ILLINOIS SCHOLARS UNDERGRADUATE RESEARCH POSTER EXPO

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College of Engineering

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ISUR Scholars 2018-2019

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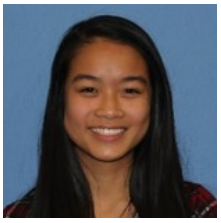

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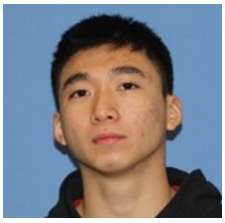

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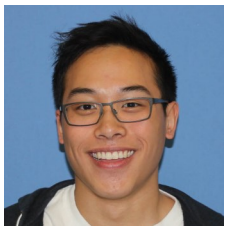

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Illinois Scholars Undergraduate Research (ISUR) Program

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

The goals of the program are to

- Introduce students to university research,
- Engage students in the College of Engineering and the research community, particularly through the learning-by-apprenticeship model; and
- Expose students to science and engineering research in the College and across campus.

Students in the program work closely with graduate student/postdoc mentors and faculty mentors/sponsors on research projects throughout the fall and spring semesters.

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. This course is designed to complement their research experience. Students learn about the basic elements of research, including the logical framework of research, science 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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A Novel Approach to Encapsulate Homogeneous Catalysts

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Research Sponsor: College of Engineering ISUR

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Homogeneous catalysis is used extensively in every industry that produces products on a large scale. However, retrieval and separation of the catalyst from the product offers new challenges as manufacturers seek to reduce the environmental and economic blow from continuously resupplying catalysts and incorporating many steps to ensure product safety. In order to prevent this situation, this study seeks to encapsulate individual catalysts within an elastomer made from hydrosilylation.

Previous experiments used Karstedt's Catalyst, an industrial catalyst, to form a cross linking gel around a secondary catalyst of interest. Recent tests used a cobalt-based catalyst for cross linking. Once encapsulated within the gel, the secondary catalyst of interest was extracted from the gel using toluene. From these experiments, the density and pore size of the cross-linking gel is better understood.

Future experiments will work to activate the secondary catalyst of interest and discern if and how the rate of catalysis is affected by placing the secondary catalyst of interest in the cross-linked gel.

"Color" Detection of Bone Microcracks *in vivo* with Hafnium Oxide Nanoparticles and Photon Counting CT

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Research Sponsor: Semiconductor Research Corporation/Intel

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Herein, the design of nanoparticles (NPs) targeting bone microcracks for robust, specific, *in vivo* imaging is presented. The NPs enabled noninvasive anaylsis of microcrack anatomy, which has implications in osteoporosis and osteoarthritis. Hafnium nanoparticles were synthesized via a base-catalyzed sol-gel chemistry combined with a water-in-oil microemulsion method and ligated to nitrilotriacetic acid (NTA), a calcium chelator. The NPs were characterized via FTIR spectroscopy, Zeta potential, NMR, and XPS; while calcium binding confirmed via ICP determined that NPs with NTA have 6.5 times more Ca binding efficiency than non-targeted. Conventional and spectral CT *ex vivo and in vivo*, respectively, showed promising results, with targeted NPs accumulating at the bone, especially at microdamage features. The usefulness of the NP as spectral CT X-Ray attenuating material was confirmed with MARS CT and the

analyzed materials decomposition data revealed the amount of NPs at a site of the microdamage while also differentiating between NPs, HA (mimicking the calcium-rich regions of the bone), lipid, and water. H & E staining of the harvested organs was carried out 7 days post-intramuscular injection and was evaluated to be within normal limits. In conclusion, the Hafnium-based NPs provided a specific, safe option for noninvasive bone microcrack visualization. A similar design could be developed in the future with a different ligand attached to the Hf NPs to target a different biological feature of interest, since safe application of Hf NPs as a radioenhancer material has already been shown in clinical trials.

In-Situ **Characterization of High Temperature Oxides up to 3000°C**

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Research Sponsor: Semiconductor Research Corporation/Intel

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In recent years, there have been rising interest in development of high temperature materials, especially for aerospace applications and hypersonic jets. Commonly, people use refractory metals, such as tungsten and molybdenum. However, attentions have switched focus to ceramic materials for potential replacement of these refractory metals because it has superior mechanical and thermodynamic properties and more cost efficient. Unfortunately, there are multiple problems that arise in characterizing high temperature materials. People could extrapolate high temperature properties from low temperature data, but this may not be accurate as material properties can drastically change at high temperatures, such as undergoing phase transformation. At high temperatures, there are many physical limitations to characterization such as melting, thermal gradient, etc.

In our research group, we have designed a system for *in-situ* high temperature X-ray characterization. Various types of oxides are fabricated with high homogeneity and density using the steric entrapment method, designed and patented by Professor Kriven. The samples are shaped into beads and heated to temperatures up to 2000 °C using quadruple lamp furnace (QLF) and 3400 °C using a conical nozzle levitator (CNL) system equipped with CO_2 laser. Structural information is obtained by coupling these devices with synchrotron X-ray Diffractions. *In-situ* data can be extracted during heating, such as lattice parameters, symmetry, and phases. Our group has investigated on multiple high temperature applications, including investigation of ternary oxide phase diagram and negative thermal expansion in anisotropic oxides.

27-Hydroxycholesterol Implicated in Breast Cancer Reemergence from Dormancy
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Research Sponsor: College of Engineering ISUR

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While there has been great progress in cancer therapies in the past decade, breast cancer remains the second leading cause of cancer death in women. Breast cancer mortality is most often caused by metastasis from the original tumor rather than the original tumor alone. Scientists believe that there is a period of dormancy within the distal tissue, prior to recurrence with symptomatic disease. Studies have shown that individuals with high cholesterol have increased chances of recurrence with metastatic breast cancer. Furthermore, cholesterol lowering medications have been shown to increase survival time. Overall, this evidence implies that cholesterol may have a role in breast cancer recurrence through its ability to facilitate scape from dormancy. Since the primary metabolite of cholesterol, 27HC, is an active signaling molecule that promotes metastasis, we hypothesize that 27HC manifests its effects by stimulating reemergence from tumor dormancy. Current studies are testing our hypothesis in a model of dormancy. D2.0R is a mammary mouse cancer cell line that forms dormant lesions in the lung of mice, and remain dormant indefinitely. Therefore, we are actively testing the hypothesis that 27HC will promote the outgrowth of these D2.0R dormant lesions.

