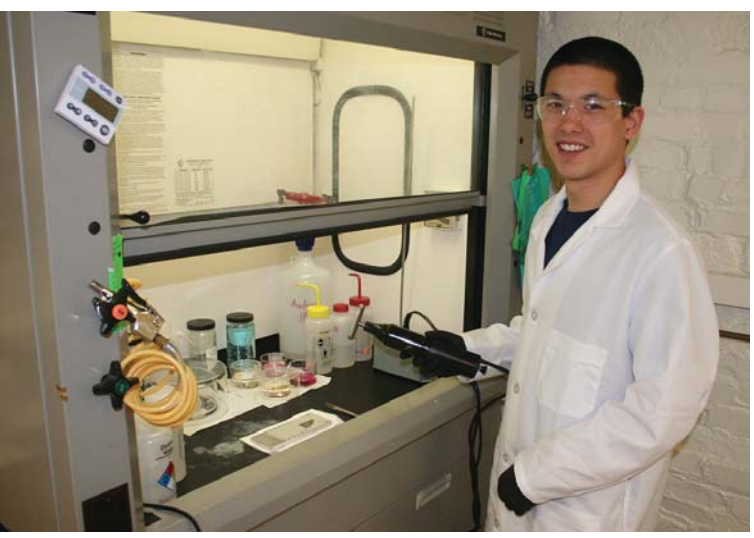
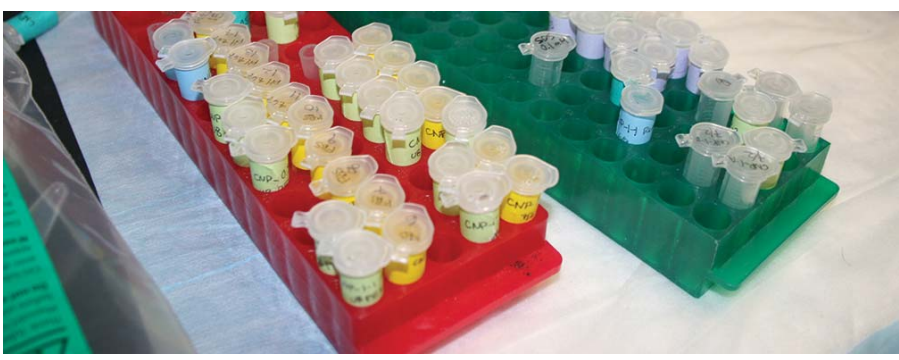
ILLINOIS SCHOLARS UNDERGRADUATE RESEARCH **POSTER EXPO** APRIL 23, 2015 ILLINI UNION **ABSTRACTS**





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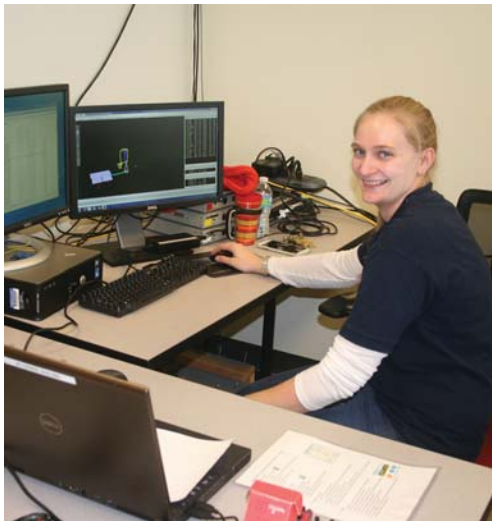

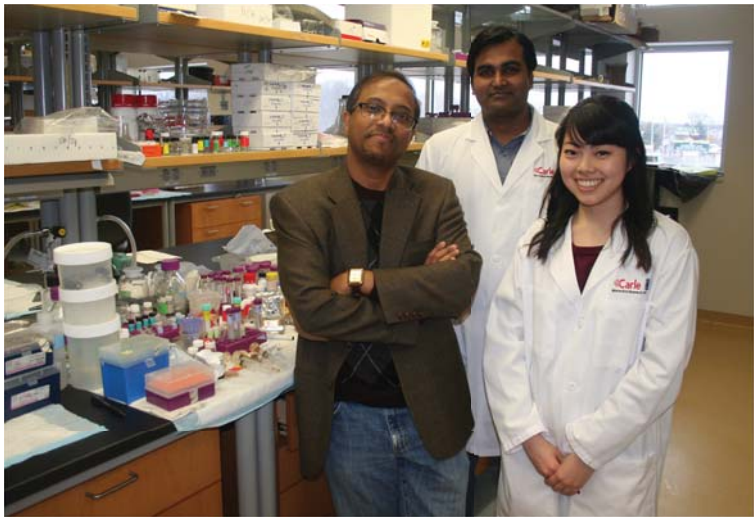

ISUR Scholars 2014-2015

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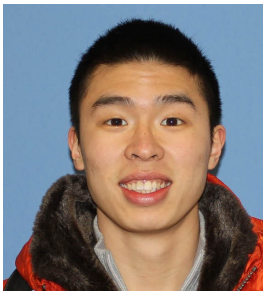

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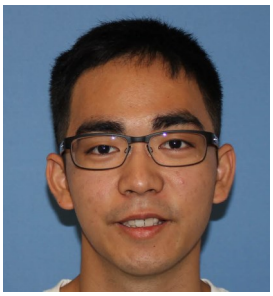

