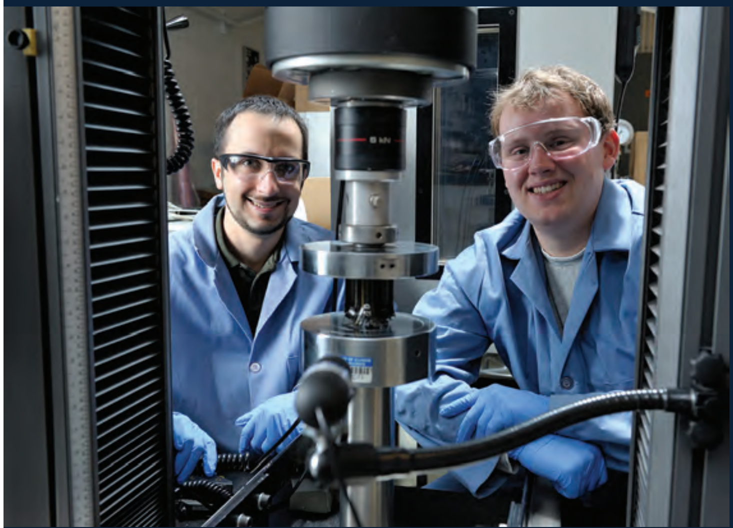
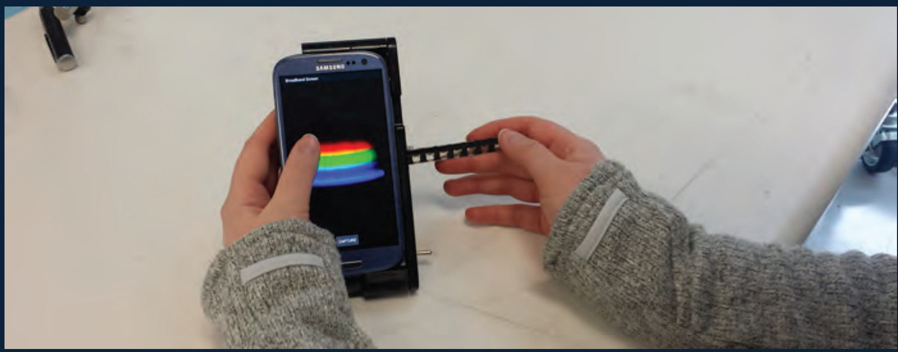
ILLINOIS SCHOLARS UNDERGRADUATE RESEARCH **POSTER EXPO** APRIL 21, 2016 ILLINI UNION **ABSTRACTS**





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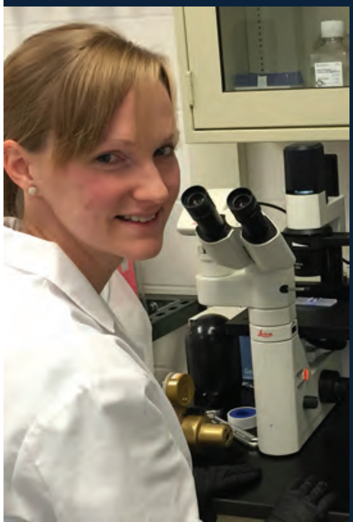

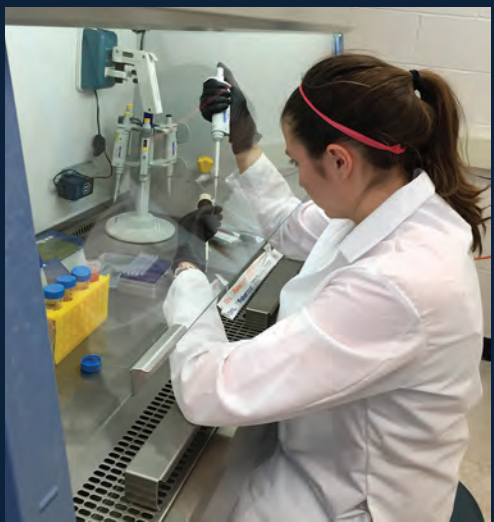

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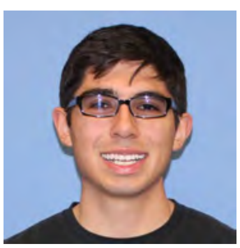
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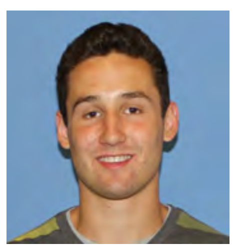
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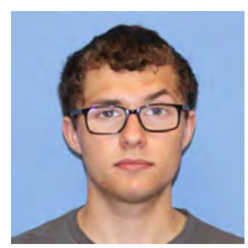
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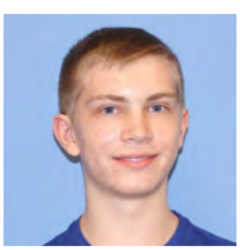
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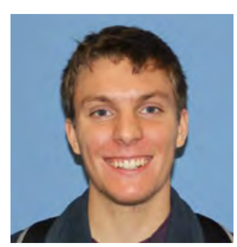
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Illinois Scholars Undergraduate Research (ISUR) Program

The College of Engineering Illinois Scholars Undergraduate Research (ISUR) program offers a select group of students a two-semester experience with a research learning community. The program provides students the opportunity to expand their 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, expose them to what graduate school entails, and gain experience needed for graduate school acceptance.

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 semiconductor, information-technology, 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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Microvascular Carbon Fiber Composites as an Actively-Cooled Structural Material

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3. Faculty Sponsor, Department of Aerospace Engineering

Microvascular carbon fiber composites contain sub-millimeter channels that are made from a sacrificial polymer that is vaporized following cure. This study considers the use of this material for actively-cooled structures through two main focuses.

First, carbon fiber composite samples were manufactured and the cooling capabilities were tested for a heat flux of 500 W m^{-2}, which is similar to the heat dissipated by batteries in electric vehicles. The results of this study indicate that microvascular carbon fiber composites are able to sufficiently dissipate heat for battery cooling. Furthermore, as a proof of concept of this technology, a microvascular carbon fiber laptop cooling board was produced, tested on a laptop running a processor stress testing software, and the cooling performance was compared to a commercially-available cooling board. The results of this study show that this technology performs comparably to the commercially-available cooling board.

