2019 George A. Jeffrey NanoExplorers Symposium

Friday, August 9, 2019, 10:00 a.m. – 4:30 p.m.

Kusch Auditorium, FN 2.102, The University of Texas at Dallas

Schedule

10:00 **Opening Remarks**
Dr. Steve Collins

Section A: Chair Monica Jung de Andrade

10:05 (A1) **Synthesizing Luminescent Silver Nanoparticles**
Sriya Teerdhala, Juanzhu Yan, Yue Chong, Lillian Ye, Kristina Fan, Jie Zheng

10:15 (A2) **A Novel Approach to Synthesizing and Characterizing Superconductors**
Satvik Dasari, Xiaoyuan Liu, Bing Lv

10:25 (A3) **RTM Synthesis of CNT-reinforced Carbon Fiber Epoxy Composites to Improve Intrinsic Mechanical Properties**
Matthew Lin, Catherine Yang, Ashan Ranmuthu, Dongyang Cao, Hongbing Lu

10:37 (A4) **Developing a Process Flow for the Manufacture of Metal-Oxide-Semiconductor Capacitors on Ga2O3 Semiconductor Substrates**
Sohum Kulkarni, Anuj Jain, Roberta Hawkins, and Chadwin D. Young

10:49 (A5) **Thermal Crosslinking of Polymer Blend Membranes for H2/CO2 Separations**
Sridatta V Teerdhala, Chamaal Karunaweera, John P Ferraris

10:59 (A6) **Creating graphene samples through various exfoliation methods while measuring and modeling physical properties**
Prayaag Gupta, Dr. Jian Liao, Dr. Xiaoyan Shi

Section B: Chair Tanner Cannedy

11:09 (B1) **Conductive Polymers for Flexible Electronics**
Ephraim Weiss, Yutika, Pedro Rocha, Dr. Benjamin Batchelor

11:19 (B2) **Microfabrication Process Compatibility of Sputtered Iridium Oxide Electrode Coatings**
Yosef E. Weiss, Justin Abbot, Jose M. Luna Vargas, Dr. Alexandra Joshi-Imre

11:29 (B3) **Leakage currents in aged amorphous silicon-carbide-based microelectrode arrays**
Shinjini Mukherjee, Negar Geramifard, and Dr. Alexandra Joshi-Imre

11:39 (B4) **Titanium Nitride Microelectrodes on Softening Neural Interfaces**
Aditya Chebrolu, Justin Abbott, Jose Manuel Luna Vargas, Alexandra Joshi-Imre

11:49 (B5) **Anti Microbial Oxygen Permeable Bandages**
Sanjana Hiremath, Yutika Ravindra Badhe, Dr. Benjamin Batchelor

11:59 (B6) **Secondary Crosslinks for Increased Toughness**
Emily Hickman, Yutika Ravindra, Ramya Krishnasamy, Dr. Benjamin Batchelor

12:09-1:00 **Lunch Break**

Section C: Chair David Mueller

1:00 (C1) **Haptic Trocar Insertion Training Tool**
Anirudh Vadduri, Andrew De Costa, Aakash Gadh, Dr. Ann Majewicz Fey

1:10 (C2) **Soft Robotic Device for Gastroschisis Closure**
Ella S. Li, Shreyas M. Annaswamy, Manoj Nair, Faisal Qureshi and Ann Majewicz Fey

1:20 (C3) **Low-Cost Reusable Trocar for Use in LMICs**
Layan Y. Dhaher and Ann Majewicz Fey

1:30 (C4) **Protective Potential of Exercise on Parkinson's Disease**
Laasya Achanta, Erin Venza

1:40 (C5) **Assessing cognitive training programs for childhood cancer survivors: a systematic review.**
Neal Reddy, Erin Venza

1:50 (C6) **Preparation of Protein Crystals for X-ray Crystallography**
Hope Giadolor, Virginia Blackwell, Prithwijit Sarkar and Sheena D'Arcy

Section D: Chair Jiuke Mu

2:00 (D1) **The Effects on the Stroke of Carbon Nanotube Based Artificial Muscles**
Lauren Pan, Xinghao Hu, Hailee Adams, Varun Menta, Ray Baughman

2:10 (D2) **Carbon Nanotubes/Reduced Graphene Oxide Yarn Twist for Energy Harvesting Applications**
Griffen Devino and Fernando Machado

2:20 (D3) **Effect of Temperature Increase on Spring Constant in Thermal-Actuating Nylon Fishing Line Artificial Muscles**
Noah M. Wong, Jiuke Mu, Ray H. Baughman

2:30 (D4) **An Analysis of the Various Effects of Varying Silicone Solutions on the Contraction Stroke of Carbon Fiber Artificial Muscles**
Varun Menta, Huanming Chen, Lauren Pan, Ray H. Baughman

2:40 (D5) **Assessment of the Fluorescent Response of Dyes Towards Transition Metals**
Yasash Gorusu and Gordon Irvine

Section E: Chair Zhong Wang

2:50 (E1) **Testing Silk as a Carbon Nanotube Alternative and Improvement to Biosensors**
Arushi Mukherjee, Yue Wang, and Zhong Wang

3:00 (E2) **Nuclear Magnetic Resonance: 1 H Relaxation Studies and 13 C Spectroscopic Monitoring of Cancer Metabolism**
Esha Bansal, Stuart Malina, Qing Wang, Christopher Parish, Lloyd Lumata

3:12 (E3) **Benchtop Potentiostat**
Joey Spiro, Sanjana Gagrani, Paul Rice, Shalini Prasad

3:22 (E4) **Measurement of Subpixel Structure**
Benjamin Oommen, Kaloyan Penev

3:32 (E5) **Mechanical Properties of Multiwall Carbon Nanotube Yarns with Applications in Thermoacoustics**
Sebastian Giordano, David Mueller, Dr. Ali Aliev

3:42 (E6) **Use of Paracoccus denitrificans co-cultures to understand biochemical pathways**
Ammar Dharani, Sneha Narvekar, and Stephen Spiro

4:02 **Closing Remarks and Certificate Ceremony**

2016 NanoExplorers Symposium Abstracts

(A1) Synthesizing Luminescent Silver Nanoparticles

Sriya Teerdhala, Juanzhu Yan, Yue Chong, Lillian Ye, Kristina Fan, Jie Zheng

Nanoparticles offer novel approaches toward targeted drug delivery, bioimaging, and gene therapy. Additionally, due to their unique, broad spectrum antimicrobial ability, silver nanoparticles have become widely used in sterilization and medical products, and the importance of their bright luminescence is also evident in the fields of medicine, chemistry, and biology. The research objective was to synthesize silver nanoparticles with high absorbance rates and bright luminescence. These silver nanoparticles had a polycrystalline structure and were created using a solid phase synthesis method. First, a solution of 1 mL glycine solution (200 mg/mL) and 0.5 mL silver nitrate solution (30 mg/mL) were created. Then, the combined glycine and silver nitrate solution was heated at 473 Kelvin to synthesize the silver nanoparticles. The thermal reduction of silver ions, and the subsequent synthesis of silver nanoparticles, was indicated by both a color change in the solution (clear to yellow to black) and the presence of a mirror-like sheen on the bottom of the beaker. Following synthesis, the purification process was used to separate the nanoparticles from the non-reacting molecules, utilizing repeated centrifugation and filtration of either the precipitate or supernatant. Next, the Olympus IX-71 microscope with a 1.3NA 100X oil- immersion objective was used to observe luminescence and conduct fluorescent microscopy of the silver nanoparticles. The Argon-ion laser at 488 nanometers excited nanoparticles prior to observation. During observation of the fluorescence microscopy, most nanoparticles aggregated along the edge of the droplet sample, making it difficult to distinguish exact intensity of light. However, the solid-phase synthesis proved to be effective in creating nanoparticles with bright luminescence. A UV visual spectrometer was also used to determine the absorbance of the silver nanoparticles; high absorbance suggests that the synthesis yield and thus the concentration of nanoparticles is higher. The silver nanoparticles had the highest absorbance of 0.3616 at a wavelength of 395.065 nanometers. Luminescent silver nanoparticles have potential application in bio-imaging and other photo-related applications. They also make excellent optical bioprobes, extending the capabilities of alternative fluorophores like organic dyes. Additionally, silver nanoparticles are used to efficiently harvest light for enhanced optical spectroscopies. Silver nanoparticles are used in numerous technologies and incorporated into a wide array of consumer products that take advantage of their desirable optical, conductive, and antibacterial properties. Since nanotechnology is a relatively new field of study, additional exploration of their implications and structures can allow further development of nanoparticles. Further experimentation with the solid phase synthesis process can be conducted to enhance brighter luminescence and increased absorbance of silver nanoparticles.