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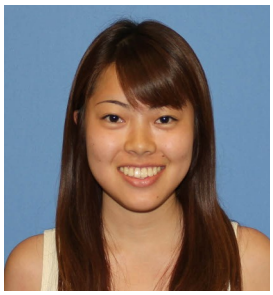

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Illinois Scholars Undergraduate Research (ISUR) Program

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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Preliminary Swelling Tests for Self-Healing GMA Polymer Gels

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Research Sponsor: Semiconductor Research Corporation (SRC)

1. Undergraduate Scholar, Department of Materials Science and Engineering
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3. Faculty Sponsor, Department of Materials Science and Engineering

To determine the ideal combination of acid and solvent for self-healing of glycidyl methacrylate (GMA) copolymer gels of different compositions, various swelling tests of macroscopic and microscopic gel samples in solution were conducted. A successful system test would result in a smaller gel volume after the acid was added. Of those performed, only a solution of trifluoro-acetic acid mixed into tetrahydrofuran produced said result, albeit temporarily.

Implementation of a Support Vector Machine to Predict the Aeroelastic Stability of a Wing

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Research Sponsor: Semiconductor Research Corporation (SRC)

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Aeroelasticity is the study of how a flexible structure interacts with a moving fluid. This topic is important in various disciplines including civil, mechanical, and aerospace engineering. My project focuses on studying the aeroelastic effects of air on an airfoil. Different aerodynamic conditions can have varying effects on aircraft control, maneuverability, and stability. Given a set of flight conditions, such as relative velocity, density of ambient air, and structural stiffness, we want to be able to accurately predict the behavior of the wing for a large domain of conditions. In the design process of aircraft, it is highly important to consider the stability of various aeroelastic responses of a wing. Support vector machines (SVMs) are useful in analyzing data, recognizing patterns and classifying data. We will use an SVM to classify the simulation responses, which will either be stable or unstable. Thus, a major part of the project involves learning how SVMs work and using them to create a decision boundary that allows us to visualize at which parameters the system begins to become unstable. First, we researched and developed an SVM algorithm that could be applied to our research. Then, we simulated a wide range of flight conditions on a simple airfoil with two structural degrees of freedom, heave and pitch, and collected data on the stability of the airfoil under different aerodynamic conditions. Then, we used the SVM to generate a decision boundary for several data sets. We also analyzed the effectiveness of the decision boundaries at predicting stability by performing multiple iterations of the simulations with both low and high density data sets and analyzing the results. From our analysis, we found that the algorithm was largely successful in predicting stability with relatively low percent error.

Duration of Exertion and SCBA Design Affect Firefighter Balance

Grace Deetjen[1], Ziming Wang[2], Michael Angelini[2], Richard Kesler, Matthew Petrucci, Karl Rosengren, Gavin Horn, Elizabeth Hsiao-Wecksler[3]

Research Sponsor: John Deere

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Slips, trips and falls are among the leading causes of fireground firefighter injury. With an increasing number of fire departments moving towards larger, extended duration air tanks (self-contained breathing apparatuses - SCBAs), changes in body kinematics are anticipated. This study investigated the effects of SCBA size/design, fatigue, and extended duration firefighting on performance during a functional balance test (FBT).

Thirty firefighters used each of three standard SCBAs with 30-, 45-, and 60-minute capacity air cylinders (S30, S45, S60); and a low-profile prototype pack (P45). Tests included two ground-level balance beam trials with and without an overhead bar at 75% of subject height. Trials were performed before and after subjects completed an exercise protocol in an environmental chamber – two minutes of four simulated firefighting tasks, with two minute rests between tasks. During separate visits, subjects completed one bout (1B), two bouts with a five-minute break (2B), or back-to-back bouts of exercise (BB) with different SCBA for a total of seven testing sessions and a baseline trial. FBT performance was quantified by error count – minor (MI – not turning in the designated platform space, bar contact) and major (MA – walking off the beam, knocking the bar off its supports) – and performance index (PI=time+MI+2*MA).

MI and time increased with the overhead bar. Greater SCBA size increased PI, indicating firefighters may have difficulty moving quickly with larger capacity tanks. Post-hoc analysis showed that inexperienced firefighters made fewer MI than intermediate-experience subjects. PI dramatically decreased from S60 to P45 with the bar overhead, showing improved balance.

Amperometric Probes for Investigating Energy Storage Processes

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Currently, lithium ion batteries suffer from short lifespans and decreasing performance with each consecutive charge cycle. Much evidence supports that a solution to these issues lies largely with micro- and nano-scale reactive heterogeneities at electroactive sites. Furthermore, an understanding of how site-specific reactivity impacts the ion-transfer capabilities of these sur-

faces has yet to be discovered.

To make an attempt in discovering more, Hg-capped electrochemical probes were created because they demonstrate mechanical stability, chemical specificity from known reduction potentials and stripping traits, and reliable current response to changes in potential and ion flux. The probes were made by sealing a 25 µm diameter Pt wire inside a 1.5 mm diameter glass capillary and making electrical contact with a Cu lead with Ag epoxy. The probes were then shaped and polished so that the ratio of the total tip radius to the Pt disc radius was less than 5. The Pt disc electrodes were capped with Hg by electrodeposition from an acidified aqueous solution of Hg $(NO_3)_2 \bullet H_2O$. These Hg-based probes were used to carry out anodic stripping of alkali ions, concentration-based calibration curves, and imaging of various substrates with a Scanning Electrochemical Microscope (SECM). These studies enabled the extraction of kinetic data for K^+ and Na^+ ions, which is essential for making meaningful interpretations of SECM data. We imitate real battery environments by working in organic media in an oxygen- and water-free glove-box.

