Interdisciplinary Materials and Materials Physics REU

Highlight Slides

Magneto-Optical Study of Lithographically Patterned Ferromagnetic Multilayer $(Co/Pt)_8$ Micro-Channels

Alexis Bowers[1], Susan Kempinger[2], Robert Fraleigh[2], Dr. Nitin Samarth[2]

[1]Department of Physics and Geology, Lock Haven University, [2]Department of Physics, The Pennsylvania State University

Controlled domain movement in magnetic structures has recently become very promising for applications in magnetic memory systems and data processing. My project examines magnetic domain nucleation and propagation within a series of lithographically patterned Co/Pt micro-channels with perpendicular magnetic anisotropy (PMA). Magnetic domains are nucleated and then manipulated using out-of-plane sweep protocols and studied in situ using magneto-optical Kerr effect (MOKE) imaging. I fabricated my samples and performed characterizations by superconducting quantum interface device (SQUID), MOKE, and atomic force microscopy(AFM).

I was successfully able to manipulate the samples by applying a biasing field protocol and estimate a domain wall velocity. This summer was a fantastic opportunity and I am very grateful to have been immersed into a lab environment. This experience has definitely help to validate my intentions of attending graduate school.

SYNTHESIS AND MICROPOSITIONING OF 2D MATERIALS

Steven R. Lippold[1], Nestor Perea López[2], and Mauricio Terrones[2,3,4]

[1]Department of Chemistry, Mathematics, and Physics, Clarion University of Pennsylvania, [2]Department of Physics and Center for 2-Dimensional and Layered Materials, Pennsylvania State University,

[3] Department of Chemistry, Pennsylvania State University, [4] Department of Materials Science and Engineering & Materials Research Institute, Pennsylvania State University

Materials limited in one of the dimensions, known as 2D materials, are an area of interest due to their unique properties. Two of these materials, in particular, that is of interest to our study is MoS_2 and WS_2. Of the techniques that can be used to synthesize these materials, one method is chemical vapor deposition (CVD). However, the substrate of the material needs to be able to withstand high temperatures. Because of that, we need a method of transferring these materials to other substrates, as well as for nanodevice fabrication and heterostructures.

My role in this project was to synthesize the material, coat with a polymer, and lift from the original substrate. From there, we have an apparatus that we would use to transfer.

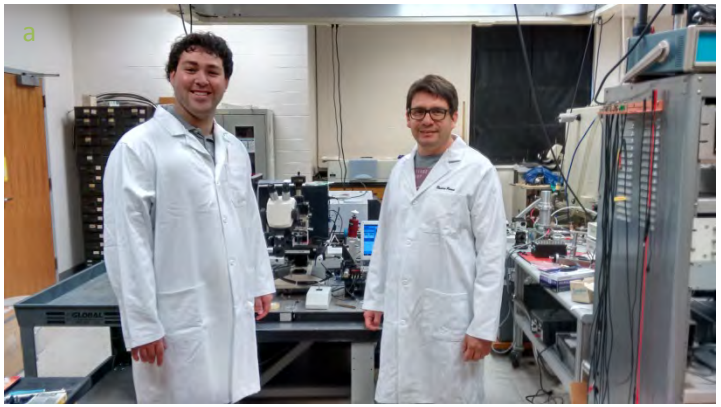
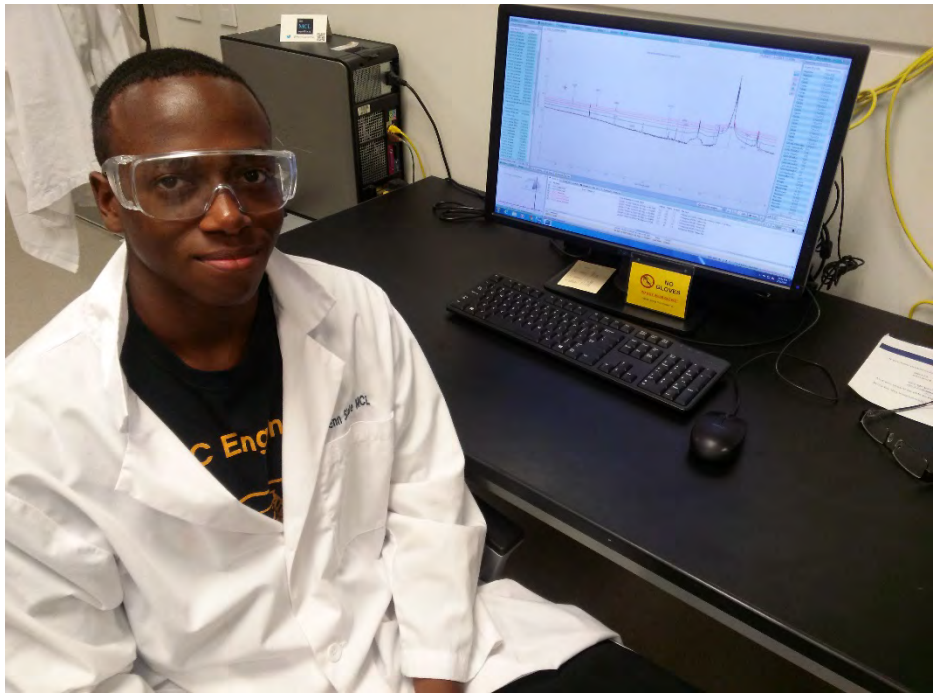