Time-Series Bacterial Colony Tracking Using Computer Vision
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Research Sponsor: College of Engineering ISUR

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2. Faculty Mentor, Department of Bioengineering

Predictive bacterial models are becoming a bigger staple in biology as the cost of computation plummets. The field of computational biology relies heavily on algorithms and models to extract novel findings from experimental data. The ability to perform experiments *in silico* saves countless hours and is invaluable to the future of biology. New models increasingly rely on vast troves of data. Additionally, machine learning-based models are rising in popularity for microbiology applications. Producing these bacterial models is a laborious undertaking, since obtaining the requisite growth kinetics requires many experiments and diligent measuring by a researcher, making certain data gathering experiments infeasible. Conventional means of getting data for any type of model requires continual sampling over the course of the bacteria's growth, oftentimes in myriad combinations of conditions. We aimed to create an imaging system that relies on low-cost hardware and a custom computer vision pipeline to enable a new type of experimentation—one that is not limited by data gathering. Our device uses four high-resolution cameras to image a single plate of bacteria on solid media over the course of its growth. We leveraged computer vision to track each colony's growth over time. The automatic imaging system is contained and does not require user interaction beyond the initial set-up and

final clean-up. High-resolution colony tracking can be important to accurately study the interaction between bacteria that live in highly structured communities, ultimately leading to new insights.

Applications of Reinforcement Learning in Planetary Rovers

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Research Sponsor: Northrop Grumman

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Reinforcement learning is a subset of machine learning wherein agents are trained to take an optimal action in response to a perceived environment. The current literature focuses on tuning the reward structure of simulated environments and altering learning parameters to maximize a metric describing performance. Past work in the simulations used in training and evaluating the policies governing these made use of MATLAB and SIMULINK. This work makes use of the OpenAI Gym framework to create a discrete environment that is easily mutated to allow for quick and effective iteration of algorithms. A further combative capture-the-flag environment (also using OpenAI Gym) is modified to accommodate a continuous range of actions. Both environments allow the creation and testing of algorithms centered about the interpretability of reinforcement learning governed agents.

Microfluidic Device for Cell Encapsulation

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Research Sponsor: College of Engineering ISUR

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2. Graduate Mentor, Department of Materials Science and Engineering
3. Faculty Sponsor, Department of Chemical and Biomolecular Engineering

Our goal is to create a microfluidic device that can encapsulate hematopietic stem cells and manipulate their response through biomolecular presentation and matrix properties in rapid high -throughput analysis. A microfluidic device allows us to produce large libraries of cell matrices with encapsulated cells for rapid screening of stem cell response to local environments. As a proof of concept, we used microfluidic devices to create hydrogel droplets to encapsulate adipose stem cells. The methods and procedure utilized in this experiment were in collaboration with the Garcia Lab at the Georgia Institute of Technology. The microfluidic devices were created from poly(dimethylsiloxane) (PDMS) using photolithography techniques. Various geometries of photomask are used to polymerize a defined pattern with UV light and the unpolymerized photoresist is washed away to create masters. Using these masters, many micro-fluidic devices can be synthesized by repeated pouring and curing of PDMS. A solution of oil, maleimide-functionalized gelatin (GelMAL), and a crosslinking agent, DDT, were loaded into

different pumps and utilized as the fluids inside the microfluidic device. The oil and GelMAL were the continuous immiscible phase and DDT was used to create hydrogel particles. Droplet size was controlled by infusion rate of the pumps. Cell encapsulation follows a Poisson distribution and the density of the cell solution used in the microfluidic device was $1.2x10^6$ cells/mL. The droplet sizes upon creation had an average size of 122 μm. However, analyzing them using ImageJ after a hydration phase in PBS, yielded a mean width of 230.9 μm and mean height of 229.5 μm. A live/dead assay was performed on the cells encapsulated in the droplets to observe the fraction of cells that survived.

Investigating the Effectiveness of MDI-QKD with Weak Coherent Pulses

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Research Sponsor: DaRin Butz Foundation, Semiconductor Research Corporation/Intel, DoD, NASA, ONR, Air Force Office of Scientific Research

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Quantum key distribution (QKD) is a quantum cryptographic task that allows a random secret key to be generated and communicated between two parties in the presence of an eavesdropper. Although QKD systems are theoretically secure according to the laws of quantum mechanics, many security loopholes have been found in practice. Measurement-device-independent quantum key distribution (MDI-QKD) improves upon previous QKD systems by removing all detector side-channels, therefore rendering many of the loopholes obsolete. However, in order to successfully implement MDI-QKD, the sources (representing the two communicating parties) must be indistinguishable. We will be implementing MDI-QKD with two independent sources of light coming from attenuated laser pulses/resonant cavity LEDs. The sources are currently being tested and characterized to determine how indistinguishable they truly are.

Development and Characterization of Stimuli-Responsive Polymer Microcapsules

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Research Sponsor: Northrop Grumman

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Underwater pipelines are conventionally coated to prevent mechanical damage and corrosion. However, conventional coatings degrade over time in response to environmental stresses and can potentially lead to catastrophic failure. An attractive strategy is to incorporate pH responsive microcapsules into the coatings to mitigate damage due to corrosion. The project explores microcapsule systems having polymeric shells made of Eudragit E100 (Doerdelmann et al 2014), cyclic polythalaldehyde (cPPA, Tang et al 2017), and butylated urea-formaldehyde

crosslinked using Pentaerythritol-tetra-3-mercaptopropionate (UF-PTMP, Matsuda et al 2019). Eudragit E100 and cPPA microcapsules were formed by bulk oil-in-water emulsion polymerization and UF-PTMP capsules were formed by bulk water-in-oil emulsion polymerization. The efficacy of these systems was tested by visualizing the microcapsules in acidic media and coated environments with brightfield microscopy, fluorescent microscopy, and scanning electron microscopy. The microcapsule systems investigated here were found to be unsuitable for corrosion resistant epoxy coatings due to either their instability to solvents present in these coatings or complex encapsulation process as in the case of UF-PTMP system.

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Differentiation of Liver Progenitor Cells in Defined 3D Microtissues

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Research Sponsor: College of Engineering ISUR

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Liver progenitor cells are the common precursor cells that proliferate and differentiate into mature liver cell types such as hepatocytes or cholangiocytes (bile ducts). Differentiation is controlled by mechanical and chemical cues in the microenvironment. These cues are important for liver development, as abnormal liver development can result in congenital liver disease. Previous research has utilized two-dimensional tissues and three-dimensional spheroids, but these studies are limited since these geometries do not accurately represent what happens in vivo. Thus, the main goal of this research is to develop a method to produce and analyze liver progenitor cells in spatially defined 3D microtissues to gain a better understanding of the influence of geometric configurations on mechanical differentiation cues. To create the defined microtissues, hydrogel micro-molds of varying geometries were fabricated from a PDMS master to create wells. Bipotential mouse embryonic liver (BMEL) cells which have the capacity to be induced towards a hepatocytic or biliary fate are then seeded in the wells. The cells are then stained and imaged for HNF4a, a hepatocytic marker, and osteopontin (OPN), a biliary marker, using confocal microscopy. Images are segmented and analyzed using MATLAB scripts to identify cells, their locations, and phenotypes. Initial results suggest a distinction in the differentiation between toroidal and non-toroidal tissues with toroids containing more OPN positive cells. There is ongoing work to improve the analysis process while continuing to explore the impact of these geometries along with cooperative effects of other, exogenous factors on structure and phenotype.

