, and timing performance while including the ability to derive depth of interaction (DOI). These parameters maximize the information attainable from the biological studies. With neurological diseases as a specific biological target, this work aimed to develop a neurodegenerative mouse brain toolkit for modeling 3D printable phantoms to be used in an experimental semiconductor Cadmium Telluride (CdTe) PET system.

**Methods:** Numerous studies have been performed assessing the development of genetically modified mice. Therefore, this information could be appended to an anatomical template toolkit to generate a 3D printable version of a disease. Using the Allen mouse brain atlas, this work looked to develop a graphical user interface which end users can easily select features and physiology of interest to quickly generate a nuclear phantom which can be used to determine a system's spatial resolution, timing resolution, and depth of interaction impact.

**Conclusion:** The toolbox increased efficiency of creating phantoms for the PET system to measure. With the creation of the toolbox, a preliminary understanding of the impact spatial resolution, timing and depth of interaction can be evaluated.

## **Alternative Fabrication Techniques for Silica Aerogel in Solar Thermal Applications**

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The purpose of this research is to experiment with alternative fabrication techniques for silica aerogels used for solar thermal applications. Silica aerogels are porous materials with unique properties that include, low density, low thermal conductivity, and low dielectric permittivity. The methods exercised in this research involved varying a set of parameters and measures when creating, aging and drying the gels for characterization purposes. The recipe followed a basis of methanol, tetramethyl orthosilicate (TMOS), dimethylformamide (DMF), and ammonium hydroxide (NH<sub>4</sub>OH). Keeping TMOS constant, the other solvents were varied through experimentation. The supercritical drying method allowed the inserted liquid CO<sub>2</sub> in the gel reach critical point while changing the liquid to vapor without changes in its density, which led to the elimination of the damage of surface on the material. Pin-hole drying allowed the ethanol surrounding the solution to slowly evaporate, thus drying the gel without harmful effects, only allowing supercritical drying if necessary. Through light spectroscopy, the gel was able to be characterized, as a result, the gel showed nearly 95% transmissivity for wavelengths of light in the vicinity of 750 nm. By achieving the proper silica aerogel's characterization goals, the silica aerogel will make new strides as insulators in solar thermal absorbers.

## **Hydrodynamic Focusing in Silica Microcapillaries with 3D Printed Microfluidic Chips**

Alan Luo<sup>1</sup>, Jeewon Suh<sup>2</sup>, Prof. Gaurav Bahl<sup>3</sup>

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Particles detection within microcapillaries are sensitive to radial position within the capillaries. Often, particles without fluidic focusing will flow along the walls of the capillaries as well as clump together; thus, decreasing the sensitivity of the detection. A solution to this problem is to use hydrodynamic focusing by creating a sheath and core flow within the capillaries. The core flow contains the particles that we are interested in detecting and the sheath flow contains the fluidic dynamic wall that ensures that the particles are not only aligned in the center of the capillary, but also not sticking to the sides of the capillary walls. Rather than the traditional microfluidic chip fabrication technique of PDMS stamping, we took an innovative approach by using 3D printing by stereolithography apparatus – saving fabrication time, and capable of creating geometries previously impractical by traditional PDMS methods.

Two syringe pumps each control the flow rate of the sheath and core flow. Varying the two fluids at different flow rates can vary the diameter of the core fluid. Through testing, the initial prototype 3D fabricated microfluidic device can focus a core flow down to 10 microns in diameter.

Further testing revealed that the current experimental setup was difficult to replicate under a practical sensing experiment; fluctuations in core flow due to vibrations in the stepper motor, and a lack of pressure resulted in poor data. Future work will focus on a pressure based pneumatic fluid pump source rather than the syringe pumps to reduce fluctuations and increase force.