These amperometric probes can be made quickly and reliably. Their unique properties permit the simultaneous quantification of multiple alkali ions over a wide concentration range. Lastly, track the flux of Li^+ in energy storing materials using SECM imaging.

Microfluidic Approach to Pharmaceutical Crystallization

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Research Sponsor: Shell

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Early in the pharmaceutical development process, many solid forms of active pharmaceutical ingredients (APIs) are screened to find a solid form that has desirable physiochemical properties. Solid forms commonly screened include polymorphs, salts, cocrystals, or hydrates/ solvates. Cocrystallazition has been shown to enhance the physiochemical properties of APIs with poor water solubility. In this work, we investigate cocrystallization of piroxicam (PRX) with 2,5-dihydroxybenzoic acid (HBA) thorough crystallization in a microfluidic platform. The platform was designed to minimize solvent loss due to evaporation, thus creating a favorable environment for the formation of thermodynamically stable crystal forms. Crystals grown on-chip were analyzed with Raman spectroscopy and subsequently removed for structure determination with single crystal X-ray diffraction. Two solid forms were identified: a cocrystal, PRX-HBA, and an acetone solvated cocrystal, PRX-HBA-ACT. Slurry crystallization was used to create bulk quantities of these cocrystals which were analyzed with powder X-ray diffraction and thermogravimetric analysis. The presence of ACT in the cocrystal was unexpected because no ACT was added to the crystallization experiment. The source of ACT was found to be an impurity in HBA. The PRX-HBA-ACT has channels and ACT desolvation occurs at 105°C. After desolvation, the powder X-ray diffraction pattern for PRX-HBA-ACT resembles the pattern for PRX-HBA.

Methodology for Production and Identification of Few-Layer Molybdenum Disulfide via Micromechanical Exfoliation

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As of recently, molybdenum disulfide (MoS_2) has been a material of increasing interest due to its unique formation of a direct bandgap as it is thinned down to mono- to few-layer thicknesses from its bulk, which is absent in semi-metallic graphene, another 2D nanomaterial of interest. In the presented study, we aimed to obtain large-area MoS_2 crystals with few-layer thicknesses through micromechanical exfoliation from bulk molybdenite crystals and various further processing techniques to reduce the overall thickness to mono- and few-layers. The attained mono- and few-layer MoS_2 was characterized through optical microscopy, Raman spectroscopy, as well as atomic force and magnetic force microscopy (AFM/MFM). Subsequent experimentation includes application and processing of MoS_2 on a thermally activated polymer, leading to the mechanically controlled tuning of the direct bandgap. These methods may be applied to creating field effect transistor (FET) based 3D sensors and device platforms based on MoS_2 via elastic strain engineering. This developed procedure is applicable not only to MoS_{2-}, but for many other thin-film and 2D nanomaterials that are of recent interest such as graphene and other transition-metal dichalcogenides (TMDs).

Impedance Sensing of Nitrate in Environmental Samples Using Microsensors

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Low-cost, portable nitrate detection sensors are essential in identifying and quantifying environmentally damaging concentrations of nitrate in natural water sources. Current portable nitrate sensors are not reliable detectors of sub-ppm nitrate concentrations and may be expensive to manufacture. The purpose of the project is to demonstrate a low cost, highly sensitive nitrate sensor based on measuring the reaction impedance of pre-concentrated nitrate, nicotinamide adenine dinucleotide phosphate (NADPH), and nitrate reductase (NaR) enzymes.

The sensor consists of interdigitated electrodes made by electron beam evaporation of 20 nm Titanium and 500 nm Copper on the surface of nitrocellulose membrane paper. The procedure starts with introducing solution based NaR enzymes uniformly on to the surface of the sample followed by NADPH. Impedance measurements were taken for nitrate standard solutions of

concentration 0 ppm to 30 ppm to construct the calibration curve. The addition of pre-concentrated nitrate solutions causes an impedance drop to occur across the copper electrodes, which is then measured by an LCR meter at a frequency of 20 kHz over 2-4 minutes. In order to analyze the reaction when the impedance dropped, exponential fitting was used to characterize the impedance over time. The results suggested that while the concentration of the nitrate increased the exponential coefficient for the reaction decreased showing decrease in reaction rate and increased surface resistance. By integrating the sensor with point-of-care impedance measurement devices, a highly sensitive, low cost sensor for rapidly quantifying nitrate can be created.

Synergistic Growth Regression in Triple Negative Breast Cancer via co-Inhibition of STAT-3 and Topoisomerase-II Pathways

Molly Imgruet[1], Santosh Misra[2], Dipanjan Pan[3]

Research Sponsor: Shell, Rockwell Collins

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There is an urgent need to develop systemic treatments for human breast carcinomas that do not respond to the standard hormonal therapies. These resistant carcinomas include Triple Negative Breast Cancers (TNBCs), which lack hormonal molecular targets such as estrogen receptor (ER), progesterone receptor (PR), or C-erbB-2 (HER2). Therapies that combine multiple chemotherapeutic agents have been used to combat drug resistance in these carcinomas. The recent development of agents targeting DNA repair, either indirectly through DNA-binding, DNA-damage potentiation or directly with poly(adenosine disphosphate-ribose) polymerase inhibitors, also represents a new approach to TNBC therapy. Topoisomerase II is a DNA repair molecule that has recently shown promise as a drug target.