Figure 1: Nestor and myself (a) at the micropositioning apparatus and (b) using the apparatus

This project has impacted my development as a researcher by giving me not only practical experience in research, but also having me learn a variety of chemical methods used in research and given me a better understanding of interdisciplinary research.

Growth of IrO_2 Thin Films

Leonard Jacques, Department of Mechanical Engineering, University of Maryland, Baltimore County
Margeaux Wallace, Dr. Susan Trolier-McKinstry, Department of Materials Science and Engineering, Penn State University

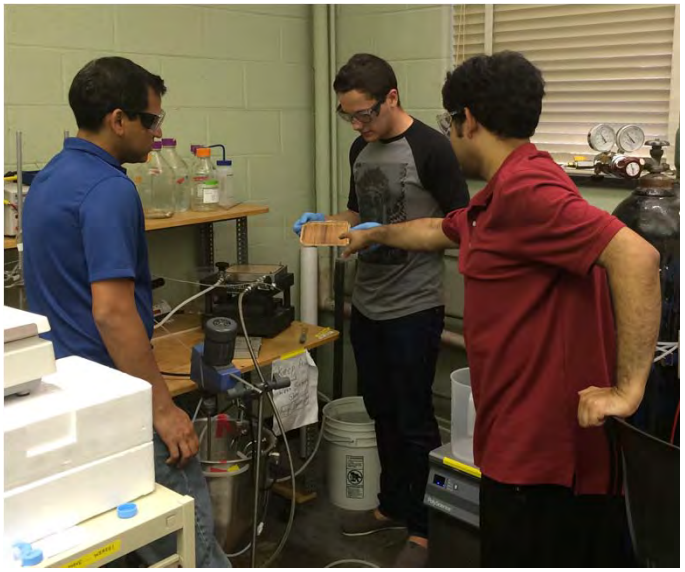


The purpose of my project is to grow iridium oxide thin films for use as top electrodes in ferroelectric devices. Platinum is commonly used as a top electrode in these devices, but IrO_2 offers better adhesion and fatigue properties. I used two techniques to grow IrO_2 thin films. The first technique involved sputtering pure Ir on a layer of Ti, and annealing the film in oxygen to convert the top Ir film to IrO_2. I also reactively sputtered IrO_2 in attempts to deposit a phase pure film. X-ray diffraction was used to determine whether we grew a phase pure film of IrO_2. Characterization of the microstructure was performed using a field emission scanning electron microscope.

It was found that IrO_2 films dewet from the substrate when exposed to high annealing temperatures. Application of a titanium adhesion layer under the sputtered Ir film reduces dewetting and boundering during the annealing process. My results suggest that reactively sputtering IrO_2 on a heated substrate could yield a phase pure IrO_2 film without the need for annealing. My summer project has helped me gain knowledge and skills that classrooms could not. Gaining experience in nanofabrication inspires confidence as I pursue my long term goal of earning a PhD in Materials Science and Engineering.