Second, corrugated carbon fiber composite samples for crush testing were manufactured, and the crashworthiness of this material was characterized by measuring the specific energy absorbed during crush tests of 50 mm min^{-1}. The results of this study indicate that volumes of channels less than 2% have little effect on the energy absorbed during crushing. Both the cooling and crush testing studies indicate that microvascular carbon fiber composites are a strong candidate for actively-cooled structures.

Vapor diffusion for fabricating large single crystals for flexible electronics

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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. Historically, the method for growing near perfect single-crystalline silicon (ingot) via the Czochralski process laid the foundation for large-scale semiconductor manufacturing and facilitated the advent of the information age. In recent years, organic semiconductors (OSCs) have emerged as an alternative to traditional semiconductor materials. However, the crystallization process is not well understood, and thus achieving large (1 mm) single crystals presents a challenge. The crystal samples in this study were created using cooling drop method and vapor diffusion method—methods previously not utilized in the organic electronic community, but promising for growing mm-size single crystals.

This project aims to consistently fabricate large OSC single crystals of 2,7-Di-trimethylsilyl-[1] benzothieno[3,2-b][1]benzothiophene (diTMS-BTBT) and 2,7-di-tert-butyl-BTBT (ditBu-BTBT) by understanding the mechanism behind nucleation and utilizing controlled vapor diffusion. A series of controlled experiments were performed to evaluate the effects of temperature, drop volume, substrate surface energy, solution concentration, and relative humidity on the cooling, evaporation, and vapor diffusion rates within the system. Preliminary results indicate the preferred nucleation for growing large single crystals is dictated by the cooling rate, and COMSOL simulations correlate to the observed nucleation time scale. Additional experiments must be performed to generate conclusive data regarding the optimal vapor diffusion operating conditions. The results of this study can be applied to additional compounds to improve the formation of large single crystal OSCs for studying charge transport properties and phase transition mechanisms.

Modulating the Immune Response using Collagen Scaffolds Containing Amniotic Membrane Matrix

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Research Sponsor: John Deere

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Collagen-glycosaminoglycan scaffolds have been developed as extracellular matrix mimics for tissue regeneration. Any biomaterial implant will be subjected to the body's native inflammatory response which can have detrimental effects such as scar formation and loss of mechanical properties. The amniotic membrane (AM) is a membrane on the fetal side of the placenta that has anti-inflammatory, anti-microbial, and anti-scarring properties. This membrane has been previously used in two-dimensional applications to promote healing in diabetic foot ulcers. In order to test its potential in three-dimensional applications, human amnion was incorporated into collagen-glycosaminoglycan scaffolds to test their anti-inflammatory effects on human mesenchymal stem cells seeded into the biomaterial. The scaffold groups being tested are collagen-glycosaminoglycan scaffolds with additions of chondroitin sulfate, hyaluronic acid, or AM. Each of these cell-seeded scaffold groups were cultured in control growth media, low inflammatory media (0.1 ng/mL IL-1β and 1 ng/mL TNF-α), or high inflammatory media (1 ng/mL IL-1β and 10 ng/mL TNF-α). On days 0, 1, 4 and 7 of the experiment, metabolic activity was tested using an alamarBlue assay, cell number was determined by a Hoechst dye assay, and gene expression was recorded using polymerase chain reaction. Results indicate limited impact of scaffolds and media condition on metabolic activity and cell number. Gene expression analysis showed early downregulation of IL-8 (pro-inflammatory) in the AM group under high inflammatory conditions as well as instances of upregulation of VEGF (pro-proliferative) in both media conditions. Future work will assess scaffold impact on culture of inflammatory cells such as macrophages.

Impulsive Solutions in the Earth-Moon System Using Invariant Manifolds

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This research focuses on energy efficient transfers in multi-body regimes, specifically the circular restricted three-body problem in the Earth-Moon system. In this three-body problem, the Earth and Moon are viewed in a rotating frame so they appear stationary which creates five solutions to this problem called the Lagrange points. The first three collinear Lagrange points are unstable and therefore each have unstable periodic orbits. Each of these orbits have stable and unstable invariant manifolds that dictate global transportation and are important to optimize this problem. Using the invariant manifolds from the dynamical structures, a solution may be found to design a low energy transfer from Earth to the periodic orbits. Specifically this problem will focus on starting at a low Earth orbit and transferring to the second Lagrange point periodic orbit. In order to travel between manifolds, we will need to view how they intersect in position and velocity. We can do this by using a Poincare surface of section. To find a continuous transfer, we must find two arcs that match up on these surfaces. Once we find two arcs that match up, we can create a continuous transfer trajectory from Earth to the second Lagrange point periodic orbit. Using this method we can find a sample of feasible trajectories within the Earth-Moon regime and compare their characterizations.

Improved Thermoelectric Properties in SiGe Quantum Dot Superlattices

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Research Sponsor: Semiconductor Research Corporation

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Thermoelectric materials are notable for their novel conversion from thermal energy to electrical energy and vice versa. Materials such as silicon-germanium are especially important in spacecraft applications and waste heat recycling in high-temperature machinery since they functions sufficiently at high temperatures (~600 ˚C to ~1000 ˚C). The functionality of a thermoelectric device requires properties such as high electrical conductivity with low thermal conductivity, as illustrated by a material's thermoelectric figure of merit, zT:

$$zT = \frac{\alpha^2 \sigma T}{\kappa}$$

This describes a material's thermoelectric dependence on its Seebeck coefficient (α, determined by the thermoelectric effect), temperature (T), electrical conductivity (σ), and thermal conductivity (κ).

Previous research shows the figure of merit for SiGe to be typically ~1 and to have reached upper limits of ~1.3 through increased phonon scattering in the boundaries of the bulk material with nanopowder structuring (Wang *et al.* 2008). Recent developments in thermoelectric efficiency improvement have proven that a nanocomposite makeup in bulk material will significantly enhance the performance of such materials (Liao & Chen. 2015).