DNA Origami Assisted Plasmonic Nanostructure

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Nanostructures constructed from noble metal conjugated to and organized by DNA are an emerging class of materials with potential to impact studies of nanophotonics. We created discrete DNA origami pyramids from semi-complementary DNA strands with gold nanoparticles conjugated to the tips. We then attempted to detect the formation of the DNA tetrahedrons through the various methods of DLS, gel electrophoresis, and SEM imaging. Through these tests, we confirmed the presence of pyramidal geometry as expected by engineered strand hybridization reaction. Further experimentation is needed to increase the yield of formation. If successful, we could ideally utilize the DNA tetrahedron as a nanosensor by measuring the ensemble optical responses of tetrahedron assembly/disassembly in the presence of a nucleic acid biomarker that denatures the tetrahedron by competitively binding to the tetrahedron's DNA.

Developing a Spatially-Defined Biomaterial Model of the Glioblastoma Perivascular Niche

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Glioblastoma (GBM) is the most common primary malignant brain tumor. The perivascular niche (PVN) has been shown to contribute to the diffuse invasion of glioblastoma (GBM) into the brain parenchyma. Due to this, there is motivation to study the interaction between the GBM and PVN cells.

PDMS microfluidic mixing devices were created through soft lithography. Then, GelMA solutions were flowed through the devices and exposed to UV light. This procedure was first done with opposing gradients of fluorescent beads, followed by PVN cells for a vascular gradient, and then with opposing gradients of PVN cells to GBM cells.

Ideal hydrogel photopolymerization conditions were found to be at a UV intensity of 7.8 mW/ cm^2 (λ = 365 nm) for 30 seconds, resulting in hydrogels with an elastic modulus of 2.54±0.29 kPa, similar to that of GBM tumor tissue. Opposing gradients of encapsulated fluorescent beads yielded differential intensity across the hydrogels, demonstrating the feasibility of incorporating opposing gradients of different cellular concentrations. Hydrogels with differential amounts of vascularization across the length of the material were established with

varying ratios of HUVECs and MSCs. Primary GBM cells were also encapsulated along with the PVN cells within the hydrogels.

Potential future studies for this project include analyzing the maintenance of cancer stem cell markers as a function of vascular presence across the hydrogels, assessing the tumor cell response to temozolomide, the current standard of chemotherapy for GBM, as a function of vascular presence, and profiling the transcriptomic differences of tumor cells across the hydrogels.

Redefining the Treatment of Peripheral Artery Disease: Role of Cellular Topology

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Research Sponsor: College of Engineering ISUR

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Peripheral artery disease (PAD) affects over 8.5 million Americans and over 200 million people worldwide. This debilitating circulatory condition displays symptoms such as claudication pain or cramping in the legs and is physiologically caused by narrowing vessels reducing blood flow to the limbs. The standard therapy for severe, limb-threatening PAD leading to the critical limb ischemia (CLI) is revascularization aiming to improve blood flow to the affected extremity. Amputation is often necessary if revascularization efforts fail or is not possible. Therapeutic stem cell therapy has gained notoriety for its potential towards restoration of perfusion to extremities that have suffered ischemia. A grand challenge seen in such efforts include the necessity for excessively large quantities of stem cells and significantly reduced viability of the stem cells following implantation. Our previous studies in preclinical models of cancer have shown that cellular topology has been observed to enhance the viability and natural metastatic phenotype of malignant melanoma.

In this study, we employed an integrated multimodal approach utilizing luciferase-based bioluminescence imaging, PET imaging using two molecular probes targeted at metabolism and angiogenesis, as well as label-free laser speckle contrast imaging to assess the effects of stem cell topology on perfusion, tissue oxygenation and neovascularization. We found that while functional differences were minute, the potential role for specific cellular topology remains a topic for further investigation. With a successful implementation of cellular topology, therapeutic stem cell therapy could address the current limitations of revascularization efforts and provide a solution for chronic cases of PAD and CLI.

Experimental Model of Mass Transfer Rates of Diffusion-Limited Emulsion Co-Polymerization

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A mathematical model was developed for predicting the rate of polymerization and polymer composition in diffusion-limited emulsion copolymerization systems. The model incorporates data on the mass transfer coefficients, density, and molecular weight of three monomers; methyl methacrylate (MMA), butyl acrylate (BA), and styrene (S). Mass transfer coefficients of each monomer was measured by conducting a batch emulsion polymerization in a bulk biphasic system; a monomer phase and a seed PMMA latex phase. The area of the phase boundary interface (PBI) was varied and the rate of polymerization was determined from the latex solid content. The model validity was tested against experimental data collected from batch emulsion copolymerization with MMA and BA in a bulk biphasic system. The composition of MMA and BA was varied and the rate of polymerization was measured. The composition of the monomer was analyzed using ^{1}H nuclear magnetic resonance (NMR) and an internal standard of polystyrene in the seed latex was used to subtract contributions from the seed latex. The mass transfer coefficients of MMA, BA, and S at 65 ^{o}C and 1 atm are measured as 0.064 cm/hr, 0.0103 cm/hr, and 0.0099 cm/hr respectively. The mass transfer coefficients are proportional to the aqueous solubility of the monomers. At high MMA concentrations, the model matches copolymerization data, however, deviations increase significantly at low MMA concentrations.

Developing Bio-Inks to Fabricate 3D Hydrogel Platforms for Glioblastoma

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Research Sponsor: Semiconductor Research Corporation/Intel

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2. Postdoctoral Mentor, Department of Chemical and Biomolecular Engineering
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Complex 3D cell-laden hydrogel platform models are used to develop treatments and study various diseases, such as glioblastoma (GBM), which is the most common and deadly form of brain cancer. One of the most commonly used hydrogel platforms is methacrylated gelatin (GelMA), which involves photopolymerization. However, exposure to UV light and generation of free radicals to cells is a major drawback. Herein, we explore the incorporation of dynamic covalent chemistry (thiolated gelatin, GelSH) and selective amine/thiol coupling (a small molecule derived from Meldrum's acid, GelMD).

The objective was to develop a hydrogel platform that does not require UV light, is degradable/ reversible, is compatible with GBM cells, and can be formulated as a bioink. The mechanical

properties of these hydrogel systems can be manipulated to mimic the brain environment (~5kPa) and to be compatible with cells. First, we incorporated Meldrum's derivative into the gelatin backbone *via* coupling with the amine groups. However, when a hydrogel was made by crosslinking with GelSH, it was very slow (hours). Thus, we explored thiol/disulfide exchange by only using GelSH. The disulfide bonds formed between two thiols can be degraded with dithiothreitol, allowing for collection of cells for further testing after use in the model. Although GelSH takes ~1 hour to crosslink, it can be catalyzed in the presence of enzymes (*e.g.*, horse radish peroxidase).