Enhancing the Fouling-Resistance of Reverse Osmosis Membranes

Lazaro Pacheco, Department of Materials Science and Engineering, Rutgers University
Rajarshi Guha, Dr. Manish Kumar, and Dr. Darrell Velegol, Department of Chemical Engineering, The Pennsylvania State University



Reverse osmosis is a pressure driven process where contaminated water is purified using a semi-permeable membrane. It has been employed as a water purification process for decades now, and fouling, or the accumulation of contaminants on the membrane surface, still remains a problem to reverse osmosis plants around the world.

To combat the problem, we have deposited catalytic nanoparticles onto the surface of commercially available membranes to see their effects on the efficiency of the process. As a membrane is fouled, efficiency drops; our catalytic membranes, however, are capable of cleaning themselves with the simple addition of hydrogen peroxide. These catalytic membranes are a step forward in solving a significant issue in the world of membrane science.

This summer has given me both a glimpse into what it will be like when I enter graduate school and the necessary skills that will be required to get there. It has also taught me the importance of interdisciplinary research, since different disciplines are trained in different ways, and having different backgrounds comprise a group is advantageous to the group as a whole.

Optimizing Charge Transfer State Electroabsorption in Planar Heterojunction Organic Photovoltaics

Emily Skiba, Alyssa Brigeman, Dr. Noel Giebink
Department of Physics, Loyola University Chicago
Department of Electrical Engineering and Computer Science, Penn State University

The mechanism by which excitons dissociate into free carriers via intermediate charge transfer (CT) states in donor-acceptor (DA) organic photovoltaics (OPVs) is not well understood, and a greater understanding is critical to improving photogeneration in such devices. However, CT states are difficult to probe directly yet are imperative for understanding the thermodynamic efficiency limit of OPV devices. While CT electroabsorption (EA) signals have been observed in bulk heterojunction (BHJ) device configurations, a similar signal in planar heterojunction (PHJ) devices is much more difficult to resolve due to a decreased number of available CT states. To circumvent this problem, a new experimental EA setup was designed to increase CT EA signal in PHJ devices. The mechanism posited is twofold: firstly, to maximize photon interaction in the device we increased the optical path length utilizing total internal reflection and a multi-bounce geometry; secondly we increased the electric field across our device using a novel “forked” pattern of cathode and anode prongs.

The new experimental design required optimization of a photolithography process to pattern contacts. This process entailed cleaning substrates then depositing aluminum with an evaporator then spin coating a positive photoresist onto the substrate. I then had to optimize the exposure time, develop, then determine effective etching time with aluminum etchant. Furthermore, a new electronic setup up consisting of high voltage amplifier and experimental setup using prisms to couple light into our sample.

Synthesis and Movement of Catalytic Janus Motors

Darius Stuvaints, Department of Mechanical & Nuclear Engineering, Virginia Commonwealth University
Sambeeta Das, Dr. Ayusman Sen, Department of Chemistry, Penn State University

The aim of this project is to synthesize Janus micromotors, and observe their behavior as motors in a substrate solution. Janus particles are special types of nano- and micoparticles whose surface has two or more distinct physical properties. A motor converts energy into movement. These Janus behave as micromotors in a solution of Hydrogen Peroxide. I was responsible for synthesizing the 4 μm particles composed of fluorescent polystyrene. They were coated with titanium, nickel, and platinum. The platinum coating of the particle acts as a catalyzing agent in the degradation of hydrogen peroxide (H_2O_2) into water (H_2O) and Oxygen (O_2), thus converting chemical into mechanical energy.

This summer research project gave me some insight on what does the life of a graduate student entail. I enjoyed learning in research field that was outside of my major, and grew to understand the importance of interdisciplinary research. This summer confirmed my passion to learn, and revitalize my confidence to apply to graduate school.