### **Molecular Perspectives on Agrochemical Control of Drought Resistance**

Moeen Meigooni<sup>1</sup>, Chuankai Zhao<sup>2</sup>, Prof. Diwakar Shukla<sup>3</sup>

Research Sponsor: John Deere

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Abscisic acid (ABA) plays a central role in regulating response to low water conditions in plants by binding to the PYL family of receptor proteins. Worsening drought-like conditions across the globe have prompted design of ABA agonists as a means of agrochemical control of plant drought resistance. Two recently discovered ABA analogues, pyrabactin and quinabactin, have been shown to selectively target the monomeric receptor PYL5. Though these agonists have been studied extensively *in vivo* and *in vitro*, none have effectively uncovered and compared the specific structural transitions that occur in response to these two ABA agonists. Here we report the conformational binding mechanism of pyrabactin and quinabactin to PYL5 and characterize key intermediate states using equilibrium all-atom molecular dynamics simulations and Markov State Models. Our findings show that the binding pathways of pyrabactin and quinabactin are highly similar and share many intermediate states, which show high potential as targets for rational design of better agrochemicals. Overall, our results demonstrate the power of Markov State Models and all-atom molecular dynamics to provide detailed characterization of protein-ligand binding processes.

## **Driving Spatially-Controlled MSC Responses in Multicompartment CG Scaffold for Tendon-Bone Junction Regeneration**

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Rotator cuff injuries are a widespread problem affecting 250,000 patients each year in America. Of these surgeries, over 80% result in failure within 5 years. The current solution, surgical fixation, is insufficient, which calls for pursuing other viable solutions. The high amount of annual injuries can be attributed to the structural weakness associated with the interface of two tissues with vastly different mechanical properties. The tendon bone junction (TBJ) is made of a highly organized extracellular matrix (ECM) gradient that spans from flexible to stiff, bridging this structural gap. If a tear forms in this structure, there is very poor healing predominantly characterized by mechanically-inferior scar tissue formation. Our solution is to seed human mesenchymal stem cells (hMSCs) onto a multi-compartment scaffold that mimics the native ECM structure and apply a cyclic tensile strain to influence the cells towards tendon and bone lineages in a spatially-dependent manner. Our lab has previously developed a multi-compartment collagen-glycosaminoglycan (CG) scaffold, which mimics the natural ECM microstructure of the TBJ in vitro with an anisotropic compartment and a stiffer mineralized compartment. We then used a custom bioreactor system to apply cyclic strain to hMSCs seeded onto the scaffolds. We found increased gene expression levels of compartment-specific ECM components along with differential cellular metabolic activity and Smad pathway activation. Here, we show how biomaterial cues in combination with cyclic tensile strain can be used to promote hMSC differentiation into spatially-distinct lineages to promote regeneration of the natural TBJ.

## **Green Delamination of CVD-Grown Graphene Films**

Widianto Putra Moestopo<sup>1</sup>, Michael Cai Wang<sup>2</sup>, Prof. SungWoo Nam<sup>3</sup>

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Ever since its discovery in 2004, the 2D material graphene has been extensively researched for its superb mechanical, electrical, and thermal properties. However, the standard transfer method of graphene from copper foil onto arbitrary substrates has not been able to achieve the scalability and quality necessary for commercial applications. The transfer method involves chemically etching the growth substrates, which produces toxic chemical by-products, induces doping of the graphene, and expends the expensive, high-quality growth substrate used in the synthesis process. The problem of having to expend the growth substrate can be resolved using

electrochemical delamination. While common electrochemical delamination methods use salt solutions to perform electrochemical reactions, here we show that the salt solutions could be replaced by deionized water injected with carbon dioxide (CO<sub>2</sub>). XPS analysis of graphene transferred by carbonic acid shows the inexistence of sodium found in graphene transferred through chemical etching and electrochemical delamination in a salt solution. Moreover, the Raman spectrum of graphene transferred via carbonic acid is comparable, if not, better than graphene transferred via growth substrate chemical etching and 0.5M sodium chloride (NaCl) solution. The ability to leave no residue on the graphene makes carbonic acid an ideal candidate for a future green large-scale manufacturing of graphene.