Future work will focus on optimization of the GelSH formulation, enzyme-catalyzed crosslinking, and GelSH development into a printable bioink with cells and bioplotter.

Rapid Fabrication of Multifunctional Vascular Composites Using Transient Polymers

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Research Sponsor: Northrop Grumman

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Microvascular materials for self-healing, self-sensing, and thermal regulation have been demonstrated for a variety of materials systems; the Vaporization of Sacrificial Components (VaSC) technique has been shown to produce these complex channels in a more seamless fashion than other vascularization techniques. However, the current sacrificial material being used, poly(lactic acid) (PLA) with catalyst, has such a high degradation temperature under vacuum (ca. 200°C) that only high-temperature matrices can be used. PLA also takes around 12 hours to fully evacuate, which consumes a lot of energy, and leaves behind considerable amounts of catalyst residue.

A new sacrificial candidate, cyclic poly(phthalaldehyde) (cPPA), was shown via TGA to degrade at much lower temperatures (ca. 110°C) and in much quicker times (ca. 1 hour) than PLA, all while leaving behind very little residue. This has the potential to greatly reduce the energy needed for VaSC and allow for the use of low-temperature matrices. One challenge with this material is that it has no observable thermal transitions, which makes it very difficult to process into usable forms.

In this study, templates of cPPA were successfully produced via solvent casting films, solvent-spinning fibers, and solvent-printing 2D patterns; the VaSC degradation properties of these templates were then characterized inside poly-DCPD matrices. However, the fibers were not mechanically robust enough for composites manufacturing. Current work is focused on fabricating cPPA fibers via dry-spinning, which should hopefully allow for more robust templates. These advancements in cPPA templating will expand the scope of bioinspired adaptive materials with hierarchical vascular networks.

Data Processing and Experimental Techniques for Small Molecule Imaging

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The structure and physiochemical interactions of molecules on surfaces are essential to determining macroscale behavior. In particular, characterization of molecular interactions can enable the development of tailored structure and chemistry for a variety of applications ranging from catalysis to drug delivery. The aim of this study is to combine sample preparation techniques for electron microscopy imaging and associated simulations to understand the structure, distributions, and surface interactions of small molecules on various surfaces including cetyltrimethylammonium bromide on gold nanoparticles and tetraphenylporphine on graphene.

Imaging was performed using graphene-substrates transferred to transmission electron microscopy (TEM) grids. These transfer techniques were developed and improved using a multi-step process to produce atomically-clean regions of graphene and high coverage across the 3 mm grids. The grids were characterized using TEM. Simulations were also developed to understand the images of molecules on gold nanoparticles, including how molecular distributions vary with nanoparticle curvature. Tetraphenylporphine on graphene was studied by simulating electron microscope images to model the interfacial interactions.

Graphene substrates enabled high-contrast images of molecular shells on gold nanoparticles. These images demonstrate a reduction in molecular binding on the ends of the nanoparticle that do not result from the surface curvature but instead from the underlying chemistry. Thus far simulating tetraphenylporphine on graphene and its interactions with the electron beam has elucidated how imaging will be impacted by various beam conditions. Future work will focus on aligning and averaging multiple simulated images of tetraphenylporphine on graphene.

Enhancing Spatial Control of Optogenetic Stimulation and Imaging with an Optical Fiber Bundle System

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Since its inception in 2005, optogenetics has enabled scientists to selectively manipulate neural activity with light. This technique involves transducing specific brain regions with channelrhodopsin, an ion channel that opens in response to light. Being able to activate and

deactivate a subset of cells allows us to determine how they contribute to their corresponding circuits, resultant behaviors, and possibly neural diseases.

We present an approach that streamlines simultaneous imaging of GCaMP6s and allows for precise stimulation of C1V1-mCherry in hippocampal neural tissue in vitro and potentially in vivo. We utilize two light sources in our system: a 488 nm continuous wave laser (Coherent, Inc.) for full-field illumination of GCAMP6s-transfected cells and a 561 nm CW laser for selective stimulation of C1V1-transfected cells. The 561 nm laser propagates through a 4F optical configuration and galvanometer-driven dual-axis scanning mirrors (SCANLAB) before being coupled into a single 7.5 μm fiber of a Schott (1534702) imaging fiber bundle. A CCD camera (Andor iXon) records its proximal plane, including the stimulation beam's entry into the bundle and the cell activity in the sample at its distal end. These live recordings are displayed on our LabVIEW GUI, which automatically identifies and tracks fluoresced cells. When the user selects a cell, the program internally converts pixel values to the voltages necessary to direct the galvanometers towards the targeted fiber.

This new method for selective stimulation of neurons in vitro has expedited the lab's optogenetic experiments and will aid the advancement of neuroscience research.

A Microfluidic Biochip Platform for Electrical Quantification of Proteins

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Worldwide, over 30 million people are affected by sepsis annually. In U.S. hospitals, sepsis is the leading cause of death, with more than 1.7 million adults developing sepsis every year. This mortality rate surpasses the combined mortality rate of prostate cancer, breast cancer and AIDS. A major part of the problem is the lack of methods for categorizing sepsis patients in terms of disease progression. Studies have demonstrated cell surface and proteome markers as viable biomarkers for early sepsis stratification. A Point-of-care (POC) platform to quantify various biomarkers would aid in the diagnosis and prognosis of sepsis progression. The proposed biochip platform focuses on quantifying inflammatory proteins in the early stages of sepsis. The versatility of the platform has been illustrated with the quantification of cell counts (CD4/CD8 T cell counts for HIV/AIDS), concentration of cellular proteins (CD64 expression on neutrophils) and the detection of plasma protein IL-6, all from a drop of whole blood using the same platform architecture. This work presents on-going research focusing on the development and optimization of multiplexed detection methods for simultaneous quantification of PCT and IL-6.

Modulation of Stem Cell Differentiation With Varying Glycosaminoglycan Scaffolds
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Research Sponsor: College of Engineering ISUR

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Composite bone replacement materials consisting of a collagen scaffold and 3D printed polymer supports show potential for improvement over current methods of bone replacement. Such composite materials can offer improved mechanical and biointegrative properties over grafts and metal implants. One promising aspect of these materials is increased bone ingrowth into the implant, which would allow the body to better heal the wound. However, lack of proper stem cell differentiation is a limiting factor in bone ingrowth, as certain properties are desired of the bone cells for complete integration into the body. Here, we show that varying the glycosaminoglycans used in collagen scaffolds, as well as varying isotropic vs. anisotropic pore size of GAGs in scaffolds, can impact the mineral formation and expression of cell type-specific genes in human mesenchymal stem cells, indicating proper differentiation and bone growth.