Identifying Stable Motifs in Discrete Modeling of Subcellular Networks

Madison Soden

Department of Physics, The University of Miami

Jorge G. T. Zañudo, Réka Albert

Department of Physics, Penn State University

My Research was focused on modeling mechanisms of cell death within human cancer cells by developing an accurate and time efficient algorithm in python to build networks that model the subcellular workings of cancer cells, such as protein interactions, and then reduces the networks until sub-networks that reflect the cell's state can be identified.

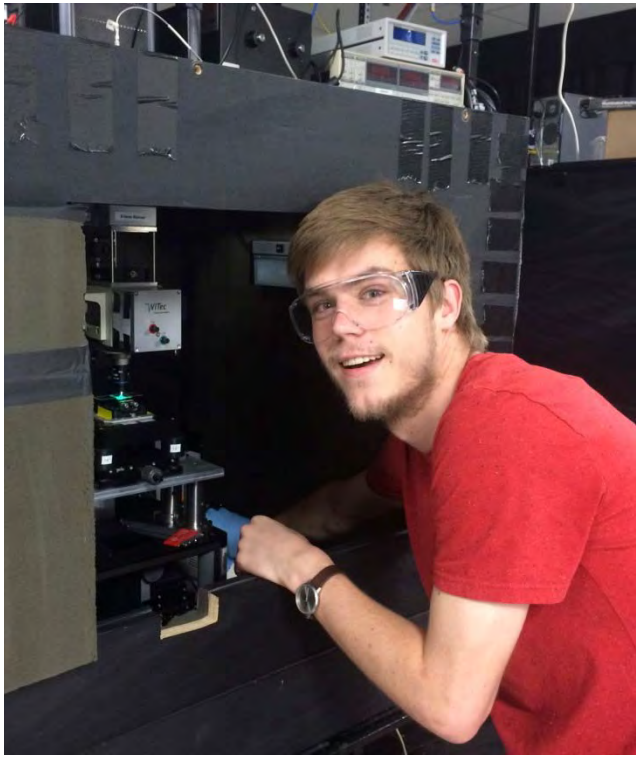
I discovered searching for stable motif patterns in discrete network models is most efficiently accomplished through the incremental growth of the size of the potential stable motifs being searched for and the simultaneous gradual reduction in the complexity of the remaining cycle network as the stable motifs are identified. Additionally, this program helped me further develop my programming knowledge and I learning to use new modeling software and IDEs as well. I also greatly improved my scientific communication knowledge and gained new experience in presenting my research. Furthermore, this program helped me decide that I wish to go to graduate school in biophysics.

Crystalline Germanium Optical Fibers for Low-loss Mid-infrared Semiconductor Waveguides

Ryan Page[1], Xiaoyu Ji[2], Subhasis Chaudhuri[3], John V. Badding[3], Venkatraman Gopalan[2]

[1]Department of Physics, Pacific Lutheran University, [2]Department of Materials Science and Engineering, The Pennsylvania State University, [3]Department of Chemistry, The Pennsylvania State University

Semiconductor optical fibers are fundamental in many fields and applications such as optoelectonics, photonics, and imaging. The wide infrared transmission window, high refractive index (n~4), and high carrier mobility of germanium make it a very attractive material for electronic and infrared imaging applications. However, the large effects of grain boundary scattering on optical loss and conductivity in polycrystalline germanium in current optical fibers prevent their use in many practical applications. Our project was to fabricate germanium waveguide fibers in such a way to reduce and ultimately eliminate grain boundary scattering. We did this using high pressure chemical vapor deposition and a laser annealing technique.