### **Fabrication and Analysis of Silica Aerogels for Solar Thermal Applications**

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Solar power accounts for a small percentage of world energy production, despite its widespread abundance. A major limitation preventing wider adoption is the low thermal efficiency (~20%), compared to fossil fuel burning power plants (~60%). Solar thermal energy works by collecting and focusing sunlight on a circulating fluid to produce steam. This steam is then converted to electrical energy through the use of a turbine and generator. During the heat conversion process, there are losses to the environment due to re-radiation and convection, which can be eliminated by proper insulation. This project investigated the fabrication and use of silica aerogels as the insulating materials to improve efficiency of solar thermal plants. Aerogels were fabricated of different chemical compositions, drying methods, and procedures. The aerogels were composed of silica and were synthesized with a sol-gel process using tetramethyl orthosilicate (TMOS). Hydrophobic and hydrophilic aerogels were fabricated and compared. The drying methods were comprised of supercritical CO<sub>2</sub> drying and subcritical drying. Once fabricated, the material properties of the aerogels were analyzed using light spectroscopy techniques. The results showed that the transmissivity of the aerogel was above 90% in the wavelength region of 0.35 μm to 2.5 μm which was desirable as it was within the solar spectrum. As many of the fabricated aerogels exhibited defects such as cracking, future research will investigate modifying the procedure to eliminate these defects.

## **Wireless Neural Implantable Needles For Optogenetics**

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The ability to record neural activity in living mammals has greatly improved our understanding of brain function. Optical techniques are becoming increasingly important to improve this understanding. Recent studies use light delivered by an implanted optic capable to excite genetically encoded calcium indicators and collect the resulting changes in fluorescence. Limitations to this approach include restrictions in free moving animals due to the cable and the size and weight of the technology which impede on the studies of the naturalistic behaviors, including social interactions and tests in complex environments. The most recent approach using fluorescence imaging and photometry has disadvantages with motion artifacts. The devices we have fabricated address many of the limitations as they are of a smaller, “injectable” photometry platform that can measure fluorescence stimulation through the use of a high performance microscale inorganic light emitting diode and captured using a co-located, sensitive microscale inorganic photodetector. This platform is ultrathin and flexible which allows for minimally invasive implantation as well as reduces the motion artifacts because they are directly injected into the deep brain at sites of interest. This platform is paired with wireless power delivery and data communication schemes, which allows for the use in awake, free moving animals. In vivo studies in freely moving animals show that this technology allows highly accurate recordings of calcium fluorescence in the deep brain, with measurements that match or exceed those in other fiber photometry systems. The ability for optical recordings on neuronal dynamics in freely moving animals has the potential for widespread applications in neuroscience.

## **Synthesis and Processing of Cyclic Polyphthalaldehyde Fibers**

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Cyclic Polyphthalaldehyde (cPPA) is a stimuli-responsive polymer which depolymerizes on-demand and has been used as a transient substrate for self-destructing electronics.<sup>[1]</sup> The depolymerization of cPPA is triggered by exposure to acid or elevated temperatures (> 100°C), leading to the formation of the monomer, o-phthalaldehyde (oPA). While the metastability of cPPA is of critical importance for transient electronic applications, it severely limits the processing methods to mold or shape cPPA into the desired morphology. To date, cPPA

processing has been limited to solvent casting films – which limits the breadth of potential applications. In this work, we present a process for spinning cPPA fibers. A fiber spinning setup was assembled to create a controlled environment for solvent spinning, including controlled rates for both volumetric fiber extrusion and air flow for drying and a collection drum. It is shown that a highly-concentrated solution of cPPA in dichloromethane (30 wt%) is effective for the dry spinning of cPPA fibers. However, the current spinning environment inadequately dries the fibers, leading to the collection of ‘wet’ fibers that deform upon collection on the take up drum. In addition, trapped solvent within the fiber leads to internal air bubbles, surface crenulations and crescent cross-sections. Future work is focused on the investigation of a wet spinning setup that will utilize coagulation baths to improve solvent extraction and fiber morphology.