On Analytical Modeling of Flaky Tests
Otto Piramuthu[1]

Research Sponsor: Semiconductor Research Corporation/Intel

1. Undergraduate Scholar, Department of Computer Science

Whenever software code updates are done, it is important to ensure that no functional issues are introduced. Regression testing is done on all parts of the code repository that are related to the new code update. Regression tests done after an update with inconsistent success or failure results are known as flaky tests. A failed test when repeated several times might eventually return a successful test outcome and vice versa in a flaky test situation. Regression tests are repeated several times to identify any inconsistent result. Such non-deterministic behavior of flaky test outcomes renders it rather difficult to identify the culprit, if any, in the code. This is because a flaky test could be due to either bad test code or bug(s) in the software code. Almost all extant studies consider the flaky test issue from an empirical evaluation perspective. Well-designed analytical studies would provide the much-needed complement to empirical studies to help understand flaky test dynamics in a bit more detail. To this end, I attempt to analytically model flaky test dynamics. Flaky tests have memory-less property since their transition to the next state depends only on the current state. I chose discrete-time Markov chain to model flaky test due to its memory-less property. My primary goal is to generate expressions for the conditions under which further testing should be stopped or continued. I derive mathematical expressions that describe the characteristics and relevant properties of flaky tests, with specific emphasis on their steady state distributions.

Study of Cargo Transport by Multiple Kinesin Motors

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Kinesin is a molecular motor that transports cellular cargo from one place to another. Each kinesin is powered by ATP and walks along a complex microtubule pathway. The motility of individual kinesins has been extensively studied during the last few decades. However, how multiple kinesins work together to transport cargo within human cells is still not completely understood. We have developed a force gliding assay to help us better understand how groups of kinesin molecules cooperate to sustain cargo motion. This assay allows us to track individual kinesins as they move a microtubule cargo, while also gaining information on how each kinesin contributes to the motion. Although the assay already allows for the study of cargo transport by multiple molecular motors, we are still developing the assay to more accurately measure the contribution of each individual motor. Once fully developed, our force gliding assay could measure the force exerted by individual kinesin motors on the cargo over extended periods of time.

Cello Timbre Analysis Using the Source/Filter Model

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The source/filter model was first used to describe speech production and can also be to describe musical instrument sounds. This model is convenient because it allows independent analysis and manipulation of the source and the filter. We aim to use the source/filter model to separate the bridge source spectrum from the cello's transfer function.

The cello was performed in an enclosure formed by sound-absorbing panels within a large room with solid walls. A far-field microphone received the cello's output signal. In our case, this filter contains the body and room transfer functions because the room was reverberant. We considered the signal from the bridge as the source spectrum. A commercial transducer at the bridge recorded the source simultaneously with the far field.

The frequency response was estimated by comparing ratios of overlapping regions of adjacent harmonic pairs and summing them together. Before source correction, the frequency response of the input and output decrease with increasing frequency. Correlation between harmonic amplitudes in their overlapping frequency regions was about 0.5 for harmonics 1-3 and

approximately 0.8 for harmonics 7-15. Unexpected source frequency response behavior was noted and may have been caused by the transducer's unknown frequency response.

Further analysis is needed to understand the behavior of higher partials and construct a more accurate transfer function. Realistic synthesis may later be performed using such a transfer function.

Source Localization Using Ultrasound Arrays for Communicating with Implanted Medical Devices

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The ultimate goal of the research is to develop technology to enable implanted medical devices in the body to transfer data using ultrasound as the communication channel. The most common current method for in body communication to implantable medical devices includes electromagnetic wave propagation. However, bandwidths are limited reducing communication rates and there is a safety concern with use of electromagnetic radiation in the body. Ultrasound has the potential to be a better form for data transfer through tissue. This is due to the fact that we can achieve higher data transfer rates with less safety concern using ultrasound compared to electromagnetic radiation. The process for ultrasound communication involves a sonometric crystal inside the body connected to a medical device, which produces the signal, and a diagnostic ultrasound probe, which receives the signal. We have been able to demonstrate high data rates (up to 30 Mbps) with co-aligned transducers. However, in the body the source and receiving transducers may not be co-aligned. Therefore, an array transducer can be used as a receiver to localize the source by adjusting the time delays on receive. We demonstrated the ability focus reception of the sonomicrocrystal to a depth of 15 cm and we explore the possibility for detecting multiple probes within a tissue. Next steps include incorporating a small circuit utilizing a sonomicrocrystal to develop a prototype of an implantable device that can transmit data at rates suitable for high definition video.

Development of a Facile Experimental Technique for the Fabrication of Double Emulsions

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Emulsions are used in a wide variety of applications due to their ability to deliver active compounds which are insoluble in a continuous media (Leal et al 2007). For many applications, it is ideal to produce monodisperse emulsions (droplets with a narrow size distribution), for instance, drug delivery. This research project proposes to develop a facile technique for producing monodisperse double emulsions while demonstrating the ability to precisely tune their size. The method here utilizes the interfacial tension between two immiscible phases to generate double emulsions. The phases to be emulsified are delivered simultaneously via reciprocation across the surface of a surfactant laden continuous phase. The effect of experimental parameters on the size of the emulsion is also investigated. Model monodisperse double emulsions of water/polymer/water were fabricated. Subsequently, an application of this technique was demonstrated by selectively gelling the polymer phase to produce monodisperse microcapsules. Monodisperse double emulsions and microcapsules were fabricated with exceptionally low polydispersity. The method demonstrated here is cost-effective, easy to set-up, reusable and has potential for scale-up.

Chiral Analysis of D-Aspartate in the Islets of Langerhans

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The islets of Langerhans are small cell clusters in the mammalian pancreas which cooperate to maintain glucose homeostasis. Immunostaining the islets revealed high concentrations of D-aspartate (D-Asp) and glucagon in alpha cells, and of D-alanine (D-Ala) and insulin in beta cells. Beta cells release D-Ala with insulin in high glucose concentrations, indicating they are co-localized in the same granules. Is D-Asp released similarly with glucagon from alpha cells at low glucose concentrations? Characterizing D-amino acids in the islets will yield information on their potential usage as pancreatic signaling molecules which may help develop diabetes therapies.

This study is conducted using capillary electrophoresis (CE) with laser-induced fluorescence (LIF). CE separates compounds based on charge, viscosity and size, and the aspartate

enantiomers are resolved by incorporating chiral additives into the buffer. All species are reacted with a fluorogenic tag to allow their relative concentrations to be determined by LIF. The D-Asp peak is identified in the complex electropherograms by standard addition and enzyme treatment experiments. Islet samples are limited, necessitating small volume injection, and analyzing D-Asp requires a low detection limit due to their natural low abundance. CE-LIF meets both of these requirements, making it the ideal choice for the study. The study is currently focused on rodent islets and is using a citric acid buffer that shows good separation of the Asp enantiomers.