We investigate the effects that introducing germanium quantum dots into a silicon matrix have on the thermal conductivity of the alloy through large-scale molecular dynamics simulation. Thus far, we have found that, for a 1,000 $Å^3$ (10Å X 10Å X 10Å) silicon block, increasing the diameter of an embedded germanium quantum dot to ≥ 5 Å will decrease the system thermal conductivity to between 10-18% of the thermal conductivity of pure silicon. Currently, we are running the same set of experiments for an 8,000 $Å^3$ silicon block to test scaling effects.

Creation and Validation of a Standard Materials Set for Tribological Experiments

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Friction coefficient is a descriptive property of a sliding system, including the materials, sliding conditions, and environment. As such, tribometers, or friction testers, typically do not use standards for calibration. In the absence of a standard value of friction coefficient that the tribometer can be "tuned" to, confidence intervals are determined by statistical methods or machine design uncertainty methods.

The objective of this project is to create and validate a set of standard materials and experimental conditions to characterize the statistical repeatability of friction coefficient measurements on a reciprocating microtribometer.

To accomplish this, we measured the friction coefficient under varying normal loads between 0.5 mN and 10 mN between a standard sample and a smooth glass probe, at sliding speed of 1 mm/s. The standard samples were tested at 0°, 45°, and 90° in order to identify any orientation effects. The values recorded were friction force, normal force, uncertainty in friction force, and uncertainty in normal force. Monte Carlo simulations ($N=10^5$) were performed on the slope of friction force versus normal force to calculate the uncertainty in the measured friction coefficient.

For the three standard samples measured, uncertainties ranged 2.6% to 17.3%, with aluminum overall showing higher uncertainty than silicone rubber or acetal. Results suggested sample flatness and parallelism contributed to uncertainties.

Intrinsic Cavity Loss in Vertical Cavity Surface Emitting Lasers

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As the rate of data transmission over the internet continues to increase, there has been increasing demand for higher performance and single mode vertical cavity surface emitting lasers (VCSELs) that provide a larger modulation bandwidth over greater distances. However, VCSELs require a lower threshold current and thus lower optical loss to achieve a higher modulation speed. Additionally, for a VCSEL to achieve single mode performance the difference in loss between the fundamental and first higher order modes must be sufficiently high. Because achieving single mode and high speed performance depends strongly on the optical loss in a VCSEL, characterizing the optical loss in VCSELs provides insight that may lead to optimized optical losses, single mode performance, and improved rates of data transmission. For this reason, the goal of this project is to characterize and compare the optical losses of oxide-confined VCSELs with varying output mirror reflectivity and photonic crystal VCSELs with varying photonic crystal patterns in order to determine how these parameters impact performance. The results show that the intrinsic cavity loss in oxide-confined VCSELs increases with decreasing output mirror reflectivity. Furthermore, the study also suggests that the particular values of the periodicity (a) and size (b) of holes in a photonic crystal pattern play little role in determining single mode behavior. Rather, the ratio of the two values and fewer rows of holes surrounding the lasing aperture lead to multimode behavior. However, these properties also lead to improved DC performance characteristics.

Solution Based Growth of Aligned Nanowires on a Crumpled Graphene Substrate

Siddhesh Dhanawade[1], Mike Cai Wang[2], Sung Woo Nam[3]

Research Sponsor: Semiconductor Research Corporation

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Crumpling and wrinkling of monolayer graphene enhances its chemical and mechanical properties. Furthermore, the peaks and corrugations of crumpled graphene are chemically enhanced due to the strain-induced changes in chemical potential energy. The purpose of our current investigation is to assess the feasibility of nanowire growth on these corrugations through a solution-based method. The ability to fabricate aligned nanowires on large scale are of great interest for applications such as sensors, photovoltaics, and piezoelectric devices.

We attempt growth of metallic nanowires by electrodepositing from a copper-based solution onto crumpled graphene cathodes. These nanowires are characterized using SEM (scanning

electron microscopy) and optical microscopy. Preliminary tests on graphene samples show growth of Cu_2O crystal facets and Cu nanoparticles that are in alignment with the graphene corrugation direction. In the future, we will extend this investigation to other materials.

Effect of tab Geometry on Vortex Dynamics and Mixing

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Vortex generating tabs are commonly used to enhance convective heat transfer in multiple industrial applications. To gain insight on their role in mixing enhancement, the turbulence statistics and vortex dynamics in the near wake regions of rectangular, trapezoidal, triangular, and ellipsoidal passive tabs were experimentally studied in a refractive-index-matching channel. Three-dimensional, three-component particle image velocimetry (PIV) was used to study the mean flow and vortex dynamics. The studied tabs share the same bulk dimensions including 17 mm height, 245^{o} inclination angle with respect to the wall, and 28 mm base width. Measurements were performed at two Reynolds numbers based on the tab height $Re_h \approx 2000$ and 13000. When a tab is placed in the streamwise direction of a flowing fluid, a pressure drop develops giving rise to a counter-rotating vortex pair (CVP). This CVP is a primary vortex structure that interacts with hairpin-like vortices that are rolled from a shear layer that forms at the tab height. This study aims to discern the effect of the tab geometry and Reynolds number on the wake characteristics and vortex strength and dynamics in the near-wake of vortex generators.

Characterization of Clofazimine Salt Crystal Structure and Properties

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Clofazamine (CFZ) is used for the treatment of leprosy and is among the World Health Organizations list of essential medicines.[1] CFZ has unique pharmokinetic properties and has been found to bioaccumulate in macrophages to form crystal like drug inclusions (CLDIs). The CLDIs have been documented to be well tolerated and recent work on macrophage phagocytosis of CFZ CLDIs reported that anti-inflammatory pathways were promoted when the macrophages underwent phagocytosis of CFZ CLDIs.[2] The CFZ CLDIs found in vivo were identified as a CFZ-HCl salt through bulk elemental analysis and powder x-ray diffraction.[3] The goal

of this work is to determine the crystallization conditions to grow diffraction quality single crystals of CFZ-HCl and characterize the resulting solid form. This is achieved through evaporation experiments performed in microfluidic dead-fill chips and small glass vials, using CFZ concentrations ranging from 2-8 mM. During our crystallization attempts we identified a second polymorph of CFZ-HCl. This crystal system is of particular interest because one polymorph is elastic while the other polymorph is brittle. Elasticity is rare in crystals since crystallinity positively correlates with brittleness, however, dispersive bonding and a corrugated structure allow the first polymorph to bend when a force is applied to the (001) crystal face and then return to the original position when the force is removed. The mechanical properties of the crystals were characterized through 3-point bend in a nanoindenter. To better understand the solid forms, we analyzed the physical properties of these solid forms and the crystal structure of both polymorphs to better understand the structural features needed for elasticity in crystals.