(A2) A Novel Approach to Synthesizing and Characterizing Superconductors

Satvik Dasari, Xiaoyuan Liu, Bing Lv

Superconductivity is observed when electrical resistance reaches zero and all magnetic flux fields are expelled. YBCO was the first material found to be superconducting above 77K. The goal of the project was to synthesize and characterize the superconductor, YBa2Cu3O7 (YBCO). 2.5 grams of the superconductor, YBCO, was synthesized using proper ratios of Yttrium Oxide, Barium Carbonate, and Copper Oxide. The X-Ray Diffraction (XRD) instrument is used to determine if there are impurities in samples. It was determined that the YBCO had zero impurities and could be considered a pure phase. The sample of YBCO was placed in a Physical Property Measurement System (PPMS) for resistance measurement. Measurements of resistivity were taken as the YBCO was cooled down from approximately 296K to 72K using

liquid nitrogen. The analysis of the XRD data and the resistivity data confirmed that the sample of the YBCO synthesized was a pure phase. Superconductors have many applications in our world. They can be used in extremely powerful electromagnets to accelerate particles to the speed of light. Another application of superconductors is Maglev (Magnetic Levitation) trains. By using superconductors and the Meissner effect the trains would be virtually frictionless. These applications of superconductors in the future could change our world substantially.

(A3) RTM Synthesis of CNT-reinforced Carbon Fiber Epoxy Composites to Improve Intrinsic Mechanical Properties

Matthew Lin, Catherine Yang, Ashan Ranmuthu, Dongyang Cao, Hongbing Lu

In this project, a novel resin transfer molding (RTM) process is applied to the synthesis of "fuzzy fiber" carbon nanotube-reinforced carbon fiber-epoxy composites in order to improve compressive and flexural strength. Previous methods of synthesizing fuzzy fiber composites relied heavily upon mechanochemical procedures, such as magnetron sputtering and hand layup processes, often resulting in compromised mechanical properties. This project aims to utilize the RTM synthesis process in order to produce composites with improved mechanical properties. 7x7 in2 carbon fiber sheets were cut from fabric and measured for mass and volume. The sheets were then stacked and transferred to the RTM mold, where they were injected with epoxy at elevated temperature and pressure for an hour. Following a post cure, the composite was removed and cut into samples, which subsequently underwent Combined Loading Compression experiment. Results showed that the samples displayed ultimate compressive stress and compressive modulus values higher than those of carbon epoxy samples manufactured with other methods. The samples underwent little to no buckling during testing, indicating a high stiffness value and flexural modulus. Based on these results, it can be extrapolated that ideal fuzzy fiber composites manufactured using the RTM should have a higher compressive strength and flexural modulus than traditionally synthesized composites. Additionally, RTM composites are considerably more efficient to synthesize in terms of both time and resources allocated. Overall, the findings of this project indicate that resin transfer molding is a viable alternative to traditional methods of synthesizing fuzzy fiber composites and can potentially have added benefits in the form of easier manufacturing and improved mechanical properties.

(A4) Developing a Process Flow for the Manufacture of Metal-Oxide-Semiconductor Capacitors on Ga2O3 Semiconductor Substrates

Sohum Kulkarni, Anuj Jain, Roberta Hawkins, and Chadwin D. Young

The use of Ga2O3 as an alternative to silicon as a semiconductor substrate for high power electronics has generated interest due to its wide band gap (4.8 eV vs silicon's 1.1 eV) and thus has begun evaluation. We demonstrate a process to manufacture metal-oxide-semiconductor capacitors (MOSCAPs) on a Ga2O3 substrate through an iterative design process on silicon. We prototyped on silicon due to the high price of Ga2O3. In seeking to replicate previous work by the group, we use an Al2O3 dielectric with Ti/Au stacks as the gate and bottom electrodes. The bulk of our research is dedicated to developing a process that eliminates a thin, reddish-brown film forming atop the gold that causes undesirable Capacitance-Voltage (C-V) and Current-Voltage (I-V) results. We use the standard capacitance equation (C=k⊠0A/d) to determine the expected experimental capacitance to measure the efficacy of the devices. The calculations found 0.759 to 0.831 μF/cm2 for the theoretical capacitance per unit area.\nUsing I-V measurements, we confirmed that the defect was a thin film formed atop the Ti/Au stack during the 400 C forming gas (95% N2, 5% H2) anneal. We then designed various manufacturing process flows to test

our hypothesis that the defect arose from the photolithography process itself. To test if the film was an organic residue left by positive photoresist, three types of photoresist removal were studied: (1) acetone was used to remove photoresist, (2) solvent known as AZ400T was used, and (3) a strong oxygen plasma was used after the solvent clean to ensure all organic residue was removed. The two types of solvent clean made no difference, while the oxygen plasma gave poor electrical results and caused a bright orange color on all electrodes. The results indicate the residue was caused by more than just lithography. Since the reddish-brown gate discoloration was initially produced in a process flow that first laid down the bottom electrode and then the gate electrode, a new lithography flow was designed that reverses that order to determine if a particular mask and its associated steps was causing the issue. This experiment yielded the same darker film formed atop the gate electrode, but no film on the bottom electrode. In addition, the C-V profiles were worse, with an average of 0.65 μF/cm2 for small and medium area devices compared to that of the standard (0.8 μF/cm2) for the same area devices.\nThe results from our experiments have led to two main conclusions: (1) the thin film is not an organic residue, and (2) the defect is not caused by steps in the lithography process. Unable to pinpoint the cause(s) of the defect, the future of our research will delve into the interaction of the materials used to produce the MOSCAP. We suspect that the residue is caused by diffusion of titanium to the surface of the gold, but more research is needed to confirm this. Knowing that the issue may lie in the materials being used, it will be interesting to see if the problem is eliminated when Ga2O3 substrates are used.

(A5) Thermal Crosslinking of Polymer Blend Membranes for H2/CO2 Separations

Sridatta V Teerdhala, Chamaal Karunaweera, John P Ferraris

Gas separation is an important step in the oil and natural gas industry. Currently, cryogenic distillation and pressure swing absorption are preferred methods. However, despite their efficiency, these methods need to be replaced as they require a tremendous amount of energy and are extremely costly. Gas separation using polymer membranes, on the other hand, is a cheaper and simpler method. Unfortunately, polymer membranes suffer from the trade-off between permeability and selectivity and are also susceptible to performance loss due to plasticization. The aim of this project is to fabricate thermally crosslinked polymer blend membranes with enhanced gas permeability and selectivity. Polybenzimidazole (PBI), which is highly selective for H2/CO2 separation, and 6FDA-DABA, which can be thermally crosslinked, were used as the two components in the polymer blends. Three different polymer blend membranes of PBI and 6FDA-DABA with ratios of 30:70, 50:50, and 70:30, and two control membranes of PBI and 6FDA-DABA were fabricated using solution casting. By combining the two polymers, permeability, as well as selectivity, were improved. For example, the pristine PBI:6FDA-DABA blend of ratio 1:1 showed an H2 permeability of 4.3 barrer and a selectivity of 13.9. Upon crosslinking, H2 permeability of this membrane increased by a factor of two and the selectivity remained at high with a value of 12.4. Thus, a polymer membrane with competitive permeability and selectivity was fabricated.