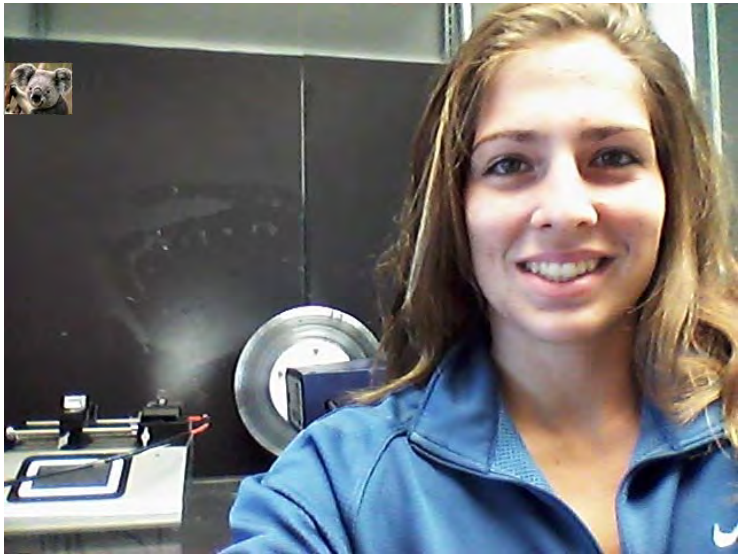


My contribution to the project this summer was to anneal the germanium fibers using an Argon-ion laser over a range of powers to optimize the crystallinity of the core. I was also responsible for extensive characterization of the crystalline and amorphous fibers using Raman spectroscopy and optical loss measurements. Additionally, I used FEM software to simulate our fibers in order to investigate their intrinsic optical losses over a range of parameters such as core width and transmission wavelength. This research experience experience has been an extremely important for my development as a researcher. Coming from a small university, I have had no opportunities to do research at my campus; This project has given me experience that will be extremely useful for job and grad school applications, as well as my future as a scientist.

Fabrication and Characterization of Aligned DEX-loaded PLGA Fibers with Sustained Drug Release for Neural Interface

Miriam Bell, Physics Department, Harvey Mudd College
Milad Khorrami, Department of Material Science and Engineering, Penn State University
Mohammed Reza Abidian, Department of Material Science and Engineering, Department of Bioengineering, Department of Chemical Engineering, Penn State University

When recording electrodes are implanted into the brain, the surrounding tissue reacts as if an injury occurred. The tissue swells and forms scar tissue around the probe, which in turn impedes the electrode's signal and decreases the quality of recording. To overcome this issue dexamethasone (DEX), an anti-inflammatory steroid, is delivered to the regions to minimize impedance and maintain a high signal to noise ratio.



I electrospun PLGA, poly(lactic-co-glycolic acid), fibers loaded with DEX, an anti-inflammatory steroid, and coated with the conductive polymer Polypyrrole, PPy. I varied electrospinning parameters to develop small, homogeneous, and aligned fibers. This project helped build on my previous experience in electrospinning while introducing me to research at a large university. The experience also provided insight into graduate school and its commitments and requirements.

Red Blood Membrane Fluctuations

Nelliza Medero Rojas, Chemical Engineering Department, Polytechnic University of Puerto Rico
Nicholas Frazzette, Dr. Peter Butler, Department of Biomedical Engineering, Penn State University

Red Blood Cells (RBCs) are in constant motion and bending, known as flickering. By bending they are able to pass trough capillaries which are smaller in diameter than RBCs. The membrane bending is dependent of the bending modulus, tension and viscosity. Knowing these properties can help to understand processes that leads to poor circulation of blood.

In this project my objective was to optimize the methods of fixing the RBCs and how to collect the data. I learned how to properly use the Differential Interference Contrast (DIC) microscopy to image the RBCs after they where stuck. Using an optical trap laser I was able to collect the bending data at different laser power and compare them using a program made by my mentor.

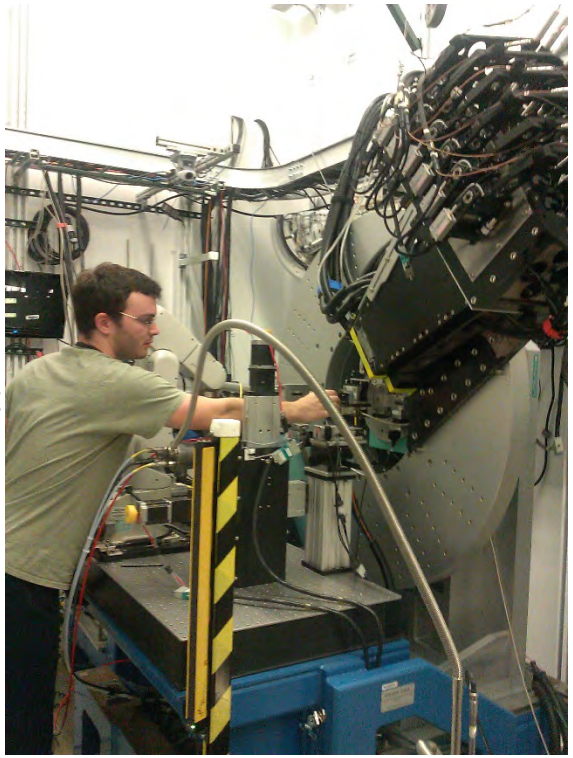
This experience gave me a better perception on how graduate school is about and different ways that engineering can be applied to. Also, it gave me a hands on opportunity to further develop my skills, like managing a research project.