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Experimental Research on the Failure Modes of the Feature Tracker in PTAM

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Visual Simultaneous Localization and Mapping (SLAM) algorithms are an ever growing field that can be used for autonomous robotics. One of the reasons that PTAM and other feature based SLAM algorithms fail can be attributed to camera motion which can decrease the quality of feature detection. In this project we attempt to characterize the relationship between camera motion and the features detected in a camera image. We gathered data using a custom 3D printed test rig. Our rig contains a motor and camera mount that can be adjusted to different heights. We used a motor to spin a checkerboard image and controlled the speed using an Arduino Board and setting various PWMs. By spinning the motor at increasing angular velocities we can measure the features in the image. The data we measured included the map points being reprojected onto the image and the amount of optimized corners in the image. Data was inconclusive and had a large amount of variation but there was a general negative correlation between angular velocity and map points. By having a successful metric between camera motion and feature detection, we become closer to being able to parameterize the motion of a camera and being able to predict when it is going to break. Future work includes building such a model and implementing it onto an autonomous vehicle.

Microassembly of a Silicon Micro-House

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3. Faculty Sponsor, Department of Mechanical Engineering

This study provides details on the design, fabrication, and documentation of a silicon “Micro-House” made by micro□masonry. Micro□masonry is a microsystem construction method that incorporates the fabrication and assembly of silicon units, or inks, by transfer printing. A model of a house was divided into 9 cross sections, and a corresponding optical mask allowed for the production of inks by conventional lithography processes. The inks were fabricated from two silicon on insulator wafers that had device layer thicknesses of 10 and 20 micron, so that different sections of the house could be made from different thickness inks. The inks were suspended on photoresist anchors, which facilitated pick-and-place assembly by transfer printing with elastomeric stamps. The structure was annealed after each layer was placed, to prevent delamination between subsequent layers. The final structure was documented with a scanning electron microscope, as a demonstrative piece to showcase the structural complexity capable through transfer printing.

Guided Formation of Three-Dimensional Helical Mesostructures by Mechanical Buckling

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Through the usage of compressive buckling, the assembly of 3D helical mesostructures was accomplished. 3D helical mesostructues are important due to their applications in a broad range of microsystem technologies. These include microelectromechanical systems (MEMS)[1,2] and strechable electronics.[3,4] The controlled compressive buckling of 2D serpentine-shaped ribbons provides a wide range of materials to be structured from soft polymers to brittle inorganic semiconductors. Previously 3D ribbon-based nano/micro-architectures using silicon, polymers, metals and combined materials were constructed. But by using a 2D serpentine-shaped ribbons 3D helical configuration was constructed. This is based on the minimization of total strain energy that results from various forms of spatially dependent deformations. Various experiments at micro- and millimeter- scales were analyzed to examine the validity of the developed model. The samples were all built using SU8 due to time constraints. Currently our team is working on developing more complex multi-level microstructures along with exploring further applications using the helical structures.

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It's just a matter of perspective(s): Crowd-Powered consensus organization of corpora

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Research Sponsor: Semiconductor Research Corporation

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We study the problem of organizing a collection of objects - images, videos - into clusters, using crowdsourcing. This problem is notoriously hard for computers to do automatically, and even with crowd workers, is challenging to orchestrate: (a) workers may cluster based on different latent hierarchies or perspectives; (b) workers may cluster at different granularities even when clustering using the same perspective; and (c) workers may only see a small portion of the objects when deciding how to cluster them (and therefore have limited understanding of the "big picture"). We develop cost-efficient, accurate algorithms for identifying the consensus organization (i.e., the organizing perspective most workers prefer to employ), and incorporate these algorithms into a cost-effective workflow for organizing a collection of objects, termed ORCHESTRA. We compare our algorithms with other algorithms for clustering, on a variety of real-world datasets, and demonstrate that ORCHESTRA organizes items better and at significantly lower costs.

Synthesizing a High Efficiency MoS_2 Water Desalinization Membrane

David Lisk [1], Michael Cai Wang[2], Professor SungWoo Nam [3]

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The global need for efficient water desalinization has only increased as climate change and persistent droughts continue. The most promising and practical method for water desalinization is reverse osmosis, whose efficiency is currently constrained by the lack of thin and highly permeable yet mechanically robust and chemically inert membranes. Molybdenum disulfide (MoS_2) is a two-dimensional nanomaterial that is mechanically stable and shows promise in a variety of applications. Recently, several computational papers have demonstrated that the atomic structure of MoS_2 possesses steric effects that make it an ideal candidate for use as a highly efficient water desalinization membrane. The goal of this investigation is to develop a method for the scalable manufacture of a high efficiency reverse osmosis water desalinization

membrane that uses MoS_2. The main technique used was to synthesize MoS_2 membranes on a cellulose ester substrate using the vacuum filtration method and expose the produced membranes to oxygen plasma. A variety of membranes were produced under varying parameters and tested in a laboratory filtration setup. Preliminary results indicate that MoS_2 filters can achieve NaCl rejection rates ~10% higher than those of the control filters.

RGB-D Object Detection for Grip Selection for a Prosthetic Hand

Bhargava Manja[1], Joseph DeGol[2], Professor Tim Bretl[3]

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In this paper, we demonstrate how automatic grasp selection can be achieved by placing a camera in the palm of a prosthetic hand and training a convolutional neural network on images of objects with corresponding grasp labels. Our labeled dataset is built from common graspable objects curated from the ImageNet dataset and from images captured from our own camera that is placed in the hand. We achieve a grasp classification accuracy of 93.2% and show through real-time grasp selection that using a camera to augment current electromyography controlled prosthetic hands may be useful.