The discovery of a novel combinatorial nanotherapy for hormone independent breast cancer is proposed here. A well-defined hyper-star polymer was synthesized and used to produce a nano-particle 'cocktail' via formulation with a STAT-3 inhibitor and a topoisomerase II inhibitor for selective growth regression in triple negative breast cancer cells. Sustained delivery of this drug combination can be achieved through this nanoparticle platform, which might assist in over-coming the previously encountered shortcomings for combination chemotherapy. Efficiencies in TNBC cells were compared to estrogen receptor (+) cells and results demonstrated multiple-fold superior efficacy and selectivity in the TNBC cells. The mechanism of the synergistic ef-fect of combining the two inhibitors was also examined using polymerase chain reaction experi-ments and assays for STAT-3 and Topoisomerase II. This novel combination of STAT-3 and topoisomerase II inhibitors encompassed in HSPs could offer new hope for TNBC patients with much desired improvements in their treatment regimen.

Analysis of Photoillumination Induced Atomic Charge State Shifts of AgInSe2 with X-Ray Photoelectron Spectroscopy

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AgInSe2 (AIS) has the potential to be an efficient material for solar cells once its electronic properties are better understood. In this study, thin film epitaxial AIS samples were grown in a hybrid sputtering growth chamber and measured with Xray Photo-electron spectroscopy (XPS) under non- illuminated and illuminated conditions. This novel adaptation to XPS allows users to observe small changes in the surface photovoltage and as well as changes to the peak shape, which is indicative of influencing charge states of defects in the material. A positive shift in the Se binding energy bands was observed following illumination, whereas Ag, In, and Cu showed no distinct binding energy shifts. Future testing will include temperature dependent photoelectron measurements.

Flow Characterization over Two- and Three-Dimensional Wavy Walls

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An experimental investigation of the flow over two- and three-dimensional large-scale wavy walls was performed using high-resolution planar particle image velocimetry in a refractive-index-matching channel. The 2D wall is described by a sinusoidal wave in the streamwise direction with amplitude to wavelength ratio $a/\lambda_x = 0.05$. The 3D wall is defined with an additional wave superimposed on the 2D wall in the spanwise direction with $a/\lambda_y = 0.1$. The flow over these walls was characterized at Reynolds numbers of ~4000 and ~40000, based on the bulk velocity and the channel half height. Instantaneous velocity fields and turbulence quantities reveal strong coupling between large-scale topography and the turbulence dynamics near the wall. Turbulence statistics show the presence of a shear layer that maintains the turbulence for the 2D wavy wall. The 3D wall exhibits different flow dynamics and significantly lower turbulence levels. The likelihood of recirculation bubbles, levels and spatial distribution of turbulence, and rate of the turbulent kinetic energy production are shown to be severely affected when a single spanwise mode is superimposed on the 2D sinusoidal wall. Differences of one and two order of magnitudes are found in the turbulence levels and Reynolds shear stress at the low Reynolds number. Further experiments studying flow over wavy walls would involve using small-scale wavy walls or performing measurements in the development region of the flow.

Mechanical Interactions of Optogenetic Skeletal Muscle Cells with their Local Environment

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Mammalian skeletal muscle cells are proven to be sensitive to the physical aspects of the micro-environment such as stiffness of the substrate and geometric confinement. The immortalized optogenetic muscle cell line, ChR2-C2C12, is genetically modified to contract under light. These cells were tested to investigate the effect of their physical environment on mutation. The aim of this study was to establish that light stimulation to the contractile cells will show different behaviors as electrical stimulation on varying substrates to determine the effect of physical environment on optogenetic efficiency.

The geometric restriction was controlled by micro-contact printing (MCP) to limits the space where cells can grow. By introducing Polydimethylsiloxane (PDMS) to the surface, the pattern will be transferred upon polymerization. PDMS acted as a stamp for the transfer of patterns, which defined where cells grow. The stiffness was controlled by using polyacrylamide (PA) gel. Cells were grown on polyacrylamide (PA) gels treated by MCP to allow the study of the combined effect of space restrictions and stiffness of the substrate. We evaluated the maturation of cells by the contractile force they produce upon stimulation and by immunofluorescence staining. Contractile force were measured by the displacement of the embedded beads in the PA gel. Electric stimulation will provide a baseline contractile force for comparison to light-induced actuation. Immunofluorescence staining will stain protein in the muscle cells that could be served as an indicator of their maturity, and the stained protein could be further observed under a fluorescence microscope.

Behavior of Oxidized and Reduced Surfaces of NiP/SiO2 Catalysts

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In recent years, the demand for liquid transportation fuel has risen, resulting in the development of renewable sources of fuel. Although biomass can be considered a carbon neutral fuel source, the oxygen content (10-15% wt.)[1] results in difficulties such as immiscibility with other hydrocarbon fuels. Hydrodeoxygenation (HDO), or the removal of oxygen using hydrogen, is a useful reaction in converting biomass into usable fuels. Nickel Phosphide (Ni_2P) has been found to be a useful catalyst for removing oxygen form biomass while preserving C-C bonds.[2] It is inex-

pensive, chemically and thermally stable, and selective for C-O bonds over C-C bonds, all of which make Ni_2P a catalyst that is well-suited for practical HDO processes.