(A6) Creating graphene samples through various exfoliation methods while measuring and modeling physical properties

Prayaag Gupta, Dr. Jian Liao, Dr. Xiaoyan Shi

Graphene, the single atomic layer of graphite, has attracted great interest due to its superior properties for various electrical, mechanical, and thermal applications. All promising applications and devices depend on the successful growth of large-area, high-quality graphene films. To meet the growing demands

in applications, mass-producing graphene has been grown in various methods, such as liquid-phase exfoliation, CVD-based growth, etc. However, mechanically exfoliated graphene still shows the highest quality for fundamental science studies. For this project, I learned the mechanical exfoliation method, then studied the influences of various tapes and other variables on the graphene exfoliation. The goal of the project is to increase the yield of ultra-thin flakes for future device fabrications using the Scotch-tape method.\nBy using several different methods such as a surface scan by an atomic force microscope (AFM) and viewing the color contrast by standard optical microscope, the samples' thicknesses were able to be measured. For three distinct flakes, flake 1, 2, and 3, the AFM showed a thickness of 0.70nm, 1.12nm, and 2.64nm, with a root mean square roughness of 0.29nm, 0.20nm, and 0.20nm respectively. As we can see, although these methods were able to create samples that were less than one nanometer thick, they were still unable to create graphene itself. We also used a Python package named Kwant to model graphene's structure and other physical properties.\nMy experiments show that using Scotch tape over the vinyl tape results in several more samples along with thinner ones. The vinyl tape was not as adhesive as the Scotch tape, which may have prevented the samples from being placed on the Polydimethylsiloxane (PDMS) or silicon wafer. Additionally, choosing flakes with a greater surface area along with maximizing the number of "separations" were most effective in creating the best samples.

(B1) Conductive Polymers for Flexible Electronics

Ephraim Weiss, Yutika, Pedro Rocha, Dr. Benjamin Batchelor

This summer, we developed a polymer capable of replacing the Thin-Film Transistor (TFT) to make flexible LCD screens. This polymer exhibits similar electrical properties to metals while retaining the mechanical properties of polymers. The base Shape Memory Polymer (SMP) requires additives to enhance its electrical properties. In our case, I added carbon to SMP-6 to enhance its electrical properties. I tested SMP-6 with a variety of carbon nanotubes and graphene at various concentrations between 0.1%-8%. We measured electrical properties under an applied voltage of 0-5 volts DC, and mechanical properties at temperatures between -20C-250C. The results were promising. The highest concentration of carbon additive in SMP-6 that still retained its polymeric properties was about 8%. I tested two cases of SMP-6 with carbon nanotubes: (1) physically oriented by spinning and (2) electrically oriented under a voltage drop. Early tests with graphene indicated that it would be less satisfactory. I tested the electrical resistance in two experiments. First at constant 5 volts DC, and then sweeping from 0-5 volts DC. The results established that the best-case polymer had the capability to provide a flexible alternative to a rigid TFT. This development might encourage the production of flexible electronics, such as phones, computers, and other devices. In addition to consumer electronics, this alternative polymer may open doors to more flexible and more durable electronic probes, sensors, and other smaller devices.

(B2) Microfabrication Process Compatibility of Sputtered Iridium Oxide Electrode Coatings

Yosef E. Weiss, Justin Abbot, Jose M. Luna Vargas, Dr. Alexandra Joshi-Imre

Electrodes are an essential component of biomedical engineering acting as the interface between electric current and ions in the body fluids and tissues. In the scope of this project, this interface occurs via specific stimulating electrodes implanted into the human body or brain. The electrical characteristics and performance rely solely upon the coating of the electrode as this is the surface in contact with the body.\nThis work explores the potential for iridium oxide coated electrodes to achieve long-term performance superior to the current standard platinum-coated electrodes. These electrodes are implanted in

biological systems, including humans, to stimulate neural tissue. Electrical charge density, storage, and injection capacity all determine the quality of the electrode interaction with biological fluids and ions. When initially created, the iridium oxide film has a high charge storage capacity and high charge injection capacity while simultaneously retaining a low impedance. New iridium oxide coated electrodes clearly exhibit superior electrical properties in comparison with platinum-coated electrodes.\nHowever, their performance advantage dramatically diminishes throughout the manufacturing process during which up to 90% of their charge storage capacity is lost. In order to determine the actual quality of the electrode, I performed electrochemical tests, including cyclic voltammetry, electrical impedance, spectroscopy, and voltage transient. Using all three of these measurements, I determined the charge storage capacity, impedance level, and charge injection capacity. I then inserted my data in a graphing software in order to visualize my data. Once the degradation was quantified, I focused our efforts on developing a rejuvenation process capable of returning iridium oxide coated electrodes to their initial electrochemical performance. This rejuvenation process consisted of cycling a potential across the electrode for about 300 cycles. This voltage sweep refreshed the iridium oxide coating which allowed us to achieve about 99% of the original charge storage capacity. Future work will focus on further improving the rejuvenation process, including both the rate and percent recovery.

(B3) Leakage currents in aged amorphous silicon-carbide-based microelectrode arrays

Shinjini Mukherjee, Negar Geramifard, and Dr. Alexandra Joshi-Imre

Biomedical applications involving the use of thin film microelectrode arrays (MEAs) face numerous failure mechanisms involving the degradation of encapsulation and interlayer delamination. Amorphous silicon-carbide (a-SiC) is an attractive material for encapsulation and promoting interlayer adhesion due to its stability, high resistivity, inertness, and low water permeability. The long-term stability of a-SiC must be predicted before a-SiC MEAs can be implanted to ensure minimum electrochemical change within its period of use in the body. The purpose of this experiment is to measure the leakage currents in a-SiC MEAs using electrochemical impedance spectroscopy measurements (EIS) and DC current-voltage measurements (IV), which can help to predict the long-term electrochemical stability of a-SiC. The aim of the project is to track the insulation properties of a-SiC, acquire EIS data with as little noise as possible, and use the leakage currents data to predict the chronic stability of a-SiC in neural interfaces devices. To test the electrochemical stability of the a-SiC, MEA samples were fabricated in the cleanroom and aged in phosphate buffered saline (PBS) to simulate the body's electrolytes for various times between one week and twenty weeks. All samples were aged at 87 C to accelerate the aging process and to simulate up to several years in the human body. Week 0 samples, or samples with no previous aging, were used as a control group. After taking measurements for each sample, it was observed that the EIS data varied significantly from sample to sample due to differences in manual assembly. It was also observed that the IV data presented three main trends: straight line indicating no leakage, resistor behavior indicating low intrinsic ionic conductivity of a-SiC, and significant leakage at high voltages due to exposed gold, indicating failure in the array. While the IV data presented three different trends, it failed to show correlation between the magnitude of leakage and the aging period. These findings indicate that a-SiC MEAs are stable in accelerated aging experiments and do not degrade from aging, suggesting that failure in the devices is fabrication dependent and a-SiC is long term stable as long as it is fabricated properly.