Method for quantifying hip circumduction during over-ground walking in persons with mild and moderate multiple sclerosis severity

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Hip circumduction is a strategy used by people with impaired mobility to ensure toe clearance as the foot comes forward during a step. Quantifications for hip circumduction include maximum coronal hip / thigh angle and maximum deviation of the foot from the line of progression. Most hip circumduction studies have been performed on a treadmill where the line of progression is constant. However, no methods for hip circumduction have been developed for multiple consecutive steps in over ground gait, where the line of progression can change step-to-step.

The objective of this study was to develop a simple method for quantifying hip circumduction during over ground walking. To demonstrate this method, hip circumduction values were compared across individuals with multiple sclerosis (MS) while walking in their shoes, with a pas-

sive ankle-foot orthosis (AFO) on their more impaired limb, or with a portable powered ankle-foot orthosis (PPAFO) on their more impaired limb.

Results indicate hip circumduction decreased for the impaired limb while wearing the PPAFO compared to the shoes and AFO conditions. However, hip circumduction remained consistent across all three conditions for the contralateral limb. Additionally, no significant differences in hip circumduction were found between the mild and moderate MS groups across conditions.

These results suggest that the PPAFO reduces the need for hip circumduction to ensure toe clearance. This method provides a systematic approach to quantify hip circumduction and has the potential to serve as a parameter for assessing interventions and therapies focused on restoring normative gait function.

Cell shapes and patterns as indicators of tissue stress in colon cancer cells

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Previous research has shown that, for single-cell layers of plant epidermis cells, shapes and patterns of cell grouping can be used as quantitative indicators of stress. The goal of this project is to apply a similar principle to human cancer cells. It has been shown that a metastasis-like phenotype (MLP) of human colon cancer cells is mediated by substrate stiffness. When cultured on soft (10-50 kPa) polyacrylamide gels, HTC-8 cells form tumor-like clusters before dissociating from one another via reduced cell-cell adhesion. However, this MLP is not observed when cells are grown on stiff substrates (3.6 GPa). The project aims to use the MLP of HTC-8 cells to evaluate how cell shapes and patterns indicate stress within the tissue, which could be relevant to the prediction of metastasis.

HTC-8 human colon cancer cells were cultured on 10 kPa polyacrylamide gels functionalized with fibronectin. Additional samples were also cultured on glass slides. Because the MLP typically occurs after 6 days, the samples were prepared for immunofluorescence staining of E-cadherin, a transmembrane protein involved in cell-cell adhesion, as well as staining of DNA via DAPI, after 3-9 days of culture. Confocal fluorescence microscopy was used to obtain images of the stained samples, and the shapes and patterns of the cells were shown by the presence of E-cadherin. Then, image analysis techniques, particularly segmentation techniques such as Voronoi reconstruction, can be employed to obtain pixels occupied by individual cells. Cells' area and their relationships with neighboring cells can then be quantified and compared.

Effects of Electropolishing and Reduced Electrolyte Concentrations on Electrochemical Delamination of CVD-Produced Graphene Films for Scalable Graphene Production

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The current lack of a scalable and high quality production process for continuous, large area graphene sheets has hindered graphene's promising commercial applications. In particular, existing chemical-based substrate etching methods to isolate CVD-produced graphene films leave stubborn residue and expend the costly catalyst material. Here, we present a clean, low-defect, electrochemical delamination method for transferring large area graphene films onto arbitrary substrates while recycling the catalyst substrate for repeated use. Specifically, we focus on analyzing the effects of electropolishing and reduced electrolyte concentration in the electrochemical delamination process and the optimization thereof. Experiments show that: (i) electropolishing on the growth substrate creates a smoother surface for graphene synthesis, which improves the quality of graphene transfer, and (ii) delamination occurs well in electrolyte concentrations as low as 0.05M NaCl with similarly good results as those previously demonstrated using 0.5M NaCl solutions. The incorporation of growth substrate electropolishing and reduced electrolyte concentration in the delamination process may reduce the impurities on the graphene films and the amount of aqueous by-products in future large-scale graphene production for novel devices such as in wearable sensors and transparent flexible conductors for solar cells.

Wireless Neural Implantable Needles For Optogenetics

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Optical techniques are becoming increasingly important in the field of neuroscience. In order to continue progress in the BRAIN initiative, more advances in these methods are vital. Developments have been made to temporarily control specific neuronal activity through the use of wireless optogenetics which deliver light to light-sensitive proteins. There are many limitations to the developments. They include not being able to provide information of neuronal populations, a lack of activity data and detection of larger neuronal networks, and restrictions in free moving animals due to electrical and optical cables. Even 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 reduces the motion artifacts because they are directly integrated into those regions of the brain we wish to study. This platform is paired with wireless power delivery and data communication schemes including NFC devices, which allows for the use in awake, free moving animals. The device has already shown the ability to detect *in vitro* fluorescent signal changes due to changes in Ca^+ concentrations. Future work on this device will include further enhancements to the technology used as well as its ability to record the fluorescence in the desired neuronal populations in free moving animals.

Guided Rendezvous of a Quadcopter

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Quadcoptors have a very wide set of applications. They range from delivery vehicles to aerial photography vehicles to surveillance vehicles. One particular application that is of interest to us is the use of quadcoptors to monitor construction sites. Currently, the inspection of construction sites is carried out manually, which is time consuming and expensive. Cameras can be deployed by quadcoptors to various locations on construction sites to monitor static progress or can be flied onboard as a payload to monitor constructions sites from various angles. On these construction sites, there will be various instances when the quadcopter must dock to other physical objects. These may include docking to a charging station, docking to a payload mechanism etc. An effective rendezvous method must be employed to maximize the success rate of docking.

In order to solve the rendezvous problem, a new algorithm was employed which showed improved probability of docking. The path was planned by solving a function known as Difference function, which was derived based on the position of the UAV and the target distance. The widely known Gradient Descent algorithm then optimized the function. Computer simulations were carried out to visualize the trajectory generated by this method. It was seen that the trajectory generated was parabolic. Even though the method of Gradient Descent proved to be robust, the time to dock must be minimized.