A MATLAB Graphical User Interface to 3D Print Anatomical Models

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Background/Purpose

The breakthroughs in 3D printing have completely revamped all aspects of the manufacturing process. This has caused 3D printing to become increasingly efficient as well as cost effective. In the healthcare field, 3D printing has the ability to produce 3D printed replicas of anatomical patients 'organs, while offering a 3D perspective of the specific structure. The aim of this project is to simplify the transition from scalar medical imaging data to 3D printed anatomical models by developing a user-friendly Graphical User Interface (GUI).

Methods

A GUI was developed using MATLAB which functions to (1) import any type of human or animal atlas in standard medical file formats such as DICOM, raw, and Analyze; (2) provide interactive exploration of images; (3) offer 3D visualization; (4) and export selected regions of interest into STL files.

Results

The GUI was used to extract, the left ventricle and the parietal lobes from a human heart and brain atlas, respectively. The anatomical regions were successfully 3D-printed using the Ultimaker 3 Extended printer using PLA and PVA as extrusion and supporting materials. The high quality final prints demonstrated the successful implementation of the interface in constructing a workflow for 3-D anatomic modeling.

Conclusion

The implemented GUI effectively extracted a region of interest from the digital scalar volume data and converted it into a physical 3D-printed model. By streamlining this procedure, the intention is to make these customizable anatomic models readily available for surgical planning and/or for training and educational purposes.

Size Based and Chemical Modulation of Genetic Noise in Pluripotent Stem Cells

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Cell size dependent gene expression may guide design strategies and applications in synthetic biology and may provide important determinants to advance diagnostics and therapies. Based upon an observed cell sized based relationship of genetic burst size seen in CD4+ T cells*, a similar trend was hypothesized to occur in other cell types, such as pluripotent stem cells. It was thus predicted that larger cells would have a larger burst size relative to small cells. Sampling of a representative mouse embryonic stem cell population showed an average diameter of small cells to be 11.81um and the average diameter of large cells to be about 16.29um. The cells were analyzed for differences in the expression level and variance of the pluripotent regulatory factors *Oct 3/4, Sox 2, and Nanog* using immunofluorescence. While large cells had larger transcriptional burst size compared to small cells for all 3 transcription factors, changes in transcriptional burst frequency between large and small cells for *Sox2* was very minimal. Chemical modulation of gene expression noise was also investigated using triciribine (AKTiV), and TSA for Sox2 gene expression noise. Physical and chemical manipulation of genetic noise in pluripotent factor networks may be further explored for applications in cell differentiation.

* Bohn-Wippert, K., Tevonian, E. N., Lu, Y., Huang, M. Y., Megaridis, M. R., & Dar, R. D. (2018). Cell Size-Based Decision-Making of a Viral Gene Circuit. Cell reports, 25(13), 3844-3857.

Determining Macrophage Polarization within Mineralized Collagen-Amnion Scaffolds for Craniomaxillofacial Bone Regeneration

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Craniomaxillofacial (CMF) defects are critical sized bone defects in the skull that require surgical intervention to heal properly. There are over 1.5 million bone graft surgeries in the US every year, yet current methods are inadequate. A second surgical site is often required, or there are graft rejection risks. Mineralized collagen (MC) scaffolds offer a promising future for bone regeneration, but lack the immunomodulatory properties to aid in healing. In this study, the amniotic membrane (AM) was investigated as a immunomodulatory component because it has low immunogenicity. By isolating a human placenta, decellularizing, and lyophilizing to create a powder, the AM was homogenized with the MC slurry to create composite scaffolds. These

scaffolds were compared to MC scaffolds with different fiber orientations to determine if the AM provided an optimized immune response. To quantify the response, monocytes were cultured and differentiated into primary macrophages then seeded onto scaffolds for 7 days. The scaffolds were analyzed via RT-PCR on days 1,4, and 7 to evaluate the genes correlated with macrophage behavior and standardized with GAPDH. The initial immune response employs M1 macrophages to remove debris and promote inflammation. After 3 days, M1 expression is expected to decline, and M2 expression is expected to increase as M2 macrophages occur in later stages of healing to remodel tissue and reduce inflammation. The results revealed that AM had no significant effect on M1 expression. However, AM did increase M2 gene expression on day 7, indicating its potential as a beneficial immunomodulator.

Magnetic Field Mapping with Dipole Models

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Magnetic localization is an increasingly prominent positioning method in which an autonomous system measures the ambient magnetic field to determine its position and orientation. Magnetic field maps are currently planar, but recent studies demonstrate the importance of accounting for magnetic field variation over height, which effects a greater amount of information to be stored. This research project aims to compress large magnetic field datasets into a few magnetic dipole moments, largely decreasing the required memory storage.

A dipole moment generates a magnetic field around it that is governed by the magnetic dipole field relation. By taking B-field measurements over multiple locations, the dipole field relation may be optimized through nonlinear least-squares methods to recover the source dipoles. Initial optimization algorithms utilized the Levenberg-Marquardt method, which converged to the local minimum through a means in between gradient descent methods and the Gauss Newton method. If the error in the current set of dipoles was too large, the algorithm increased the number of dipoles to minimize until the error was within the acceptable tolerance. Convergence tests showed that if the initial guess was within 1 meter of the true location the algorithm would always converge to the global minimum.

Due to the nonconvexity of the cost function, the algorithm would not always converge to the global minimum if the initial guess was more than 1 meter away from the true location. Future work will involve using convex relaxations to optimize the L1-regularized cost function to ensure global convergence from any initial guess.

The Missing Link Between Acoustic Stealth and Poroelasticity: A Soft Filament Approach
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Research Sponsor: Semiconductor Research Corporation/Intel

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3. Faculty Sponsor, Department of Mechanical Science and Engineering

The primary focus of this paper is to understand the mechanisms behind the acoustic stealth of the owl. This is done through the use of computational mechanics, computational aeroacoustics, and stochastic optimization. In this presentation, methods to implement experimental owl wing data and to simplify an owl's wing into a computational model will be presented. Furthermore, a fully elastic and deformable owl's wing model with functioning muscle actuation will be shown. This model sets the stage for a rigorous study of the underlying link between elasticity and acoustic radiation through the use of Lighthill's acoustic analogy.

High-throughput Bacterial Colony Tracking Using Computer Vision
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Research Sponsor: College of Engineering ISUR

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The process of automatically tracking the growth of bacteria is essential for creating predictive bacterial models. Currently, off-the-shelf, high-resolution, high-throughput, continuous tracking is tedious, requires expensive equipment, and does not exist for bacterial colonies on solid media. This is an important space, as for bacteria native to environments such as soil, skin, and mucosal membranes, solid media is a more realistic representation than liquid. In separate works we have described a compact device that images bacteria. Our goal here is to create a program that can take these images and distinguish distinct bacterial colonies to track their growth on solid media.