(B4) Titanium Nitride Microelectrodes on Softening Neural Interfaces

Aditya Chebrolu, Justin Abbott, Jose Manuel Luna Vargas, Alexandra Joshi-Imre

Softening neural interfaces are characterized by their ability to be stiff when dry and soft when implanted and can be used to treat those with nervous system deficiencies and chronic pain syndromes. As a result, they have gained increased relevance in the field of implantable bioelectronics by reducing complications after implantation when compared to previously used rigid neural stimulation & recording devices. Titanium nitride (TiN) has long been used for neural stimulation and recording electrodes due to its high geometrical surface area (GSA) to electrochemical surface area (ESA) ratio and therefore is a favorable material as electrode coatings for softening neural interfaces. However, the thickness of TiN limits bending and conformal placement of the softening neural interface. Therefore, we investigated the effects of varying TiN film thickness on the electrochemical properties of softening neural interfaces. \nWe tested 200 micrometer diameter microelectrodes with TiN thicknesses in the range of 95 to 645 nm. The electrodes were fabricated on 8 silicon wafers with 4 different TiN deposition times: 120, 60, 30 and 15 minutes, on 2 wafers each. The wafers were inspected under an optical microscope to confirm the dimensions of the electrode sites. In-vitro electrochemical characterization of the electrodes was then performed in phosphate buffered saline (PBS) using cyclic voltammetry (CV), electrical impedance spectroscopy (EIS), and voltage transient tests (VT). Scanning electron microscopy (SEM) of a cross section of each wafer was then used to determine the thickness of the TiN coating on the wafer. Thereafter, softening TiN microelectrode arrays were characterized using CV, EIS, and VT measurements.\nOur results demonstrate that microelectrodes with higher TiN thicknesses exhibit lower electrochemical impedance magnitudes as well as higher charge storage capacities and charge injection capacities in a linear trend. However, normalization of all data with the thickness of the TiN coatings showed that microelectrodes with thinner films of TiN had a slightly enhanced volumetric electrochemical quality. According to our measurements, films of TiN as thin as 185 nm can provide a charge injection capacity of 0.156 mC/cm2, which surpasses that of the commonly used platinum and platinum-iridium alloys for neural stimulation. Our findings show significant potential for the use of thinner films of TiN for softening neural interfaces to assist those with neural disabilities and chronic pain syndromes.

(B5) Anti Microbial Oxygen Permeable Bandages

Sanjana Hiremath, Yutika Ravindra Badhe, Dr. Benjamin Batchelor

Wound healing is a complex process with three main phases: inflammation, proliferation, and tissue remodeling. Specifically, the inflammatory stage focuses on destroying bacteria and removing debris, mainly to prepare the wound bed for the growth of new tissue. However, bacteria and other microbes that survive this stage can be detrimental to the wound healing process. This results in chronic wounds, wounds that do not heal in an orderly set of stages and in a predictable amount of time the way most wounds do. The aim of this project is to create an antimicrobial, oxygen permeable film that can be placed in bandages to help deter infections.To get the antimicrobial effect, Iodobutane was utilized as post-polymerization modification to the film. Iodobutane is known to have antimicrobial effects as it is extremely similar to iodomethane in that its polymer composition allows it to bond to the same substances as iodomethane, though with a longer half-life. The film itself was made from the monomer triazole acrylate(TA) because it provides the bonding sites for Iodobutane. The synthesis for TA is through a modified Michael Addition with triazole and methyl. The monomer was confirmed through Fourier-transform infrared spectroscopy (FTIR) and Nuclear Magnetic Resonance (NMR).\n Films were made through modifications of standard shape memory polymer (SMP) formulations with different concentrations of triazole acrylate. After the films were made, the final step was to bind the Iodobutane to the films. However, a model study was needed to establish that the monomer would bind to the iodobutane in the first place. This was done by first modifying the monomer with Hydrochloric and Acetic Acid, and then Iodobutane. Through NMR analysis, both the acids and Iodobutane successfully bonded to the monomer. Following

the model study, the final step was to bind Iodobutane to the films. To bind the iodobutane to the films, the same procedure was followed for the model study, only replacing the monomer with the film.\n Overall, the results from the experiment show that Iodobutane has the ability to bind with the monomer Triazole Acrylate. These results mean that there is potential in creating bandages with new formulations of shape memory polymers. The binding itself is a step forward to achieving the antimicrobial films.

(B6) Secondary Crosslinks for Increased Toughness

Emily Hickman, Yutika Ravindra, Ramya Krishnasamy, Dr. Benjamin Batchelor

Additive manufacturing (also known as 3-D printing), is a modern, efficient process that allows for the rapid and affordable mass production of products. However, this process is lacking in quality, a drawback that prevents this type of manufacturing to be widely used. The development of a new polymer, or plastic, with increased strength and other properties, would bridge the gap between opportunity and usage. My project aims to develop a new polymer that will be stronger and more durable than its previous counterparts.\nSeveral chemicals were mixed together in order to formulate these two new monomers through several steps. The first step combines 1-5 Cyclooctadiene, Sulfur Monochloride, and Sulfonyl Chloride, followed by a reaction with acrylochloride, the resulting solid was a crystalline powder, called 9-TBCD (9-Thiabicyclononane Diacrylate). Once the liquid formulation of each polymer was formed with either of the new monomers, films were created by combining with typical shape memory polymer (SMP). A slide coated with the formulation was placed into two UV ovens, then placed into a post-cure oven to eliminate excess monomers. 9-TBCD tended to react too quickly, so an inhibitor, called BHT (butylated hydroxide), was added. The strongest and thickest film resulted from this combination. It was suggested too that I formulate a similar monomer with different reactive group. The same process was repeated, with the exception of the last step. Instead of the addition of AC, Allyl Bromide (AB) was added, to create 9-TBCA (9-Thiabicyclononane Allyl). This formulation is only partly compatible with the other monomers and makes very weak and thin films.\nThe work completed this summer has made small but influential steps into creating a stronger and more durable material for use in additive manufacturing. The most important aspect of this achievement is that it shows that an acrylate, such as the 9-TBCD formulated this summer, creates stronger plastics compared to the one made with the formulated 9-TBCA. Additionally, the procedures taken to produce both of these monomers can now be easily replicated and/or modified for further experimentation.

(C1) Haptic Trocar Insertion Training Tool

Anirudh Vadduri, Andrew De Costa, Aakash Gadh, Dr. Ann Majewicz Fey

Laparoscopic surgery is growing in popularity throughout the modern medical world. Open surgery is being simplified to small incisions, reducing the risk of contamination. These laparoscopic surgeries rely on trocar insertions, which provide the portal for the surgeon to operate through the patient's skin. A trocar insertion is a delicate operation and is subject to complexities. The intricacies of the forces acting on human tissue, and the sensitive internal organs of a patient, are to be accounted for by the surgeon administering the operation. Surgeons must master their abilities to lower the risk of punctured arteries and organs. The purpose of this project was to create a teaching tool to facilitate the learning curve of this procedure and reduce the risk of surgery complications. We created a Stewart platform, which has six degrees of freedom, in order to accomplish this goal. We collected the force data from a surgeon inserting a trocar and played it back through the device. Our device is programmed to give haptic feedback to the user to simulate the forces of inserting a trocar into a patient. This product is still being developed, and

experiments on the effectiveness of the device have not been conducted yet. To date, no virtual trocar insertion simulator has been fully developed. Since this procedure is new and training methods are still elementary, the creation of a virtual environment, with haptic feedback, will result in improvements in trocar insertion procedures. Amateur and experienced surgeons alike would be able to train in virtual reality (VR) and benefit by reducing the risk of a surgical complication.

(C2) Soft Robotic Device for Gastroschisis Closure

Ella S. Li, Shreyas M. Annaswamy, Manoj Nair, Faisal Qureshi and Ann Majewicz Fey

Gastroschisis is a congenital malformation in which the intestines extend through an opening in the abdominal wall. Currently, successful closure of the abdominal wall is performed routinely thanks to the many efficient methods of closure available, including primary closure, a hand sewn silo bag, a preformed silo, and a spring loaded silo, to name a few, yet clinical controversies remain regarding the optimal surgical management of gastroschisis due to adverse postoperative patient outcomes, such as poor cosmesis, positive fluid balance and metabolic acidosis, greater umbilical hernia occurrences following sutureless closure, and increased hospital stays. As a result, clinical focus has shifted towards reducing those postoperative consequences. We propose a novel device to actively close the abdominal defect by using a soft-robotic, pneumatically controlled curvature changing mechanism. Meant to reduce the overall defect size during healing, potentially improving patient outcomes, this device is designed to change in diameter pneumatically without changing in thickness. We optimized the design of the device using finite element analysis methods and evaluated the physical device through mechanical testing. Since each device is made out of stilicon, we started out by designing a mold consisting of one long chamber with a continuous helical constraint circling the tube. After the design mold was finalized and printed, we created inserts with different sizes in order for the devices to have varying diameters. The finished device has its ends together to form a continuous ring. We plan to test this device three ways through diameter testing, maximum pressure testing, and endurance testing. Once tested, we anticipate this device to significantly improve the recovery and cosmesis of gastroschisis patients.