Current and future work includes determining a trajectory that can produce robust trajectory such as the one generated by the Difference function/Gradient Descent algorithm and at the same time minimize the time to dock. In addition, a Monte Carlo simulation comparing an intermediate path planner (An algorithm that minimizes the time to dock while maximizing the probability to dock), a straight line path and the path generated by the Difference function/ Gradient Descent algorithm will be carried out as well.

Impact of height heterogeneity on canopy turbulence

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The flow development above and within homogeneous and heterogeneous canopies was experimentally studied using particle image velocimetry (PIV) in a refractive-index-matching channel. The experiments were designed to gain insight into the effect of height heterogeneity on the structure and spatial distribution of the turbulence. The homogeneous model (base case) is constituted of elements of height h arranged in a staggered configuration; whereas the heterogeneous canopy consisted of elements of two heights $h_1 = h + 1/3\ h$ and $h_2 = h - 1/3\ h$ alternated every two rows. Both canopies had the same density, element geometry, and mean height. The flow was studied under three submergences $H/h = 2, 3, 4$, where H denotes the flow depth. The experiments were performed at Reynolds number $Re_H \approx 6500$, 11300, and 12300. Turbulence statistics reveal richer flow dynamics induced by height heterogeneity. Further alternations were induced in the magnitude and distribution of the turbulent kinetic energy, Reynolds shear stress, and characteristics of the canopy mixing layer evidencing enhanced mixing and turbulent transport for the heterogeneous canopy especially at lower submergence depths. Overall, the results highlight the distinctive topographic effects on the flow within and above heterogeneous canopies.

Defining the HfO_2-Ta_2O_5-TiO_2 Phase Space

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The phase space of the HfO_2-Ta_2O_5-TiO_2 was characterized in search of a new high temperature ceramic phase which could combine the beneficial properties of the three precursor oxides. Hafnium chloride, tantalum chloride, and titanium isopropoxide were sterically entrapped in solution amongst poly ethylene glycol organic molecules and crystalized at 1300°C for eight hours via the steric entrapment ceramic processing method. The composition synthesized resided on pseudo-binary tielines across the ternary phase space limiting the system to two equilibrium phases. These phases were characterized using the Siemens D5000 powder x-ray diffractometer, and the phase diagram at room temperature was constructed. The previously solved binary compounds $Hf_6Ta_2O_{17}$ and $TaTiO_7$ appeared to dominate the phase space, and were present in a wide range of compositions, suggesting they are more thermodynamically stable than other known compounds in the system. Solid solutions where Hafnium and Tantalum exchanged positions on lattice sites was also implied, however, remains to be proven.

Fabrication of Vertical GaN Devices by Various Methods

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One of the major challenges in the semiconductor industry today is the fabrication of low-cost, high-quality Gallium Nitride (GaN) devices suitable for use in high power applications, such as in the aerospace and electric automobile industries. GaN is an ideal candidate for high power devices due to its large band gap, which allows for stable operation at very high temperatures and current loads. Our work seeks to fabricate prototype GaN diodes and MOSFETs with a novel combination of several fabrication techniques, including spray deposition, Plasma-Assisted Molecular Beam Epitaxy (PAMBE), and Chemical Vapor Deposition (CVD). A large part of my work included helping to reconstruct and upgrade the PAMBE system and constructing and operating the CVD system. While large strides have been made in terms of GaN growth on silicon, much progress needs to be made regarding device fabrication, and unfortunately due to the large amount of unpublished data regarding this, I have been asked to not share some of the more sensitive details of our work.

Design and Performance of Open-Source Myoelectric Prosthetic Hands

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This research presents the further development of the Tact hand---an anthropomorphic, open-source, myoelectric prosthetic hand that was designed for use by people with transradial amputations in developing countries. This hand matches or exceeds the performance of other state-of-the-art myoelectric prosthetic hands, but costs significantly less. Design improvements have created a reliable non-backdriveable mechanism in the fingers to save power and create strong holding forces. The inclusion of rubber casting in the hands and pressure sensors allow for advanced control techniques that are uncommonly sensitive compared to standard commercial hands. This also allows for compliance in the fingers and palm for easier grasping and reduced impact forces which extend the life of the hand.

Optical characterization of pathogenic biofilms in the human upper respiratory tract.

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Research Sponsor: John Deere

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Ventilator associated pneumonia (VAP) is a severe lung infection that affects 8-28% of hospital patients on mechanical ventilators. Mechanical ventilation is an invasive process that assists or replaces breathing through the use of an endotracheal tube (ETT). Previous research shows that VAP is linked to the presence of multi-species, self-forming bacterial structures called biofilms, which adhere and grow within the ETT. The medical community lacks a reliable way to image ETT biofilm growth real-time. The aim of this study is to use optical coherence tomography (OCT) to image lab-grown biofilms in order to test its prospective use as a detection tool of ETT biofilms *in vivo.*

Multiple variations of flow cells were designed to simulate real-world ETT conditions. Infected media was pumped through a pediatric ETT, and the growth of biofilm was imaged periodically with benchtop and catheter-based OCT systems. Time-lapse videos were created to demonstrate growth characteristics over time. The tube was also sectioned, stained, and imaged with a fluorescent microscope. Several used ETTs from Carle Hospital in Urbana, IL were sectioned and stained as well. We observed similar biofilm structures in both sets of samples, confirming the success of our flow cell in simulating real-world biofilms.

Results show that the OCT system is a successful technique to longitudinally image biofilm growth. Future work will focus on testing the OCT catheter system on hospital patients as a way to determine the effectiveness of hospital ETT cleaning techniques and detect the early growth of biofilm in order to prevent VAP.

Biological Dynamics of Top2A Prostate Cancer Cell Lines in Response to Changes in Matrix Stiffness

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Identification of prognostic markers in prostate cancer cell lines can potentially be utilized in clinical practice for improving patient care. Assessing the response of cancer cells expressing these markers to combination drug therapy can pave the way for more efficient treatments. Levels of topoisomerase 2A (Top2A) have been shown to have a high correlation in predicting systemic progression in high grade prostate cancer.[1] The primary objective of this work was to develop a three-dimensional (3D) biomaterial platform that can recapitulate the native aspects of prostate tumors for future therapeutic targeting studies.