In this study, we analyze the surface of a Ni_2P/SiO_2 catalyst under oxidizing and reducing conditions to develop a clear understanding of the reactive surface during the HDO of 2-methyltetrahydrofuran (2-MTHF), a model reactant for HDO. Carbon monoxide (CO), a product from the HDO of 2-MTHF, inhibits HDO reaction rate on Ni_2P, which is consistent with its high binding energies on the surface.[3] CO uptakes, measured form volumetric CO adsorption isotherms, are 35% less on oxidized surfaces than reduced surfaces. These experiments also measured the particle size to be ~5% larger in comparison with values measured by transmission electron microscopy. Based on these results, more efficient processes for HDO of biomass to liquid fuels can be designed by operating under less reducing conditions (i.e., lower H_2:2-MTHF ratio), which decrease the inhibiting effects of CO on the Ni_2P surface.

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[3]A. Cho, H. Kim, A. Iino, A. Takagaki, S.T. Oyama. Kinetic and FTIR studies of 2-methyltetrahydroguran hydrodeoxygenation on Ni2P/SiO2. J. Catal., 318, 151-161 (2014)

Measuring Changes in Gait Variability in Persons with Multiple Sclerosis While Wearing Pneumatically Powered Ankle Foot Orthosis

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Research Sponsor: Semiconductor Research Corporation (SRC)

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Gait variability is an identifier of step-by-step fluctuations in walking and is an indicator of neuromuscular and motor function. Distributional metrics such as standard deviation (SD) and coefficient of variance (CV) are most commonly used to quantify the gait variability of spatiotemporal and kinematic gait parameters [1]. Gait impairment is often the most severe symptom of multiple sclerosis (MS), a degenerative neurological disease, and can affect the person's overall quality of life [2]. We have developed a portable powered ankle foot orthosis (PPAFO), which provides bidirectional assistance at the ankle during gait to assist those with gait impairments [3]. For this study, persons with multiple sclerosis walked under three conditions: with shoes, their own ankle foot orthosis (AFO), and the PPAFO. An analysis of stride length, stride time, and stride width shows persons with mild gait disability have significantly less variable stride time than those with severe gait disability and stride time was significantly more variable wearing the PPAFO compared to both the SHOES and AFO conditions ($p < 0.05$). An understanding of the effects of assistive devices on gait can lead to more advanced device design and rehabilitation programs.

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Incorporation of Laminin into Collagen-Gag Scaffolds for Muscle Tissue Engineering

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Skeletal muscle is notoriously difficult to regenerate and heal. In vivo, myoblasts are the tissue's cell reserve that differentiates in response to injury. These satellite cells are few in number, slow to proliferate, and are quiescent under normal conditions. We proposed to use laminin incorporated into collagen-glycosaminoglycan (GAG) scaffolds to create a more hospitable environment for myoblast proliferation and differentiation. Collagen-GAG (CG) scaffolds can be lyophilized to fabricate a highly aligned, porous structure. This has been shown to be a viable platform for engineering other musculoskeletal tissues and could be conducive to culturing myoblasts. Here, we demonstrate that CG scaffolds alone are a viable platform for culturing myoblasts. Further, when cultured in CG scaffolds crosslinked with laminin, we see a significant increase in cell number and the expression of myogenic genes after seven days. Thus, we have demonstrated that CG scaffolds incorporated with lamin can be used to drive myoblast proliferation and differentiation and has potential applications in skeletal muscle tissue engineering and regeneration.

Next Generation Carbon Nanoparticles for Efficient Gene Therapy

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In a pursuit to develop a commercially exploitable and traceable gene delivery vehicle, here, we develop next generation carbon nanoparticle-DNA complex (CNPLex). CNPLexes were used to transfect green fluorescent protein (GFP) reporter gene containing plasmid DNA (pDNA) pEGFP-N1 targeting breast cancer cells MCF-7 and MDA-MB231. Prepared CNPs were optimized for particle size, surface potential, polymer surface decoration, absorbance efficiency, fluorescence efficiency, IR spectroscopic signatures, and DNA loading and release efficiencies. Rigorous biophysical methods were employed to determine the variations in physicochemical properties of CNPs after surface decoration with polymers followed by complexation with pDNA. Optimized CNPLexes were used to deliver pEGFP-N1 plasmid and efficiency of GFP was followed by fluorescence microscopy and quantified by flow assisted cell sorting. Lipofec-

tamine2000 was used as positive control according to manufacturer's protocol and found to be comparative in transfection efficiency with one of our novel formulations. Further evaluation of cell toxicity and cell viability was performed by LDH activity and MTT assay, respectively. It was found that cell toxicity furnished by polymer decorated carbon nanoparticles was significantly low compared to the parent polymer (polyethylenimine, PEI). Similarly cell viability was found to be much higher with CNPLexes compared to PEI alone. This established the developed particles as better transfecting agents for reporter gene plasmid pEGFP-N1 compared to PEI and showed similar efficacy to one of the best known commercial transfection agents Liofectamine2000 in breast cancer cells MCF-7 and MDA-MB231.