(C3) Low-Cost Reusable Trocar for Use in LMICs

Layan Y. Dhaher and Ann Majewicz Fey

Minimally invasive surgery (MIS) is preferred over open surgery in most developed countries because it is safer for patients and results in a shorter hospital stay. However, the high startup costs for laparoscopic surgery make it difficult to adopt in low and middle-income countries (LMICs). During laparoscopy, trocars are inserted into the patient's abdomen as ports for other instruments such as cutters and graspers and are also used to inflate the abdomen with CO2. It is common to use four to five trocars per patient to access the abdomen. These trocars are often times not reusable, so new ones are used for every patient. Our goal was to design a reusable trocar from simple parts that can easily be assembled and used in LMICs. We began by analyzing how existing trocars looked and how each part was tied to their roles in laparoscopy in order to understand which aspects of the trocar were necessary to the design. Next, we found simple, affordable parts that would serve the purpose without being excessive. Since our device is reusable, metal was used in order to allow it to be easily sterilized after every use. Our next step is to test the device's ability to inflate something that would resemble an abdomen and hold the pressure for a period of time. We also plan to have surgeons give their opinions on how well they believe it would work and how it compares to existing trocars. Once tested, this trocar will help to significantly reduce the cost of laparoscopic surgery in LMICs, where safe surgery is needed.

(C4) Protective Potential of Exercise on Parkinson's Disease

Laasya Achanta, Erin Venza

The purpose of this research was to review studies that explored physical exercise and its relationship to patients with Parkinson's disease(PD), ultimately to elucidate the protective potential of lifestyle factors against the onset of PD.\nPD is a progressive neurodegenerative disease that results from the loss of dopamine producing neurons in the Substantia Nigra (SN). The symptoms of Parkinson's disease fall under two categories: non-motor and motor symptoms. Non-motor symptoms such as sleep disturbance, diminished sense of smell, and cognitive impairment tend to show up before the hallmark motor characteristics of PD: trembling, instability, rigidity, and slow movements. \nThese symptoms are ultimately caused by neural impairments. Neurons in the SN express concentrations of brain derived neurotrophic factors (BDNF) that modulate brain plasticity, neurotransmitter release, and help induce neuronal depolarization. The loss of neurons in the SN causes an imbalance in the inhibitory pathways of the basal ganglia. This leads to the over activation and increased inhibition of the DA-D2R pathway, which results in the loss of motor skills as well as a decrease in BDNF proteins. Current treatments include surgeries and medication such as Deep Brain Simulation and Levodopa respectively. However, these treatments do not provide a long term solution and they are not without their side effects which range from nausea to heart abnormalities.\nThe presented research suggests that moderate exercise lowers the risk of PD. \nFor patients diagnosed with PD, moderate exercise was found to increase the binding potential of the DA-D2R pathway, which prevents the loss of motor skills. It was also seen that patients who exercised in an individual setting with a physical therapist showed the most improvement in the Physical Performance test when compared to patients who exercised in a home or a group setting, proving that the method of delivery for exercise could optimize its benefits. Additionally, exercise was found to improve the cognition of patients with PD in terms of spatial working memory and verbal fluency, hypothesized to be a result of the increased BDNF. These studies suggest a strong link between exercise and an improvement in cognitive and motor function for PD patients; however, further studies must be conducted to prove that exercise delays the onset of PD.

(C5) Assessing cognitive training programs for childhood cancer survivors: a systematic review.

Neal Reddy, Erin Venza

With the growth of survival rates in childhood cancers in recent decades, attention has shifted towards the prophylaxis and remediation of chemotherapy related side effects. Cognitive impairment affects 33% of childhood cancer survivors in the US, and the neurotoxicity of chemotherapy regimens to treat childhood cancers is well documented (Castellino et al., 2014). From the reduction of white matter volume to the disruption of neurogenesis in the hippocampus, observed impairment in chemotherapy is diverse. The manifestation of this neurotoxicity in different locations in the brain and different cognitive domains examined by various measures varies greatly in the examined literature as well. This review seeks to outline published non-pharmacologic interventions in childhood cancer survivors with cognitive impairments.\nA literature search conducted on PubMed with the key words "cognitive training," "cognitive intervention," "childhood cancer," "chemobrain," and combinations of these keywords yielded 123 articles. Fifteen articles were selected due to their relevance (use of pediatric cancer survivors as subjects and inclusion of a cognitive training program). Of these fifteen articles, three were removed due to them being case studies, four were removed using a non-cognition focused training program such as social skills training, and two were referenced but not analyzed due to being systematic reviews from several years ago. The remaining six articles were examined, and their findings were interpreted.\nOut

of the selected studies, all reported a statistically significant improvement in at least one cognitive domain, more commonly attention and working memory, related to the objective of the program used. Butler et al. (2008) observed a noticeable improvement in attention, as well as academic achievement and incorporation of metacognitive strategies after the implementation of a cognitive remediation program. Patel et al. (2009) noticed a signifcant improvement in several objective performance scores such as the California Verbal Learning Test and Woodcock-Johnson Achievement Test. Three studies found cognitive intervention to significantly improve working memory (Hardy et al., 2010; Hardy et al., 2013; Moore et al., 2012). Whereas Conklin et al. (2015) found significant improvement across measures of attention, working memory and processing speed.\nThe published data suggests that cognitive training programs, online and in-person, have significant potential in helping remediate the cancer-related cognitive dysfunction in pediatric cancer survivors. Thus, cognitive training programs should be considered a viable non-pharmacological intervention for cancer patients with cognitive complaints. Future directions should include developing a singular, effective cognitive training program that consolidates the varied benefits of each of the referenced studies' programs, and further analyzing the pathophysiology that leads to the cognitive complaints to possibly alter chemotherapy regimens.

(C6) Preparation of Protein Crystals for X-ray Crystallography

Hope Giadolor, Virginia Blackwell, Prithwijit Sarkar and Sheena D'Arcy

The cell is the basic building block of life (in structure and function) which is what all organisms are made up of. Think of it as a factory, each structure is like a machine that performs a different task to keep the factory running. The metabolism of a cell makes all of the chemicals necessary for the cell to survive. The molecules produced are amino acids, the compounds that can be added together to make proteins, large molecules made from stringing amino acids together. We take the protein we want and other proteins and perform SEC (Size Exclusion Chromatography) which is a method of separating mixtures and size exclusion separates proteins by their size. Sample passing through the SEC column is collected via fractionation. Samples collected from SEC were run on an SDS-PAGE gel to confirm the presence of the proteins. These gels separate proteins by their size as well, but for analytical purposes rather than preparative. Properly folded proteins recovered from SEC and confirmed by SDS-PAGE were then concentrated and used to set up hanging-drop crystal trays with a variety of conditions. After a waiting period of a few days, drops were then observed under a microscope for the presence of multiple crystals. Certain drops containing prospective protein crystals were selected for recovery, then harvested and frozen. The primary objective is to obtain viable, protein crystals and a reliable structure to support the function of the protein. Scanning of crystal trays showed crystal formation in twenty-one of thirty-eight conditions, with three appearing viable for fishing. Twenty crystals were fished and frozen in liquid nitrogen for future analysis. The preserved crystals will be sent for X-ray analysis to obtain a 3D structure of the protein. We want protein structure since it is critically related to a protein's function.