[1] C. W. Park, S.-K. Kang, H. L. Hernandez, J. a. Kaitz, D. S. Wie, J. Shin, O. P. Lee, N. R. Sottos, J. S. Moore, J. a. Rogers, S. R. White, *Adv. Mater.* **2015**, *27*, 3783.

## **Two Color Super-Resolution Imaging of AMPA Receptors and Synaptic Scaffolding Proteins**

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Synapses are the cellular junctions present between neurons facilitating signal transmittance. Glutamate receptors—the most prevalent of which are AMPA receptors (AMPA)—play a key role in synaptic transmission by altering signal strength. AMPAR are known to bind the scaffolding proteins PSD95 and SAP97 which permeate the post-synaptic density. Studying the network of the complexes formed by AMPAR and scaffolds is vital for the understanding of signal regulation and neurological disorders—such as Alzheimer’s disease and autism—on a single-molecule level. Studies of synaptic organization have been restricted due to the diffraction limit of light. The super-resolution technique PALM (photo-activated localization microscopy) allows for imaging below the diffraction limit. By introducing replacement constructs of PSD95 and SAP97 tagged with fluorescent proteins and staining the existing AMPAR with fluorescent dyes, PALM can be used to image populations of each at physiological concentrations. By performing colocalization analysis, we have characterized the organization of AMPAR and scaffold on a synapse by synapse basis via cross-correlation statistics. Preliminary results show a high probability of colocalization between AMPAR and scaffolds between ~100 and 700 nm with SAP97 particularly dense at small distances (100 - 200 nm).

## **Transition to Turbulence over 2D and 3D Periodic Large-Scale Roughnesses**

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A laboratory investigation was performed to study distinctive features of the laminar-to-turbulent transition over distributed roughness characterized by two-dimensional (2D) and three-dimensional (3D) periodic, low-order topographies at roughness Reynolds number  $Re_k \approx 300$ . Systematic experiments were performed using high-spatial-resolution planar particle image velocimetry (PIV) in a refractive-index-matching (RIM) channel, where the roughness covered the entire length of the test section. The results show that the flow over the 2D roughness becomes turbulent much sooner than its 3D counterpart ( $Re_x = 50000$  versus  $120000$ ). This is attributed to the presence of a velocity inflection point resulting from flow separation within the troughs of the 2D roughness. In the transitional region, unsteady disturbances above the two roughnesses appear upstream of near-roughness disturbances. The above-roughness disturbances are associated with the inflection point in the vertically displaced boundary layer for the 2D case, and with the mean velocity deficit resulting from the interaction of the wakes of upstream elements for the 3D case. The near-roughness fluctuations are associated with the shear layer present behind the crests of both roughnesses. The transitional region is characterized by the interaction between above- and near-roughness disturbances, which merge, leading to a rapid vertical growth of the turbulent fluctuations.

## **Spontaneous Activity Patterns in Clustered *in vitro* Neuronal Circuits**

Shreya Santhanam<sup>1,3</sup>, Carlos Renteria<sup>1,3</sup>, Stephen A. Bopp<sup>1,2,3</sup>, Parijat Sengupta<sup>1,3</sup>

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The brain is the most complex organ in the body. We can gain knowledge on how the brain learns and functions through understanding of how brain cells interact with each other in a network. Neurons and glia can form spontaneously active networks when cultured *in vitro*. Studying this activity can give insight into how cells utilize chemical and electrical signals to convey information to neighboring neurons. Primary neuron and glial cells were cultured from GCaMP6s positive mice. GCaMP6s is a genetically encoded calcium indicator that allows for the visualization of calcium release in neurons, this indicator expressed in these mice. Observing calcium release in neurons visually indicates the generation of an action potential. Spontaneous neuronal responses, neuron activity in the absence of a sensory or motor output, were recorded by detecting calcium activity via fluorescence microscopy with GCaMP6s.