Deuto-Dox for Vibrational Spectroscopy *In Vitro* Tracking Doxorubicin Abundance in Cellular Cytoplasm

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Nanomedicine approach of drug delivery has been criticized for its lack of clarity on delivery mechanisms and less control on cytoplasmic trafficking. Previously, research using fluorescent probes has succeeded in revealing cell internalization, membrane interaction, endosomal escape and cytoplasmic distribution of fluorophore-conjugated drugs but their mode and extent, chemistry, and trafficking, respectively, are yet to be investigated. Recently vibrational spectroscopy has garnered attention in distinguishing cellular background from delivered particles/drugs. Here we present "Deuto-DOX," a model system to study cellular distribution of doxorubicin (DOX), a chemotherapeutic drug, loaded in a deuterated phospholipid (dodecyl phosphocholine -d38) vesicle (DDP-d38). The different vibrational frequencies of C-H and C-D bonds allow differentiation from cellular background while DOX's auto-fluorescence validates drug internalization. Physical characterization has shown DDP-d38 to be sub-200 nm, negatively charged spheroidal particles. DDP-38 was compared with DOX-loaded dodecyl phosphocholine (DDP) vesicles (lipo-DOX) and their interactions with duplex DNA were different from free DOX under absorption spectroscopy and gel electrophoresis. Formulations delivered in MCF-7 (ER(+) breast cancer) cells to investigate cell internalization indicated enhanced delivery of DOX in nanoparticle form. MTT evaluation of delivered DOX supported better cancer cell growth inhibition by nanoformulations. Cells treated with Deuto-DOX and lipo-DOX were scanned by Raman spectroscopy to reveal co-localization of DDP-d38 and DOX while lack of differentiability from cellular background showed DDP was not effectively traceable in the cellular cytoplasm. Co-localization of C-D vibrational intensity with DOX fluorescence supported its effective delivery while additional studies are warranted to specify mechanisms of DOX release and cellular cytoplasmic trafficking.

Integration of Thin-Film Microscale III-V Lasers onto Si

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In next generation electronics, increasing operations speeds is a necessary improvement. In order to increase speeds, data must be transferred at a quicker pace within the device without adding excess heat or taking up excessive space. Light can be used to transport data at quicker speeds without taking up space within the integrated circuit. Using lasers is a way to emit light within the circuit. This project involved integrating thin-film microscale III-V lasers onto Si based circuits. III-V materials, though difficult to fully integrate onto Si based circuits, were used because they have beneficial optoelectronic properties for data transfer. By growing lasers on a separate substrate and transferring them via an elastomeric stamp, we were able to fully integrate lasers onto Si without losing any optoelectronic properties.

Multi-Body Dynamic Simulations of Interactions between a Small Unmanned Aerial Vehicle and a Passive Gripping Mechanism

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The purpose of this research is to simulate interactions between a quadrotor and its gripping mechanism using a multi-body dynamics software. Researchers at the Bretl Research Group have developed a passive gripping mechanism that can be attached to a small unmanned aerial vehicle to grasp, move and place objects. In this project, we aim to study the gripper-UAV model in a multi-body dynamics package and then develop a new set of algorithms to improve current control strategies. In this project, we initially started by using a MATLAB based simulator called the RPI-MATLAB simulator. A Computer Aided design model of the gripper was imported into the simulator. It was noted that because of an extremely complex and large mesh of the mechanism, current version of the simulator was unable to carry out the simulation. It was also noted that RPI-MATLAB simulation package is unable to handle a non-convex mesh of our mechanism. Another possible simulation package that can be used to solve above inferred complications is the Open Dynamics Engine. Future work will focus on carrying out a multi-body dynamic simulation in Open Dynamics Engine, interpreting the results and then developing appropriate control policies to improve the performance of the gripping mechanism.

Real Time Quadcopter Simulation and Control

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In the field of robotics and control, real time simulation of robots has great potential. Not only would it prevent physical damage to equipment, but it also allows for quick changes to the testing environment, reliability of parts and sensors, and fast reproduction of an experiment. Our simulator is designed as a C++ program using OpenGL and FLTK to render an interactive GUI with a 3D environment. The program starts by loading necessary assets and then begins a loop where steps needed for simulation are repeated in each cycle. These include (i) estimation, in which position and data are taken from all robots and their sensors, (ii) control, telling a robot how it should move, and (iii) physics, where the state values of a robot are updated based on a robot's equations of motion. Final steps of the loop are to handle rendering and gui actions in addition to incrementing a time step. Originally designed solely as a quadcopter simulator, the simulator has been redesigned with the hopes that in the future, users will be able to add in their own robots for a more custom experience.

Characterizing Bone through Demineralization and Deproteinization

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Bone has a complex hierarchical structure that is still not yet fully understood. Consequently, there is a limited understanding of the full properties of bone, making modeling its mechanical and structural properties a difficult task. It is a composite that is typically composed of 32-55% organics, 33-43% minerals and 15-25% water. By treating bone to isolate the protein and mineral phases through demineralization and deproteinization respectively, its characteristics can be studied in-depth. By testing demineralized and deproteinized bone specimens at different maturity levels, up to 20-24 weeks old, the structure and various properties of bone will be analyzed. Raman spectroscopy, micro-CT, and acoustic emission tests are currently being done on prepared bone samples. Other tests to be done include: nanoindentation, scanning electron microscopy, ultrasound characterization, mechanical strength tests etc. The results of these tests from the treated samples will be compared to the results from untreated bone samples. Along with the testing of structural and mechanical properties of bone, insight into the effects of aging and treatment will be investigated.

Tact: Design and Performance of an Open-Source, Affordable, Myoelectric Prosthetic Hand

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This paper presents 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 two orders of magnitude less (~$250) and is easy to manufacture with a 3D printer and off-the-shelf parts. We describe our design process, evaluate the Tact hand with both qualitative and quantitative measures of performance, and show examples of using this hand to grasp household objects.