Symmetry and Structural Investigations of HRTiO4 (R=Sm, Eu) Compounds at Low Temperatures

Forrest G. Brown
Department of Chemistry, Physics, and Astronomy, Georgia College
Arnab Sen Gupta, Dr. Hirofumi Akamatsu, Dr. Venkatraman Gopalan
Department of Material Science and Engineering, Penn State University

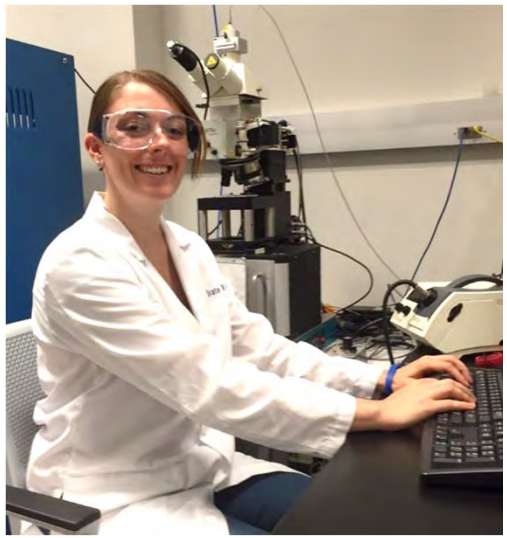
Layered perovskite-like oxides are a rich mine of applicable properties such as catalytic activity, ionic conductivity, high temperature superconductivity, and colossal magnetoresistance. The NaRTiO4 (R=rare-earth metal) compounds were originally characterized as centrosymmetric; but recent low temperature dependent experiments have revealed the acentric and piezoelectric nature of the series. This revelation has spurred a reinvestigation into the true symmetry of HRTiO4 RP compounds. The HRTiO4 (R=Sm, Eu) compounds were first synthesized and then characterized by optical second harmonic generation (SHG) and synchrotron x-ray diffraction.

I contributed to this project by synthesizing each of the two compounds, which involved first a solid state synthesis and then an ion exchange synthesis. Also, I probed the symmetry of HSmTiO4 and HEuTiO4, with temperature dependent optical second harmonic generation and synchrotron x-ray diffraction. My summer project has impact my development as a researcher by allowing me to interact in a research focused environment, which will give me a better idea of what type of research that I may want to do in the future.



Optoelectronic Modulation of van der Waals Solids *via* Metal-to-Insulating Transition Substrates

Kursti DeLello, Department of Physics, University of Central Florida
Yu-Chuan Lin, Dr. Joshua Robinson, Department of Materials Science and Engineering, Pennsylvania State University



Transition metal dichalcogenides (TMDs) are layered materials with the form MX_2, where M is a transition metal, such as Mo or We, and X is a chalcogen, such as S or Se. Recently these materials have been receiving increased attention due to new techniques which allow scientists to isolate layers of TMDs down to the monolayer limit. Monolayer TMDs exhibit interesting optoelectronic properties not seen in their bulk counterparts, making them attractive candidates for a wide range of applications, such as high mobility field-effect transistors, solar cells, photo detectors, and more. Metal oxide materials, such as VO_2 have also been receiving increased attention due to their metal-to-insulating phase transition, generally induced by some kind of strain, such as temperature. VO_2 is especially interesting given that its phase transition occurs near room temperature, ~65^0C. This research aims to explore the interactions between these novel materials by creating a junction between MoS_2 and VO_2, using VO_2 as the substrate, whose phase is modified by increasing the temperature, and observing the photoluminescence response of the MoS_2.