Videos were analyzed to see how this activity changed over time. Our results show that network connectivity affects cellular response. Neurons were able to transfer signals to neighboring neurons through synaptic connections, eliciting a series of calcium responses in these cells. Separate clusters of neurons that were not connected via synaptic connections fired at different amplitudes and frequencies. Studying spontaneous activity in neuronal networks is critical to understanding how cellular interconnectivity may influence signal transfer. Once understood, this information can be used to study other neurobiological phenomena, such as determining how neurodegeneration may affect signal propagation and transfer.

### **Fabrication of Perovskite Solar Cells via Flow-Limited Field Injection Electrostatic Spraying**

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One of the great engineering challenges of today is the development of renewable energy sources that can rival the inexpensiveness and ubiquity of fossil fuels. An emerging technology that may solve this problem is perovskite-based solar technology. Methylammonium lead halide perovskite solar cell technology has several distinct advantages over other cell technologies, including its chemically adjustable band gap and optical properties, high quantum efficiency, ambipolar charge transport, and large (~1 micron) diffusion length. Because of these properties, it has been used successfully in the past<sup>1</sup> to create high efficiency (~20%), low cost solar cells. My research aims to create an even more cost effective perovskite solar cell by applying flow-limited field injection electrostatic spraying (FFESS) technology. FFESS is capable of creating incredibly smooth films with nanometer depth precision, and has the flexibility of spraying both organic and inorganic layers on a large scale for minimal cost. These traits make it an excellent candidate method for commercial production of perovskite solar cells. The goal of current research is to create a cell modeled after past experiments to determine the relative efficiency of our method and determine whether FFESS is a candidate for commercial perovskite cell technology.

## **Developing Application Specific Semiconductor Imaging Modalities: High Resolution Neurological Imaging Using PET (Neuro-PET)**

John Smith<sup>1</sup>, Andrew Groll<sup>2</sup>, Prof. Ling-Jian Meng<sup>3</sup>

Research Sponsor: National Science Foundation  
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Neurodegenerative diseases are on the rise with more deaths than breast and prostate cancer combined. It is estimated that by the year 2050 more than 14 million people will be diagnosed with Alzheimer's Disease. It is necessary to develop better imaging modalities that allow early detection of the disease and tracking of disease progression. A couple of modalities have been used (MRI, SPECT, Photo-acoustic) but PET is a promising imaging modality. This presentation looks at the use of a PET-X-Ray Fluorescence (XRF) system to allow imaging of metal cation concentrations along with complimentary information delivered through PET systems today. This is done through the use of a CdTe semiconductor detector system that allows cathode/anode readout of each detector pixel. From the cathode readout we can derive information such as timing, depth of interaction (DOI), and energy. This provides a means to improve timing performance, energy resolution, and spatial resolution by parallax correction. Four different source spectra were looked at, including Am-241, Ba-133, Cs-137, and Na-22. DOI derivation by waveform fitting was performed for each spectrum to determine the viability of using the cathode waveform for X-Ray and PET energy levels while retaining the ability to determine DOI. It was found that this system is viable for elements with k-edges greater than 80 keV due to the systems intrinsic inability to fit waveforms at lower energies. In order to image metal cations relevant to Alzheimer's disease, the system must be able to resolve k-edges around 10 keV at the most.

## **The Design and Fabrication of a Non-Invasive Thermometry Platform for Accurate Dehydration Detection**

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Despite its prevalence as a symptom or precursor of many serious diseases, dehydration is difficult to accurately detect before the onset of symptoms. In this investigation, we analyze the strengths and limitations of a  $3\omega$  thermometry platform for use as a non-invasive, simple, fast, and affordable skin dehydration sensor with the capability to detect dehydration before symptoms occur. The sensor aims to detect water content changes deep within the skin, where water loss due to dehydration is more pronounced and thus is more detectable.