The biological response of cell lines with two different Top2A expressions, a positive-expressing cell type (T14) and negative-expressing cell type (T25), was assessed in a 3D biomaterial. Previous studies have demonstrated the biocompatibility of a Gelatin-based hydrogel platform.[2,3] Methacrylamide-functionalized gelatin (GelMA) can be crosslinked via UV light and in presence of a photoinitator, enabling fabrication of hydrogels with a broad range of tunable physical properties (matrix stiffness, ligand density etc.). Changing the degree of functionalization (DOF) of the GelMA provides further control over the cross-linking density. In order to determine the difference in stiffness between each gel variant, their mechanical strength (modulus) was measured via compressive testing. The biological response of T25 and T14 cells lines was investigated at 4% high DOF, 5% high and low DOF, and 7.5% high DOF GelMA gels. Cells were cultured *in vitro* for up to 14 days and their metabolic activity (via MTT Assay) and protein expression of TOP2A and androgen receptor (AR) (via Western Blot) was measured. All analyses were done at time points of 0, 1, 7 and 14 days from seeding.

Mechanical tests indicate that gel stiffness increases with increasing gel density (wt %), with the 7,5 wt% gel being the stiffest and the 4% gel being the softest. Similarly, reducing the DOF led to softer gels as was evidenced with the 5% low and high DOF gels. Both the T25 and T14 cells showed similar trends in metabolic activity across all gel types, where a significant increase in metabolic activity was seen over 14 days for both cell types. Additionally, stiffer gels were shown to result in lower bioactivity, with the exception being the 4% high DOF gels for the T25 cells. Interestingly, although the cellular metabolic activity increased, the protein expression of both Top2A and AR was shown to decrease over the 14-day incubation period for the T14 cell line.

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Prototyping Photodynamic Therapy: Benchtop X-ray Fluorescence & Luminescence System Quantification Study of Y_2O_3 and LaF_3 Nanoparticles

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Photodynamic therapy has gained much attention for its unique therapeutic effect in treating malignant tumors. However, the penetration depth for activating this effect using visible light is limited. The aim of this study is characterize the ability of a prototype benchtop X-ray system to quantify the fluorescence and luminescence of yttrium oxide (Y_2O_3) and lanthanum fluoride (LaF_3) nanoparticles (NPs) with the ultimate goal of designing a theranostic-capable system.

The first step in quantifying the system's ability to activate the nanoparticles (NPs) is maximizing both the fluorescent and luminescent yield of the NPs. To do this, solid NPs were activated via various irradiation schemes incorporating different combinations of polychromatic sources (Oxford Instruments 5000 series X-ray tube – cone beam), monochromatic sources (Xenocs GeniX 3D Mo 17.4 keV source – 100 um pencil beam width) and filters of aluminum, tungsten and cerium. K-edge energies of yttrium and lanthanum are 17.04 keV and 38.93 keV respectively, and L-edge energies are 2.37 keV and 6.24 keV, respectively. X-ray luminescent yield was measured using the Andor iXon EMCCD camera (512x512 16um^2 pixels) while fluorescent yield and dose were measured using the Amptek XR-100T-CdTe detector. Preliminary images of the NPs were also taken using the EMCCD and the Andor iKon CCD (2048x2048 13.5um^2 pixels).

Quantification of the fluorescent and luminescent yields indicates that separate optimal irradiation schemes exist for each NP. Additionally, these yields prove sufficient in imaging studies. Future work will focus on determining biologically relevant concentrations of each NP.

Salt Assisted Synthesis of Few/ Monolayer Molybdenum Disulfide // Synthesis of Thermally Activated Programmable Shape Memory Polymers

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In recent years, transition metal dichalcogenides (TMDC) materials have been proposed as a potential two dimensional, monolayer material successor to graphene, especially for applications within the semiconductor industry. Due to its intrinsic direct band gap, molybdenum disulfide (MoS_2) is a prototypical example of a TMDC that is an attractive alternative. While MoS_2 is widely available in commercial applications in bulk form, a scalable synthesis method for few layer to monolayer MoS_2 has been a topic of interest. Here, we report a salt assisted solution based synthesis method for few layer MoS_2 from bulk MoS_2 powder. Through the use of sonication liquid exfoliation, filtration, and centrifugation, a suspended stratum of few layer to mono layer MoS_2 was isolated. Analysis through Raman spectroscopy and SEM imaging has thus far validated the existence of < 5 layer MoS_2 flakes with lateral dimensions on the order of micrometers.

Previous work from our group has demonstrated that thermally activated memory shape polymers can provide a single step strategy for three-dimensional texturing of graphene and other two dimensional (2D) materials. By condensing surface area, electrical performance in devices such as electrodes could be improved; furthermore, such texturing could allow for the creation of omniphobic coatings. While these substrates have previously been acquired commercially, we report an in-house method for the synthesis of a thermally activated, programmable, shape-memory polymer. A chemically cross linked, thermoset polymer was synthesized through photo initiation from the monomer tert-butyl acrylate with the crosslinking agent poly(ethylene glycol) dimethacrylate.

Effect of Wind Turbine Winglets on Wake Dynamics and Mean Loadings

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Previous research investigated the effects of winglets on the wake dynamics and power coefficients of wind turbines, as well as tip-effects due to vortices shed by turbine blades. This research has shown that the addition of winglets results in higher power coefficients, as well as reduced tip-loss effects. The purpose of this research is to analyze the effects of varied lengths of turbine winglets on the mean loads and wake dynamics wind turbines.

Three turbines, one without winglets and two with winglets of length 2 mm and 6 mm, were placed in the cross-flow of an open loop wind tunnel. Particle image velocimetry was used to measure velocity fields in the turbines' wake. Turbines were moved to three different positions, each 16 cm apart, to record data from 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. Mean thrust values were calculated by integrating the product of the free stream velocity and velocity deficit over the cross-sectional area of the wake and multiplying by the density of air.

Recorded data produced mean thrust coefficients of .8644, .9421, and .9587 for the non-wingletted, short-wingletted, and long-wingletted turbine respectively, though these are preliminary values and subject to change as more data is processed. Future research will investigate the effects of different winglet geometries, including cant angle and twist angle, as well as the fluctuating foundation loadings, through the use of a high-resolution force balance.