(D1) The Effects on the Stroke of Carbon Nanotube Based Artificial Muscles

Lauren Pan, Xinghao Hu, Hailee Adams, Varun Menta, Ray Baughman

In the rapidly developing modern world, there is a growing need of actuators that are flexible, capable of bending or changing shape to fill the increasing demand for prosthetic limbs, microscale machines, and robots. New methods for creating carbon nanotube based artificial muscles have surfaced. Starting with a carbon nanotube forest grown on a silicon plate, anywhere from 3 to 15 sheets are pulled in long,

translucent layers. A polymer coating can be added after pulling each layer via a spraying method. After, the nanotubes are uniformly twisted into a very thin threadlike structure, then coiled into testable samples. To test for actuation, the sample is then fixed to a magnetic clamp with a fine platinum wire tied to the end enclosed in the clamp, connected to a screw which prevents the untwist of the sample, and placed in varying aqueous electrolyte solutions or various concentrations. Normally, a three electrode measurement system consisting of a working, counter, and reference electrode is used to actuate the muscle. The reference electrode is either a thick, rigid platinum wire or a Ag/AgCl solution. With this setup, many variables can be changed and tested. For example, a lighter load results in greater stroke. With more strain exerted on the muscle, the ability for it to contract is significantly lessened. As greater loads are applied to the muscle, they start to elongate and are unable to return to their initial state. Additionally, as scan rate, which is the rate at which voltage is applied, decreases, stroke increases. The more time that the voltage of a cycle takes to hit the maximum and minimum preset voltages, the more time the current has to travel through the entire muscle, allowing the muscle to contract and expand to its full potential. At intervals of 10°C, starting at 20°C all the way up to 70°C, scan rate was tested. There was a negative correlation between temperature and stroke, but the peak stroke % correlated with the same scan rate at each temperature. But even with this negative trend, carbon nanotube based artificial muscles are capable of withstanding extreme heat. Lastly, the voltage range was varied. The tests showed the larger the voltage range, the greater the stroke. A larger voltage corresponds with a more powerful current if resistance stays constant. A more powerful current allows for greater stroke. However, if the absolute value of the maximum and minimum voltages are too high, the electricity will cause a reaction in the aqueous electrolyte solutions, releasing hydrogen and oxygen gas, potentially changing the concentration of the solution. Testing all these variables gives an idea of the ideal conditions for this actuator to operate. There are large opportunities to expand electrochemical powered actuation in an ever increasing field of research for real world actuators. These artificial muscles will eventually have wide ranging applications from robotics to implantable medical devices.

(D2) Carbon Nanotubes/Reduced Graphene Oxide Yarn Twist for Energy Harvesting Applications

Griffen Devino and Fernando Machado

Energy harvesting is the process of converting different types of energy into electrical energy and the process by which energy is derived from external sources. Carbon-based structures have promising applications as energy harvesting materials. Carbon nanomaterials such as carbon nanotubes (CNT) and reduced graphene oxide (rGO) have high surface area and excellent electronic properties. These properties make these materials especially suitable for energy harvesting applications, which justifies the use of these materials. The objective of this project was to produce a new composite using carbon nanotubes as a host material and reduced graphene oxide as a guest material for use in energy harvesting.\nFor the production of twistron yarns we drew a CNT sheet (from multiwalled CNT) and attached it to a pane of glass which was previously cleaned and dried. After, a compressed air gun was used to spray the CNT sheet with a previously prepared graphene oxide (GO) solution of either 0.21 mg/ml, 0.7 mg/ml, and 1.0 mg/ml. We repeated these steps for 5 sheets then rolled up the CNT/GO sheets into a yarn and let excess moisture escape to increase the accuracy of the results. After letting the CNT/GO yarn dry it was then twisted for 200 turns and then untwisted, this was to increase the compactness of the yarn and to assist in removing any defects due to the drawing process. We then tested the resistance of the yarn and recorded it. After testing the resistance the yarn was placed in a vacuum chamber and 70-80V of electricity ran through the yarn, reaching 2000-3000°C, for a period of 2, 3, and 4 minutes in a process known as the Incandescent Tension Annealing Process (ITAP). This step converted the GO into rGO, in-

creasing the electronic properties, it also increased the surface area between the bundles of nanotubes. We then removed the yarn from the vacuum chamber and allowed it to cool to increase the accuracy of the results, after which we recorded the post-ITAP resistance. The yarn was then twisted until all of the yarn had a uniform spring index. The twistron was then placed in a container of hydrochloric acid (HCl of 0.1M) along with a reference electrode to check the electrochemical properties for energy harvesting.\n We found that in the 0.21 mg/ml samples the resistance increased post-ITAP, this was likely due to the process damaging the sample and not having enough GO converted to rGO to account for the damage. The best result obtained with 0.21 mg/ml was a peak to peak open-circuit voltage (OCV) of 226 mV at 75% strain. Our best result was accomplished with 0.7 mg/ml of GO using 80V for a period of 2 minutes, reaching a peak to peak OCV of 384 mV at 95% strain, a 130% increase as compared to only CNT without the ITAP. The 1.0 mg/ml sample reached a peak to peak OCV of 275 mV at 110% strain.\n Our best result, 0.7 mg/ml at 80V with a peak to peak OCV of 384 mV indicates a success in a new form of energy harvesting as it is a large increase over the original twistron experiment.

(D3) Effect of Temperature Increase on Spring Constant in Thermal-Actuating Nylon Fishing Line Artificial Muscles

Noah M. Wong, Jiuke Mu, Ray H. Baughman

Thermal-actuating nylon fishing line artificial muscles provide an array of useful properties applicable to many fields of scientific research. These muscles have the ability to contract, bend, and rotate when stimulated by an electric, solar, or ambient temperature change. Most importantly, these powerful nylon artificial muscles are produced by twisting and coiling cheap fishing line and sewing thread, making them more widely and readily available than their expensive alternatives. Current artificial muscle research focuses on developing strategies for understanding linear deformation on its resulting spring constant. A hot-water bath apparatus was developed to affix the muscle to a 20 gram load. While constantly being heated by the increasing water temperature, the muscle was tested for spring constant by measuring the initial actuation and the resultant displacement after adding a second load. Three muscles with differing diameters were tested for spring constant dependence on thermal-actuation; they had diameters of 150□m, 200□m, and 400□m. Spring constant measurements were taken at 10 °C intervals, starting at room temperature and ending at 90 °C. The muscle with a diameter of 400□m had an increase of 190% from its initial spring constant at room temperature. However, the muscle with diameter of 150□m only had an increase of 135%, while the muscle with the diameter of 200□m had an increase of 150% from its initial spring constant at room temperature. It was concluded that actuation and spring constant are directly relational as temperature increases. It was also concluded that nylon fishing line artificial muscles with a larger diameter have a proportionately larger spring constant. The artificial muscles that were developed in this study may be further developed for the applications of minimally invasive robotic microsurgery, extensive robotic exoskeletons, and practical prosthetic muscles.