My role in this research was to transfer chemical vapor deposition grown monolayer MoS_2 onto VO_2 using a wet transfer method, and perform temperature dependent Raman and photoluminescence spectroscopy measurements on the samples. This project has given me a better understanding of what it means to develop your own research project efficiently, as well as given me a glimpse into what life will be like during graduate school. I've learned how different groups , and even different departments collaborate on different research projects, and how to approach people for equipment and materials to help me with my own interests. I feel significantly more prepared for graduate school thanks to this experience and I'm glad to have gotten the opportunity to participate in such an excellent program.

Epitaxial Graphene Growth Optimization for Nanoribbons

Karina Keefe, Chemical Engineering, University of Maryland Baltimore County
Shruti Subramanian, Joshua Robinson, Department of Materials Science and Engineering, Penn State University

Graphene is unique because of its many impressive qualities, which range from excellent conductivity to cost effectiveness to near transparency. The objectives of this study were to understand epitaxial graphene growth by rebuilding and utilizing a hot zone furnace, to optimize the recipe for growth of monolayer graphene and eventually graphene nanoribbons (GNR's), and to characterize the graphene produced using various methods. GNR's are an important area of study because they could introduce a band gap to graphene, thus vastly expanding potential applications for future electronics.

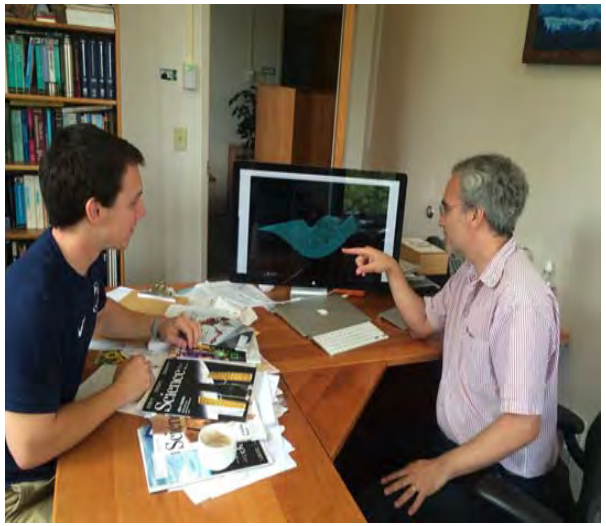
I contributed to the research by preparing substrates for epitaxial graphene growth, assisting with the replacement of various components of the hot zone furnace, and using Raman spectroscopy, atomic force microscopy, and optical profilometry to characterize the graphene produced. The experience helped me better understand the working environment of graduate school and academic research in general. I definitely feel more comfortable in a laboratory setting and more confident in my ability and desire to pursue a graduate degree as well as a career in engineering and perhaps materials science.

Reconfigurable arrays of bistable graphene nanocones created through topological defects

Ryan M. Katona, Department of Physics and Mathematics, Lynchburg College

Dr. Vincent H. Crespi, Department of Physics and Materials Research Institute, Penn State University

Topological defects – changes in the number of atoms in a ring of carbon atoms – have been shown to change the physical properties of a perfect graphene sheet. Pentagons built in to a perfect hexagonal lattice create nanocones that are bistable: they have both upright and inverted configurations. Saddle-like structures are created by interspersed heptagons. Through the use of certain cuts in graphene, the position of these heptagons and pentagons can be controlled. An approach is introduced to create stable arrays of nanocones and nanosaddles. Stitching these flakes together yields many different stable configurations as the upright/inverted state of the nanocones can be controlled.



Throughout this summer I have created many different arrays of graphene nanocones and this has yielded many different stable configurations. We are currently working on forming this graphene sheet to different shaped substrates. Through working on this project, I have learned many computer skills as well as how to work through difficulties in research. Through working with others in the research group, I have a good understanding as to what areas of research I am interested in pursuing.