The sensor operates by measuring the temperature rise of an encapsulated thin metal wire placed on the volar forearm in response to an applied alternating current. We evaluated its detectability, the difference in temperature response between normal and dehydrated skin, using thermal conduction finite-element-analysis of an idealized sensor-on-skin model. Results indicate that the detectability is found to be more pronounced for low alternating current frequencies and for greater magnitudes of dehydration. The difference in the normalized root-mean-square temperature rise between the two responses are on the order of 0.1-0.2 (K)/W/m and thus dehydration is detectable at low AC frequencies ( $\sim 0.1$  Hz) and/or moderate dehydration levels ( $\sim 5$ -10% water loss) in an ideal scenario. In addition, we also analyzed the sensitivity of the sensor temperature response with respect to varying skin and sensor thermal properties. The implications of our findings suggest improvements for the design and manufacturability of a sensor for clinical use.

### **Effect of Windbreak Porosity on the Power Generation of Leeward Wind Turbines**

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Previous research investigated the wake dynamics of porous windbreaks and their effects on the power generation of leeward wind turbines. This research aims to analyze the functional dependence of this increase on the porosity of the windbreak. Ultimately, the research will allow for the prediction of power generation for windbreaks of varying heights and porosities.

Three windbreaks of porosities of 0, .1, and .2 were placed in the cross-flow of an open loop wind tunnel. The velocity fields in the wake were measured using particle image velocimetry. These windbreaks were moved to three different positions, each 16 cm apart, to obtain data for the complete wake in three fields of view. A turbulence generator placed at the inlet of the wind tunnel produced a more realistic analogue of the atmospheric boundary layer. Streamwise velocity perturbations were proportionally calculated from the vertical displacement of incoming streamlines to provide predictions for increased power output.

Experimental data was obtained for a scale-model wind turbine in the near lee of nine windbreaks with heights of 12 mm, 18 mm, and 24 mm with porosities of 0, .1, and .2. The mean voltage generated by the turbine in each case was compared to the no-windbreak case to provide experimental power generation values. These values were then compared to theoretical values. As predicted, the greatest power increase was observed for 0 porosity and the lowest for .2 porosity, both experimentally and theoretically, with a positive correlation between power increase and windbreak height.

## **Carbon Dioxide Capture Using Polyamines**

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The increase in the temperature of Earth's atmosphere and oceans is permanently changing the planet's climate, and humans are largely responsible. Global warming is caused by releasing increased quantities of greenhouse gases which trap abnormally high amounts of energy inside the atmosphere. Carbon dioxide (CO<sub>2</sub>) is the main greenhouse gas emitted due to human activities, such as the combustion of fossil fuels. Currently liquid amines are used to capture CO<sub>2</sub> from flue gas industrially to prevent its emission into the atmosphere. The liquid amines used have drawbacks such as corrosiveness and hazards to human health and the environment, and as a result there are efforts to create new materials for CO<sub>2</sub> capture. To create a material that is capable of CO<sub>2</sub> capture, studies were performed to create polymers with high amine content. A Pd catalyst was synthesized which was used to create polyethylene with amine incorporation under high temperature and pressure using a Buchi reactor.

## **Fabrication of Complex Refractory Oxides (HfO<sub>2</sub>-Ta<sub>2</sub>O<sub>5</sub>-TiO<sub>2</sub>) and their Melting Points**

Whitney Tso<sup>1</sup>, Scott McCormack<sup>2</sup>, Prof. Waltraud Kriven<sup>3</sup>

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To evaluate the potential of the complex refractory oxides (HfO<sub>2</sub>-Ta<sub>2</sub>O<sub>5</sub>-TiO<sub>2</sub>) in high-temperature applications, a large array of samples were fabricated in order to understand how the atomic structure affects the melting point of the compounds and to determine the phase equilibria. The main focus of this research is fabrication. The steric entrapment method, designed and patented by Kriven (2008), was used to synthesize samples using low energy, with high chemical homogeneity, and mixing on the atomic scale. All these factors help achieve equilibrium faster than traditional processing methods. The samples were then heated using a CO<sub>2</sub> laser off site to determine their cooling traces and then calculate their melting points. The data is used to gain a better understanding of the phase equilibria in the HfO<sub>2</sub>-Ta<sub>2</sub>O<sub>5</sub>-TiO<sub>2</sub> system and how the complex crystal structures and multi-phase samples affect the melting point.