(D4) An Analysis of the Various Effects of Varying Silicone Solutions on the Contraction Stroke of Carbon Fiber Artificial Muscles

Varun Menta, Huanming Chen, Lauren Pan, Ray H. Baughman

Artificial muscles are a relatively new concept and are at the forefront of science due to their wide range of applications such as medical devices, prosthetics, and implants. To prepare the artificial muscles, carbon fibers are split and infiltrated with a silicone solution. After the silicone solution permeates into the

carbon fiber the solution is then spread throughout the fiber to allow even coiling for the muscle to perform at its peak performance. Silicone being an insulator restricts the current, so the excess solution is removed to allow the current to easily pass through the muscle and provide energy to initiate contraction. Next, the fibers are left at room temperature for 5 hours to allow the silicone to cure. Finally, the cured fibers are coiled and tested to determine the effects of the solution on the muscle and its contraction stroke. To analyze these effects, 3 variables are tested: load(25 - 100 grams), frequency(0.05, 0.1, 0.15, 0.2 Hz), and voltage (4 - 10 V). These variables allow for understanding which solution worked best at low voltage, high voltage, heavier load, faster frequencies, etc. The testing process begins with tethering one side of the muscle to a hook and the other side to a 25 gram load. Then 2 electrodes are attached to the muscle with a distance of 20 mm in between the electrodes. This allows a consistent distance to measure overall contraction. The electrodes are attached to the Gamry Reference 3000 Potentiostat and the Gamry Virtual Front Panel software is used to input voltage into the muscle. A sensor is then used to measure the height of the load and as the muscle contracts, the load is used as a reference to determine the contraction stroke. To determine the contraction stroke the sensor displays the height of the load throughout the contraction, therefore, the highest and lowest points are taken to determine the distance of the contraction. Finally, that number is then divided by the distance between the electrodes, which varies between weights due to the stretching of the muscle, to determine the contraction stroke.\nWhen categorizing the results there are 3 determining factors that determine the best silicone solution. First being the contraction stroke at the heaviest load. Next, the contraction stroke at the fastest frequency. Finally the contraction stroke at the highest voltage, the lowest frequency, and the lowest load to determine the peak contraction of the muscle. The muscle that is made with carbon fiber and Ecoflex outputs the highest contraction at the heaviest load(100g) with a contraction stroke of 22.08%. The muscle that is made with carbon fiber, Ecoflex, methanol, and hexane provides the highest contraction at the highest frequency(0.2Hz) with a contraction stroke of 12%. Finally, the muscle made with carbon fiber, Ecoflex, methanol, and hexane provides the best peak contraction with a contraction stroke of 34%.

(D5) Assessment of the Fluorescent Response of Dyes Towards Transition Metals

Yasash Gorusu and Gordon Irvine

Metal homeostasis is the process of maintaining essential metal concentrations within an optimal range for biological function. To maintain ideal metal concentrations, membrane proteins transport metals from the environment to inside the cell and vice versa. Transition metals such as cadmium, zinc and lead require transport proteins to pass through the membrane. To measure metal transport, fluorescent dyes can be used because their fluorescence intensity changes when binding to metals, which can be measured by a spectrofluorometer. This study sought to determine the optimal dyes for sensing zinc, cadmium, and lead during metal transport in a membrane protein buffer. Indo-1, CaGreen-1, and Fluo-4 dyes were used, as a large change in fluorescence intensity upon metal binding allows for more sensitive detection in complex buffer solutions. The metals were titrated from 0 to 40 □M into buffer solutions containing 10 □M of the dye and compared to the manufacturer's tests whose buffer contained 10 mM EGTA and 10 μM TPEN, which bind calcium and zinc, respectively. The experiments were performed in a buffer containing 1 mM DTT (reducing agent), 20 mM MOPS (buffer compound, pH 7), and 250 mM NaCl. For one set of tests the buffer was treated with chelex resin to remove trace transition metals. For Indo-1 and zinc binding, the manufacturer reported a change in fluorescence intensity of -10%, similar to that observed in our untreated buffer but the opposite response was observed in the chelex-treated buffer. For Indo-1 and lead, the manufacturer reported a +10% fluorescence change, whereas quenching was observed in the untreated buffer and increase in fluorescence was observed in the chelex-treated buffers. For Fluo-4 binding with cadmium, the manufacturer reported a 275-fold increase in fluorescence,

but the chelex-treated buffer showed a smaller increase and the untreated buffer showed the opposite trend. For Fluo-4 and lead, the manufacturer reported a 20-fold fluorescence increase, while the titrations in the membrane buffers showed a similar trend but with much smaller fluorescence increases. The remaining metal titrations were similar to manufacturer's results. Overall, the dyes in the untreated and chelex-treated buffers showed less dramatic changes in fluorescence intensity than suggested by the manufacturer. The metals likely were bound to DTT in addition to the dyes and the different fluorescence trends between the untreated and chelex-treated buffers was due to contaminant metals in the untreated buffer. CaGreen-1 was suitable for all three metals as it exhibited a constant increasing trend and produced large changes in fluorescence intensity. Compared to the other dyes, CaGreen-1 exhibited large changes for zinc (123.57%) in untreated buffer and produced consistent results between buffers. Therefore, CaGreen-1 is ideal to measure metal transport of membrane proteins

(E1) Testing Silk as a Carbon Nanotube Alternative and Improvement to Biosensors

Arushi Mukherjee, Yue Wang, and Zhong Wang

Carbon nanotubes (CNTs) are seemingly perfect: they are incredibly strong, lightweight, and conductive of electricity. They are also incredibly expensive. As a result, scientists are seeking other materials that have the same properties as CNTs. For our experiments, we focused on silk. To increase both the strength and conductivity of silk to the levels of carbon nanotubes, we prepared the silk two ways: carbonization and graphite oxide coating. To carbonize, we burned the silk into carbon under an atmosphere of argon gas. To test strength, we used a motor controller machine to twist the silk into a "twistron" until it coiled over itself or broke. We then attached both ends of the silk to an electric current reader to record the conductivity. Based on this procedure, we found that silk was closest to CNT conductivity when heated to 350°C for one hour and then at 800°C for one hour. Unfortunately, that preparation of carbonized silk was too weak to maintain a coil. We then tried coating the silk in graphite oxide (a highly conductive material), but that conductivity was much lower than that of CNTs. To increase the conductivity but retain strength, we tried coating the sample in chitosan before graphite oxide. With this preparation, the silk had high tensile strength, but the conductivity value was still much lower than CNT levels. We will continue to experiment with how long and in what material the silk should soak in to replicate the strength and conductivity of CNTs.\nWe also experimented with another application of CNTs: biosensors. The type of biosensor our experiment concerns is a glucose biosensor, used for a variety of purposes including blood glucose detection. The accuracy of these sensors depends on the material used. To attempt to improve the accuracy of these sensors, we tested 3 materials: carbonized silk (prepared in the same way as in the strength/conductivity experiments), carbon fiber, and carbon nanotubes. Each of the three materials soaked in a solution of glucose oxidase, the enzyme that breaks down glucose, and methylene blue, which helps transfer the electrons produced in the enzyme reaction between glucose and glucose oxidase. After soaking, we put the materials in a buffer solution (pH 5.5) and recorded the current with and without glucose. Through this procedure, we could see which material facilitated the reaction between glucose and glucose oxidase the best. After many trials, no one material proved to be the best for detection, suggesting that other materials may be more effective to use in a glucose biosensor.\nThrough the first experiment, we were able to narrow down the preparation of silk most similar to CNTs. With the results of the second experiment regarding biosensors, we were able to eliminate silk, CNTs, and carbon fibers as effective facilitators of the enzyme reaction. Both experiments pushed the boundaries of silk and explored potential applications of carbon nanotubes and its alternatives.

(E2) Nuclear Magnetic Resonance: 1 H Relaxation Studies and 13 C Spectroscopic Monitoring of Cancer Metabolism

Esha Bansal, Stuart Malina, Qing Wang, Christopher Parish, Lloyd Lumata

Nuclear magnetic resonance (NMR) is a powerful and non-invasive analytical tool used for\nstructural elucidation and chemical characterization of a variety of materials, including living\nsubjects. Herein, we (nanoexplorers Stuart Malina and Esha Bansal) have studied the factors\naffecting 1H nuclear relaxation of water which includes paramagnetic doping via 4-oxo-TEMPO,\nviscosity via varying glycerol/water content, and the influence of heteronuclear dipolar coupling\nby modifying H2O/D2O content. Furthermore, we have also employed 13C NMR spectroscopy\nto monitor the metabolism of 13C-alpha ketoisocaproate (KIC) into 13C-leucine catalyzed by the\nbranched-chain amino acid transferase (BCAT) in SfXL glioblastoma cells. The high production\nof leucine from KIC is a potential biomarker for glioblastoma which correlates with the\noverexpression of the BCAT enzyme in these cells.