Here, we describe ColonyTrack's software, a program that takes time series images of bacteria seeded on solid media and outputs each colony's growth rate among other useful features. The program pipelines images through three major steps, image pre-processing, image processing, and colony tracking. In the pre-processing step, the raw images from multiple cameras are stitched together, smoothed, and an average background is created. From there, the images are processed with background subtraction and region of interest masking. Finally, the program tracks the growth of each colony found and reports their features.

To verify the program, we spread *Streptococcus Mutans* UA159 culture onto a petri dish. We place the plate inside the ColonyTrack device and incubate the assembly. After 60 hours, we run the ColonyTrack software on the collected images. The software finds all colonies accurately and is sensitive enough to show lag between the individual colonies' growth and their rates.

The Effect of Mixture Proportioning on the Relationship Between Slump and Yield Stress of Concrete

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Concrete, commonly made using different proportions of cement, fine aggregate (sand), coarse aggregate (gravel, limestone, etc.), and water, is a semi-flowable material that hardens over time as cement undergoes hydration reaction. The workability of concrete is currently measured by the slump test, which gives arbitrary values and can be skewed by human error. It is generally understood that the slump of concrete is related to its yield stress (the stress beyond which a material begins to deform non-reversibly). Therefore, an approach using yield stress instead of slump to describe workability was explored in this study.

A three-dimensional design space was used to define concrete and study three relative proportions (volumetric sand percentage, volumetric paste percentage, and water-cement ratio). These factors were varied within a boundary to understand how slump and yield stress responds to changes in mixture design. The slump and yield stress were obtained via the slump test and stress growth test (using an ICAR concrete rheometer) respectively.

The results from this study show a general increase in slump and decrease in yield stress with increasing volumetric paste content for a given volumetric sand content and water-cement ratio. A model to describe the relation between between slump and yield stress was developed by fitting a curve to the available data. The developed model had a better fit to data than others found in literature. Future work will involve focus on verifying these results at other water-cement ratios and applying it in the perspective of concrete 3D printing.

One Step Synthesis of Protein and Membrane-Functionalized Gold Nanoparticles Completely Devoid of Synthetic Products, Heating, or pH Manipulation

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Research Sponsor: Shell Corporation

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Cancer is a genetic disease characterized by cell abnormalities. Gold nanoparticles (GNPs) can combat cancer by acting as an early theranostic. GNPs are ideal for cancer applications since they are bioinert, unique in their optical properties, used in photothermal ablative therapy, and suitable for various imaging techniques (infrared, computed tomography, fluorescence, photoacoustic). To make the GNPs specifically targetable to cancer, they can be combined with

cancer specific proteins, functionalizing them. Current synthesis methods to prepare functionalized GNPs (fGNPs) rely on heating, pH changes, and synthetic materials. These methods can degrade or modify targeting-protein characteristics.

Here we have developed and optimized a single-step synthesis of fGNPs using nicotinamide adenine dinucleotide (NADH), a coenzyme in all cellular life involved with redox metabolism, as a reducing agent. Our synthesis method involves the direct addition of NADH to ionic gold (Au^{3+}) in the presence of protein. For our experiments, we used fetal bovine serum (FBS) as our model protein and membrane extracted from cells for our in vitro studies. We have optimized this synthesis for protein adhesion to the GNPs and to maintain protein integrity. With this method, fGNPs can be synthesized in a single-step without degrading the protein. GNP formation was confirmed using ultraviolet-visible light spectroscopy and transmission electron microscopy imaging. Interactions between GNPs and proteins were characterized using SDS-PAGE.

The next step includes targeting the fGNPs back to the cells and identifying the location of the cancerous cells using imaging techniques.

Nanopatterned Thin Film Heterostructures as Majorana Platform

Amy Wu[1], Yulia Maximenko[2], Vidya Madhavan[3]

Research Sponsor: DaRin Butz Foundation, College of Engineering ISUR

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3. Faculty Sponsor, Department of Physics

The study of topological superconductor (TSC) has the potential to be used in quantum computation. TSC is a platform for Majorana fermions (MF), and MFs are non-Abelian anyons with highly degenerate ground state. We are creating a heterostructure to investigate the topological surface states of a topological insulator (TI) when proximity superconductivity is induced. Recent research has already studied the stacked superconductor (SC) and Ti, but this cause the problem of hybridization of MFs. We are proposing the heterostructures of coexisting SC and TIs in the same plane. The sample is probe in scanning tunneling microscopy (STM) to look for superconductivity. In our experiment, we discovered that niobium oxides in air and become insulating. Currently, we are working to replace niobium with lead.

Ultrasound Heating of Mouse Lymphocytes

David Yan[1], Edward Roy[2], Michael Oelze[3]

Research Sponsor: Rockwell Collins, Office of Undergraduate Research

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2. Faculty Mentor, School of Molecular and Cellular Biology
3. Faculty Sponsor, Department of Electrical and Computer Engineering

Purpose

Recently, ultrasound heating of cervical lymph nodes has been shown to affect the relapse-remit pattern of autoimmune encephalomyelitis in rats. One potential mechanism for this is ultrasound-induced death of autoreactive $CD8^+$ T cells, which may alleviate autoinflammation and disease symptoms. In this study, we sought to determine whether mouse lymphocytes could be killed by ultrasound heating in vitro.

Experimental Design

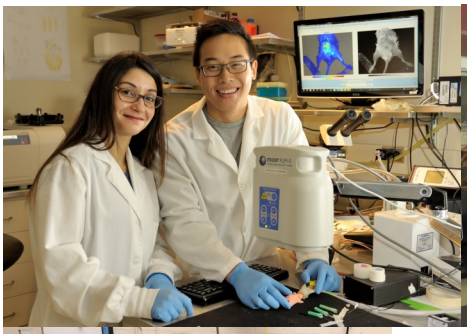
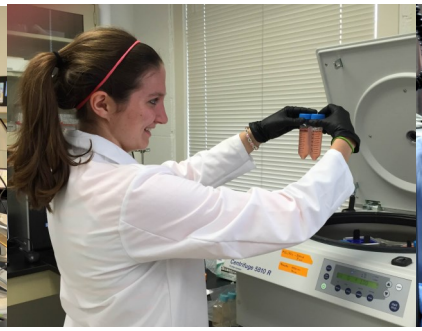
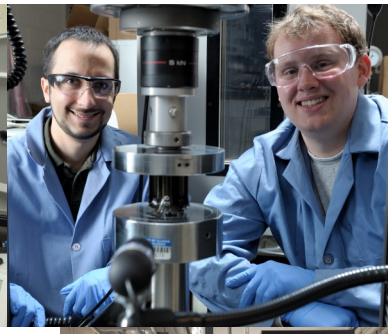
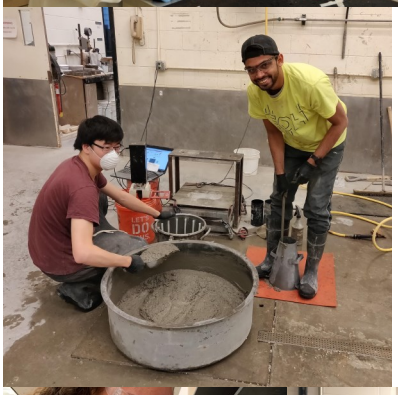
Lymph nodes were dissected from four female C57BL/6 mice and were made into single cell suspensions. Cells were plated in 96-well plates with $5x10^5$ cells per well. A high intensity ultrasound transducer was then coupled directly to culture media containing lymphocytes, and the cells were heated for 20 minutes per well, to temperatures in the range of 30-50°C. After heating, samples were stained and analyzed by flow cytometry.