Synthesis of Optically Transparent Aerogels for Use in Solar Steam Generation

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Solar energy is an optimistic and abundant form of renewable energy. Currently, the most common means of absorbing this energy is through the use of a solar selective surface. It is structured to have a low thermal emissivity (~5%) and high solar absorptivity (~95%). A promising alternative material that can provide transparent insulation in solar energy applications is an aerogel. Aerogels are ideal since they can be made to have a relatively high transmissivity in the solar spectrum, be opaque in the infrared spectrum to limit re-radiation losses, and have a low thermal conductivity to limit conduction losses. This study aims to increase the transparency of aerogels in the solar spectrum of 300nm < λ < 2.5μm, while maintaining infrared opacity in the thermal emission window of λ > 2.5 μm, and minimizing thermal conductivity.

Silica based aerogels were synthesized with a sol-gel process using either TMOS or TEOS as the silica source and either ethanol or methanol as a medium for gelation. The sol-gel process was divided into the following steps: forming a solution, gelation, aging, drying, and densification; a CO_2 critical point dryer was used to extract the ethanol from the aged gel, producing the final aerogel.

Current results show that a new method must be implemented to dry the sol-gel into the aerogel. During the ethanol-CO_2 exchange in the critical point dryer, the aerogel cracks. Regardless, the aerogels show promising results with transmissivity (~90%). Further analysis on already pro-

duced aerogels and experiments with synthesizing different variations of new aerogels will be the focus of future work.

Physical and Biological Dynamics of Gelatin Methacrylamide Polymer

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Gelatin-based hydrogels have been shown to provide an efficient platform for stem cell culture. In this study, we analyze properties of the gelatin methacrylamide (GelMA) hydrogel and cell response when encapsulated within these gels *in vitro*.

The physical dynamics of the UV cross-linked GelMA hydrogels were investigated via rheological analysis. A lack of torsional dependence and linear strain versus stress dependence indicated properties unique to that of a viscoelastic material. Additional trials provided consistency with these observations and a baseline for future analysis of hydrogels with different geometries.

Biological dynamics of the GelMA hydrogels were investigated by evaluating their response to a prostate cancer cell line. The effects of photoinitiator concentration, UV intensity, and exposure time on cell viability were determined. We found that these factors as part of the UV cross-linking procedure significantly impacted cell vitality within these gels. Lower photoinitiator concentrations and UV intensity resulted in the highest cell retention rate. Utilizing this solution composition, cells were seeded in gels at varying cell densities and their bioactivity over time was determined for each sample. Additionally, the same cells were seeded in 9.5 cm^2 plates, and confluence time was noted, allowing a comparison between growth rate of cells in 2D and 3D environments.

This work examines the effect of an external environment on the growth and development of cells within the context of a 3D culture. Future work will aim at utilizing this data to model synthetic environments that more closely resemble that of a standard biological environment.

Valuation of American Options: Numerical Methods, and Developing Microbial Models

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Research Sponsor: Shell

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Numerical methods are applicable to a breadth of problems. The finite difference method, binomial tree method, and Monte Carlo method are the numerical methods of interest for the valuation of American options. The goal is to utilize published research to further the usage of numerical methods in other fields, such as computational biology.

The finite difference method, binomial tree method, and Monte Carlo method are advantageous in different ways, respectively performance is decreasing when used for the valuation of American options. The finite difference method is more efficient than the binomial method when considering parallelization as well, respectively having a 10x speedup and a 2x speedup. The application of the finite difference method and Monte Carlo method is common in biological applications. There is little to none research into using the binomial tree method for biological applications. Conceptually, biological models and the valuation of American options are related by their foundational mathematics.

American options and biological models are related by the underlying notion of Brownian motion and the Kolmogorov equations. Biological models are often simplified to avoid non-analytic solutions. Simplifications such as time-independent inactivation rates ignore at least two of three system parameters: temperature-dependence, the colonized medium, and coexistence of bacterial communities. To implement such a mathematical model the finite difference method and Monte Carlo method are essential.

The various barriers to developing this model will be discussed: data aggregation and data cleansing.

Using Shape Memory Biocompatible Thermoplastic Substrates for Texturing of 2D Materials and Rapid Thermal Processing (RTP) of 2D Materials

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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, texturing could allow for the creation of omniphobic coatings. While polystyrene has been the current polymeric substrate used for this method, flexible biocompatible polymeric substrates would allow for in-vivo implantation of graphene based electronics, as this could provide attractive qualities such as intimate cellular contact. Commercially available biocompatible polymeric films including BoPP, HDPE, LDPE, and PVC were tested. All materials were subjected to glass transition induced contraction. Polystyrene exhibits an area reduction of upwards of 70%; pre-strained BoPP and PVC yielded an area reduction of 10.1 ± 5.7% and 50.3 ± 8.1%, respectively.

While 2D materials such as graphene and molybdenum sulfide (MoS_2) have gained a significant amount of research interest for their novel properties in recent years, these materials remain difficult to synthesize and current methods are not scalable. Rapid Thermal Processing (RTP) has been proposed as a method to synthesize large-scale, transfer-free, uniform few-layer MoS2 films. RTP MoS_2 fabrication will be conducted through a spun-coat solution-based precursor without the need for vacuum processes. This method eliminates the need for mechanical exfoliation, making this method a transfer free process. This solution-based approach will also be applied to other 2D materials including transition metal dichalcogenides and black phosphorous dichalcogenides.