Copper Catalyst Design for Controlling Dehydrogenation and Esterification Selectivity

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n-Butanol is an important chemical used in consumer products, solvents, plasticizers, and has also been considered as a fuel additive due to its higher energy density compared to ethanol. The current production method for n-butanol is the oxo process, an energy consuming and expensive set of reactions over metal catalysts.[1] Alternatively, n-butanol can be synthesized by Guerbet reactions of ethanol over metal oxide catalysts. However, previous studies have shown C-C bonds are formed between aldehyde intermediates rather than alcohols, and that excess ethanol inhibits C-C bond formation.[2] This study focuses on designing catalysts for selective dehydrogenation of ethanol to acetaldehyde, which is necessary to form larger alcohols selectively and at high rates from ethanol feedstreams.

Copper (Cu) nanoparticle catalysts (2-35 nm) on various supports (e.g., $Al\text{-}_2O_3$, SiO_2, and C) are investigated. Catalysts synthesized by the ion exchange, sol-gel, incipient wetness, and co-precipitation (CPT) methods are characterized using x-ray absorption spectroscopy, inductively coupled plasma optical emission spectrometry, temperature programmed reduction, and transmission electron microscopy. Cu-Zn (CPT, 5.4 nm) catalysts give the highest dehydrogenation selectivity (99.4 %) with only 0.3 % selectivity to esterification of ethanol (the major side reaction), while Cu-Al (CPT) show the highest esterification selectivity of 7.0 %. These differences in selectivity are attributed to remaining Cu^+ atoms after reduction due to a combination of particle diameter and support effects. Relationships between cluster size, composition, support identity, and selectivity help determine underlying factors that control reaction pathway in order to design efficient catalysts for production of n-butanol.

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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_2) 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_2 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_2 capture.

In order to create a material that is capable of CO_2 capture, polymers with high amine content were synthesized. Carbon monoxide and ethylene were copolymerized with a palladium catalyst to yield a polyketone. This was then converted to a polyamine via reductive amination with an amine source and a ruthenium catalyst. Conversion was calculated to be 90% using CHN analysis and confirmed with FTIR by observing a broad signal around 3400 cm^{-1} corresponding to amine stretching.

The polyamine was exposed to CO_2 for adsorption studies and upon the analysis of the product it was found that no adsorption occurred yet the amine peak in FTIR had disappeared, calling into question the accuracy of previous results. Further analysis showed that the reductive amination reaction was potentially unsuccessful and will need to be revisited before more adsorption studies are performed.

Vibrational Behavior of Three-Dimensional Structures Assembled by Compressive Buckling

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Numerous micro energy harvesters have been developed to convert ambient mechanical vibrations to electricity. However, current energy harvester devices are two-dimensional, and are usually cantilever beams or bridges clamped at opposite ends. Since conventional micro-resonators vibrate in a 2D plane and generally utilize only one vibrational mode, the configuration has significantly limited the capability and efficiency of such devices. Thus, this study aims to develop three-dimensional structural platforms for multimode, broadband, and tunable energy harvesters. With the use of a laser measurement system, SU-8 photoresist-based structures of various size, strain, and geometry were characterized for frequency response.

Development of liquid assay cartridge for handheld smartphone biosensor

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Increases in the availability and usage of point-of-care testing can be aided by the development of devices that allow for simple, low-cost measurement of biological samples. The ability to adapt existing widespread smartphone technology to read and analyze 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 develop an easily and consistently replicable fabrication process for the liquid assay cartridge used in a multi-modal handheld smartphone biosensor.

While initial designs attempted to harness the increasing availability of 3D-printing technologies to create a PLA cartridge body, inconsistencies in the printing process and further assembly techniques resulted in frequent cartridge failures. To address these issues, a different cartridge design was developed utilizing layers of glass and laser-cut acrylic attached with double-sided adhesive. 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. By dying the main acrylic layer black, the contents of each cell can be optically isolated for precise measurement. This improved design allows for measurement repeatability and affordable fabrication and assembly while avoiding issues of sample loss and damage to the spectroscopic smartphone cradle itself from previously experienced cartridge leaks.

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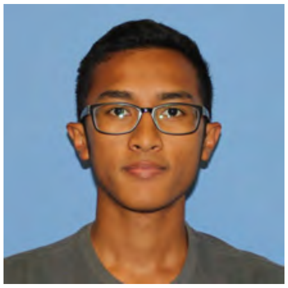

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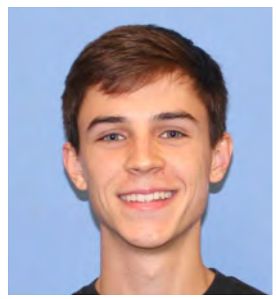

Patrick Slade
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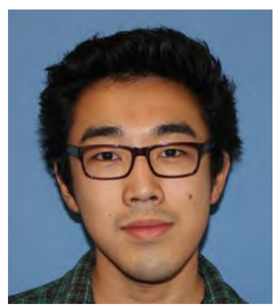

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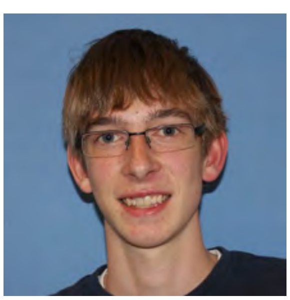

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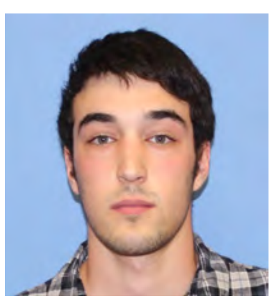
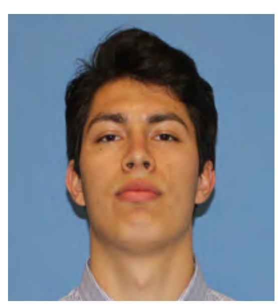


Regev Trigalo
ChemE



Gabriel Velarde
MatSE

Elizabeth Woodburn
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We gratefully acknowledge support from our 2015 - 2016 sponsors:

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