Results

Flow cytometry data indicated that ultrasound heating of mouse lymphocytes can kill $CD8^+$ T cells. Temperatures below 38°C showed little death of $CD8^+$ T cells relative to the control. At 39-42°C, death of $CD8^+$ T cells increased by ~25% compared to controls. Above 42°C, significant cell death occurred, with >90% of $CD8^+$ T cells dead. No evidence of preferential killing of $CD8^+$ T cells was found.

Conclusion

Based on our flow cytometry data, ultrasound heating of lymphocytes has the ability to kill $CD8^+$ T cells at temperatures above 42°C.

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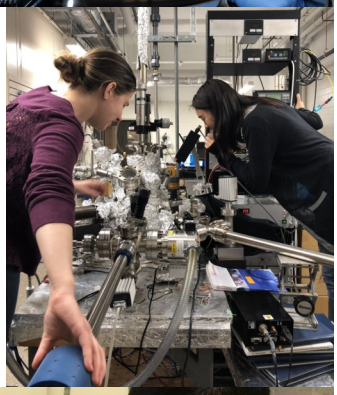
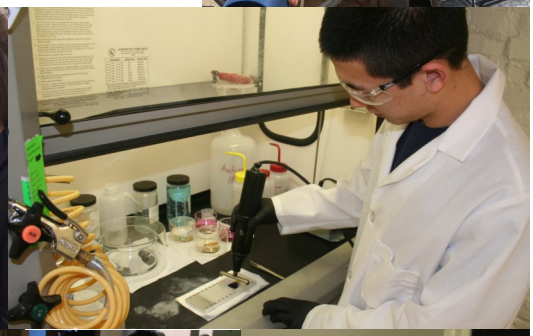
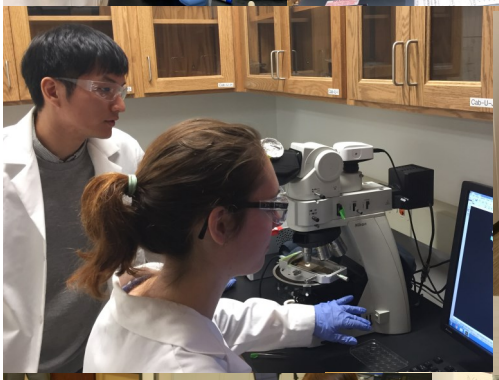
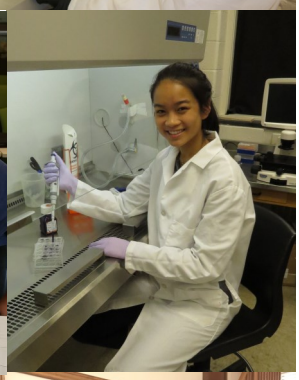
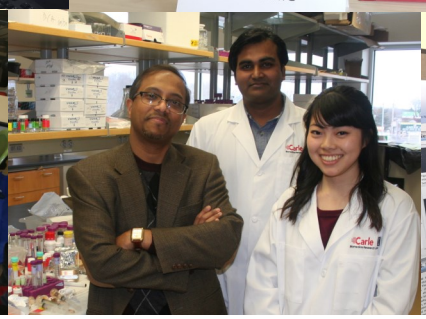
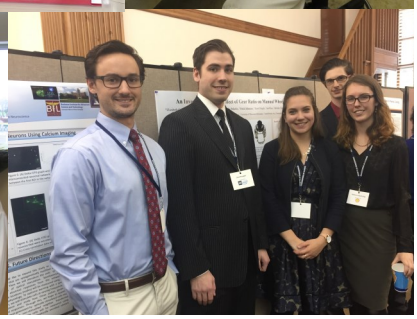


ISUR TEAMBUILDING

ISUR POSTER EXPO

2016

2017


2018

ISUR Scholars 2018-2019

Andrey Nosatov
MatSE

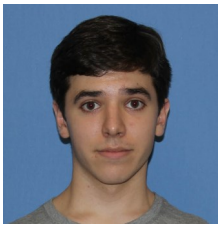
Otto Piramuthu
CS

Jake Ribich
EPhysics

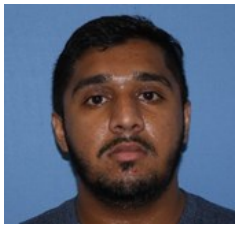
Anabel Rivera
EE

Kanad Sarkar
EE

Grayson Schaer
AE



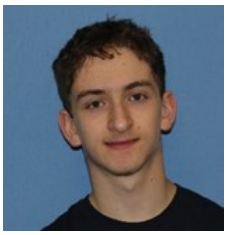
Jack Schnieders
ChemE



Muzammil Siddiqui
NPRE

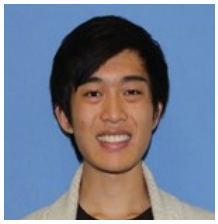
Harpal Singh
BioE

Diana Slater
BioE

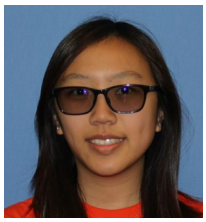


Daniel Steinberg
AE

Greg Stroot
MechE

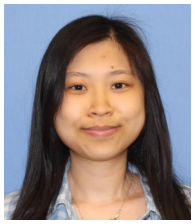


Matthew Tang
BioE

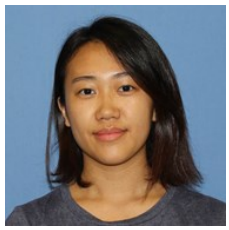


Whitney Tso
MatSE

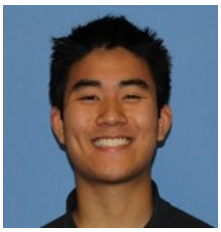
Benjamin Tung
CEE



Rachele Wen
BioE



Amy Wu
EPhysics



David Yan
EE

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