Photocatalytic Reactions on Titania Nanosheets

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Production of hydrogen gas through solar water splitting is a potentially renewable, clean source of fuel. Using hydrogen as a fuel produces only water, not CO_2 or other greenhouse gases. In photocatalytic water splitting using solar energy, in combination with titanium dioxide nanosheets, hydrogen gas is produced without the use of non-renewable energy sources. Experimental results from Professor Shintaro Ida, partner at Kyushu University in Japan, suggest that the Rh-doped lepidocrocite structure TiO_2 allows for maximum surface area and higher efficiency of the photocatalytic reaction.

To understand how this reaction takes place, the steps of water splitting on lepidocrocite-TiO_2 nanosheets were modeled. Total energies are calculated with density functional theory (DFT) within the Vienna ab initio software package (VASP), using a generalized gradient approximation GGA (PBE), and projector augmented wave (PAW) pseudopotential. To run these simulations, an atomic slab model of the nanosheet had to be created. The energy required for the water splitting reaction was then calculated.

Preliminary conclusions were found for the optimal k-points to use during the simulations, as well as the optimal energy cutoff and the lattice constants for the slab model. The different steps

of the water splitting process were modeled and simulated, giving a total energy required for each water splitting step.

Future research will include the full steps of the water splitting process. Further, these results will be used as a benchmark for the simulation of Rh-doped titanium dioxide nanosheets, which were found to be more efficient than pure titanium dioxide nanosheets.

PA-MBE Growth of GaN-Based HEMT Devices

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Within this study, plasma assisted molecular beam epitaxial (PA-MBE) growth of GaN-based high electron mobility transistors (HEMT) were vertically facilitated upon free standing GaN substrates. Specifically, with the implementation of a shutter microcontroller, precise elemental compositions may be varied and achieved to the accuracy of 0.1 at%, with applied maximum shutter frequencies of 100 Hz. Such control would allow for the energetic tuning and interfacial integrity control of the device layers for increased device switch-speed and breakdown voltage.

Chroma Tags: A Colored Fiducial Marker

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Fiducial markers are used in robotics to identify specific locations of items and provide a position estimate of a camera's location in relation to the markers. The current state of the art in image-based fiducial markers relies on costly quadrilateral detection where many false positives are found due to the rectangular nature of many man-made objects. To address this challenge, we created ChromaTags. ChromaTags are colored tags that use the CIE Lab or YUV color space. This enables a camera to convert RGB image frames into Lab or YUV, then search for the tag in color channels, as opposed to only a black and white image frame. The advantage of this method, is that the number of edges detected in the Lab or YUV space are minimal, and as such we can process scenes faster than previous methods. Future work will focus on improving the ability to identify and localize ChromaTags, as well as explore different configurations of ChromaTags.

Design of Electromyography System for Myoelectric Controlled Prosthetic Arms

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Today's marketable technology currently limits the capability and availability of robotic prosthetics for amputees. For instance, one current model is the mechanical prosthetic arm which works simply with a strap over the shoulder for control. This evidently comes nowhere close to the capabilities of the human arm. An alternate yet affordable method is using electromyography (EMG), a medical technique which harvests electrical signals from the muscle, to replicate real human movement for amputees much more closely. The goal is to research the properties of these EMG signals and to then design a portable EMG system that will be used in conjunction with a 3-D printed prosthetic to mimic real human control.

EMG works by attaching electrodes onto the user and reading the electrical activity which the muscles produce. By passing these signals through a machine learning algorithm, one can classify the signals into different patterns, which in turn can be translated into different hand configurations. However, the major problems with EMG is reducing signal noise and amplifying the signal since it is very small. There are also constraints on the design of the EMG system such as the size of the circuit since it must be able to fit into the prosthetic hand.

The current design of the EMG system contains eight channels and the PCB has been designed and fabricated. This EMG system is able to control the prosthetic arm successfully. However, as the design moves forward, we are looking into using a more specific chip to further reduce the size and increase precision.

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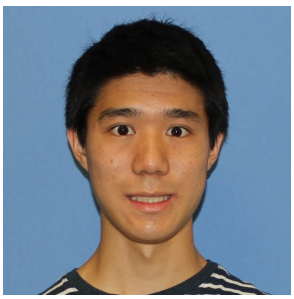
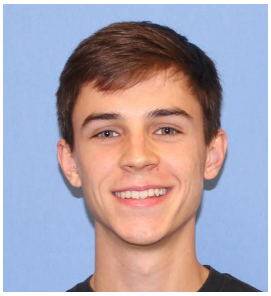
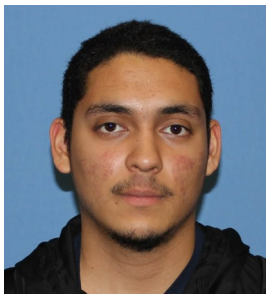


Peter Shyu
BioE



Patrick Slade
MechE



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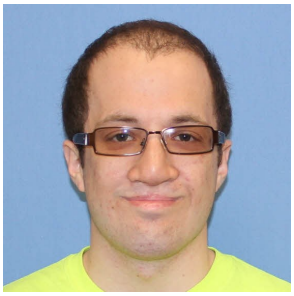

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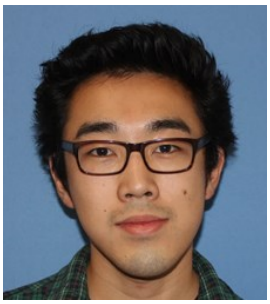

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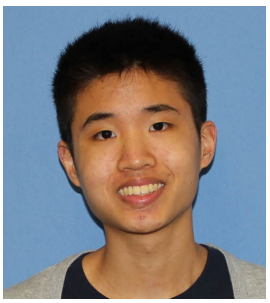

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