(E3) Benchtop Potentiostat

Joey Spiro, Sanjana Gagrani, Paul Rice, Shalini Prasad

Biosensors are increasingly used to detect and measure different hormones and other chemical substances. For example, diabetics can use a biosensor to provide a continuous measurement of blood sugar concentration. The benchtop biosensor device that our group created is responsible for measuring the concentration of cortisol in a sweat sample. Cortisol is a steroid hormone that is made in the adrenal gland and delivered throughout the body. It is used to control blood sugar levels in order to regulate metabolism, and plays a role in memory formation, the immune system, blood pressure, and other processes. The main method of detection that most biosensors use is impedance, which consists of the quantification of the active and passive components of resistance. To find impedance, there is an application of an AC potential to an electrochemical cell, and the resulting current through the cell is measured. The sensor's method of detecting cortisol in the samples is called Single Frequency EIS which uses a potentiostat to intermittently measure electrochemical impedance at a certain frequency, while an AC potential is being applied to the cell. A potentiostat, the main component of our circuit and device, is an instrument that helps control and regulate the voltage difference between the working and reference electrode. These two electrodes are in charge of measuring each other's potential and controlling where and how the current is measured. The potentiostat is where the sine waves were read and transformed into relevant data. The sine waves, which served as the input and output of the circuit, served to show us the amount of cortisol that came out of the sample. However, the output sine wave had changes in the amplitude and changes in phase compared to the input sine wave. Using the differences between the outputs and the inputs, we were able to calculate the impedance of the liquid on the sensor. In our approach to creating our benchtop device, we used an op amp (operational amplifier) driven circuit with passive components, an ARM processor, gain amplifier, and signal attenuator. We aimed to create a wearable biosensing platform that could measure cortisol levels.

(E4) Measurement of Subpixel Structure

Benjamin Oommen, Kaloyan Penev

This project centered around the detection of exoplanets and making their identification more accurate. One of the main ways to detect exoplanets is to monitor the brightness of stars that exoplanets are orbiting. When a star dims, that is a good indicator that a planet is crossing in front of it. The light of the

stars is received on a detector plane where the response of each pixel can be analyzed. An issue with this method is the fact that the edges of a pixel on the detector plane are not as sensitive as the center of the pixel. If the light from the star were to fall on the edge of a pixel rather than the center, that would cause a decrease in the brightness and add lots of unnecessary noise to the pixel response measurement. A solution to this problem would be to determine the sensitivity of each part of the pixel and mathematically correct for these discrepancies when analyzing the data. \nIn order to solve for a map of the pixel sensitivities, an experiment can be set up in which the wavelength and destination of the waves are predefined. The wave will be directed onto the image plane and converge to its point spread function, which is the distribution of its intensity. This can subsequently be equated to the definition of intensity of a pixel (Point Spread Function), which is the point spread function integrated over each subpixel and multiplied by the respective coefficient, and then summing the integrands for each subpixel. Based on this, we can use a least squares linear regression to solve for the coefficients. Before solving however we modeled the point spread function, which is a convolution between an airy disk and a Gaussian. This convolution was achieved in the most mathematically efficient way possible by using Fourier transforms rather than numerical integration of the convolution integral. Obtaining the Point Response Function (PRF) was also done optimally, by making use of fast fourier transforms to return to the real space. \nThe point spread function and point response function were both successfully modeled, and plotting their values on a graph verified that the desired results were achieved. In order to prepare for future work,a python script that called the C++ PSF and PRF model generation was developed. From this, when given a set of responses and experiment constants, the coefficients of the subpixel sensitivity map were solved for using linear regression.

(E5) Mechanical Properties of Multiwall Carbon Nanotube Yarns with Applications in Thermoacoustics

Sebastian Giordano, David Mueller, Dr. Ali Aliev

The goal of this work was both to document and maximize the mechanical properties of carbon nanotube (CNT) yarns. Previous studies have been published on the synthesis of CNT yarns and their mechanical properties, finding a Young's Modulus (YM) of 30-50 GPa and a Tensile Strength (TS) of 500 MPa or higher for yarns infiltrated with methanol or other polymer solutions. This work focuses on minimizing defects, testing the effect of spinning the yarn under tension, and verifying previous studies. CNT sheets have been used in thermoacoustic films for several years, but CNT yarns have yet to be tested in this field. For this reason, the goal for this research was to synthesize CNT yarn with optimal mechanical properties for thermoacoustic speakers.\nThe CNT yarn is synthesized using densification and applied tension, which, according to previous studies, should increase TS and YM, while being stretched and spun by a motor attached to a traveler. The densification is achieved through a methanol bath, and tension was applied by passing the yarn around three stainless steel prongs. Once the traveler has gone to one meter, the yarn is truncated onto a length of paper backed by any rigid object leaving out the first and last portions which both tend to have the most defects and, in the case of densified yarn, did not enter the methanol bath. Using the paper as a frame for the samples, the yarns are glued down using either epoxy or standard super glue. This process was repeated without tension or densification and only tension to act as reference points. Data was collected using the Instron 5848 MicroTester (Instron). After being clamped onto by the Instron, each type of yarn was put through a test which slowly put the yarn under increasing tension as it was extended, generating graphs that displayed the stress (GPa) versus strain (mm/mm). \nThe yarns tested were drawn from a forest 106 microns tall, and the lengths of the samples were around 12 millimeters. The TS increased from untreated yarn to yarn with applied tension (two prongs) to densified yarn with applied tension as expected. However, one curiosity was that the diameter decreased across

these three types of yarn. While the TSs reflected the desired outcome, the YMs did not. The YM for the untreated yarn was the highest, and the YM for the yarn with applied tension was the lowest.\nWhile the results for both TS and YM were low, it may simply be a result of using a short forest or slipping during testing. Studies have shown that taller forests that generate longer, thinner CNTs are often stronger. The drop in diameter upon the application of tension and densification may be due to an increased amount of rotations during synthesis since the yarn likely got caught on the prongs due to friction. Overall, the results were consistent with previous studies of similarly structured CNT yarns. Further testing should be done using longer and thinner CNTs, increased tension in the synthesis, and different polymers for infiltration.

(E6) Use of Paracoccus denitrificans co-cultures to understand biochemical pathways

Ammar Dharani, Sneha Narvekar, and Stephen Spiro

Denitrification is a microbially facilitated process in which nitrate (NO3-) is reduced to dinitrogen (N2) through a series of nitrogen oxyanion and oxide intermediates. Nitrate and the intermediates (nitrite, nitric oxide and nitrous oxide) function as terminal electron acceptors to allow energy generation by respiration under anaerobic conditions. In this biochemical pathway, four oxidoreductases reduce nitrate successively to nitrite, nitric oxide, nitrous oxide, and ultimately molecular nitrogen. It has been observed in previous co-culture experiments that the reduction of nitrate to molecular nitrogen in the environment does not exclusively require complete denitrifiers but rather a diverse population of partial denitrifiers. Furthermore, studies have indicated factors that affect denitrification activity in soils, including oxygen levels, pH, copper concentrations, and water content. In this study, we use Paracoccus denitrificans, a well-understood soil bacterium and complete denitrifier, to further explore this biochemical pathway and factors that affect it. By co-culturing two Paracoccus mutants, one with nitrite reductase (Nir) and one with nitric oxide reductase (Nor) knocked out, at different ratios, we come to the conclusion that there is efficient cross-feeding of the denitrification intermediates. In addition, our results from growth experiments suggest that nitrate concentration and the inoculum size of different strains are important influences on the growth kinetics and yields of mixed cultures. Understanding the biological denitrification process will be critical to combating climate change, reducing the amount of nitrogen released in wastewater treatment, and developing microbial fuel cells.