## **Optimization of Cradle and Assay Cartridge for Handheld Smartphone Biosensor**

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Increases in the availability and usage of point-of-care testing have been facilitated by the development of devices that allow for simple, low-cost measurement of biological samples. The ability to adapt the nearly-ubiquitous smartphone to serve as the core of an analysis platform for existing assays would allow their diagnostic potential to reach a larger user population by lowering the associated equipment costs and increasing portability. Previous work by Prof. Brian Cunningham's Nano Sensors Group has generated three separate cradles capable of harnessing a smartphone camera's power to perform label-free biodetection, portable enzyme-linked immunosorbent assays, and fluorescence spectroscopy. The aim of this project is to optimize the design and assembly processes for the cradle and liquid assay cartridges for a handheld smartphone biosensor device.

A cartridge design was developed utilizing layers of laser-cut acrylic and double-sided adhesive combined with glass, polycarbonate film, or photonic crystal material. Each new cartridge holds up to eight samples, which are measured individually for fluorescence (when excited at 532 nm by a green laser diode), absorbance, or label-free detection. When used to perform an assay to detect phenylalanine in human serum, the cartridges and cradle system were able to detect linear concentration-dependent changes in fluorescence emission comparable in accuracy to a standard benchtop plate reader device. Additional cradles were fabricated using a stereolithography 3D printer, and optical components were custom-fit to allow for multimodal sample analysis. A power supply circuit was designed, fabricated, and installed to control the laser diode used for fluorescence excitation.

## **Production and Testing of Bi-Tortuous Activated Carbon Electrodes**

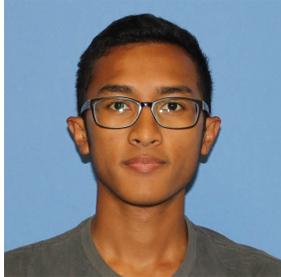
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Modern society relies heavily on the use of energy storage technology in applications ranging from personal electronics, to vehicles, to medical technology. However, the full extent of power that can be gleaned from these devices has not yet been achieved. This research aims to increase the charge and discharge capacity of such electronic devices by reducing the tortuosity of the anodes carried within them. It is hypothesized that an electrode's tortuosity, a measure of the twistedness of the paths through an electrode, can be, on average, reduced via the imprinting of macropores onto its surface through contact between a heated die manufactured via wire EDM and the electrode itself. In this experiment, such macropores were introduced into activated carbon electrodes. Following impression, these electrodes were tested for capacitance via cyclic voltammetry in a Swagelok cell using another imprinted electrode as an auxiliary. Prior simulation work shows that these macropores can increase the amount of charge a cell can output, depending on size and percentage of pore coverage. However, preliminary data cannot conclusively confirm or deny the postulated outcomes. The results to date show both improvement and a lack thereof when comparing imprinted to unmodified electrodes with similar physical properties tested under identical conditions. Through a modification of the standard electrode fabrication procedure, it may be possible to increase the effectiveness of energy storage technology, which can in turn be used to further fuel the wide variety of applications that necessitate it.

# ISUR Scholars 2016-2017



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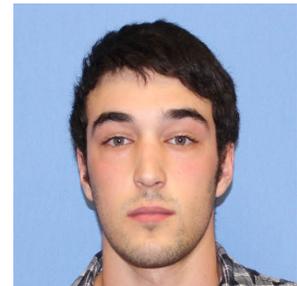
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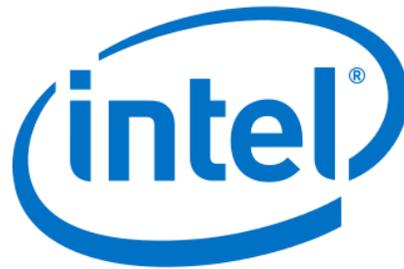


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