Synthesis of Interconnecting Graphene and Carbon Nanotubes through Hydrothermal Reaction and Chemical Vapor Deposition

Olivia Vilella, Physics Department, Penn State University
Yu Lei, Kazunori Fujisawa, Mauricio Terrones, Departments of Physics, Chemistry, and Materials Science and Engineering, Penn State University

My research involved synthesizing a 3D interconnecting structure of graphene and multi-walled carbon nanotubes (MWCTs) in order to improve the conductivity of the material. Grapehene oxide was first reduced, then a nanocomposite of the the graphene and metal catalyst (iron and magnesium acetylacetonate) was formed via hydrothermal reaction. Then, chemical vapor deposition was used to deposit MWCTs on the surface of the graphene. Results were varied based on percentage of catalyst, but samples with the desired 3D structure were formed.

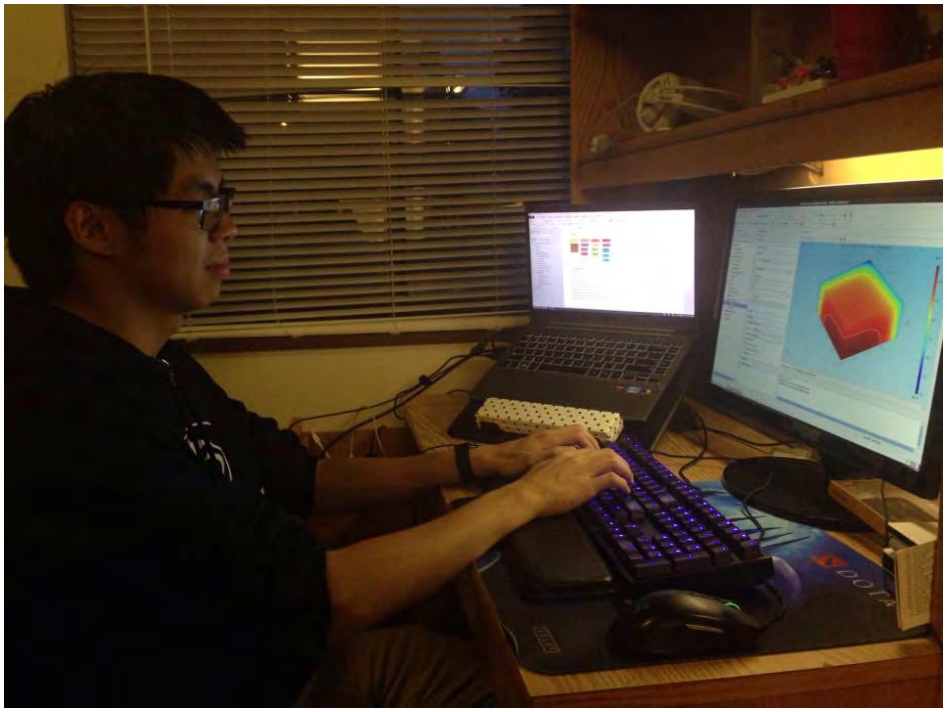
In this project, I worked directly synthesizing the structures, both by hydrothermal reaction and chemical vapor deposition. I also analyzed secondary growth on the image using a scanning electron microscope and energy dispersive X-ray spectroscopy. This was my first research experience, and I was able to develop important lab skills like using certain lab instruments, but also the ability to work with a research group and change my methods when they aren't yielding the desired results. This experience had a large impact on me and even convinced me to change my major from engineering to physics. This experience has been a great opportunity to work in a lab environment in preparation for graduate school.

Combined Numerical and Experimental Method for Developing a Metalized High Temperature Thin Film Polymer Capacitor

Wei Trinh, Department of Physics, University of Maryland, Baltimore County
Dr. Lei Chen, Dr. Long-Qing Chen, Department of Materials Science and Engineering, Penn State University

Capacitors are found in every day technologies, used for energy storage purposes. Being able to create high temperature polymer capacitors is imperative for future use because by nature, polymer capacitors are flexibly, but unable to operate at high temperatures, resulting in large cooling systems.

In this project, I worked on the numerical methods of modeling the capacitor in Comsol in order to examine how a capacitor would act under certain conditions, and deriving conclusions from the model.



The end goal of this project was to produce a set of guidelines for creating capacitors for industrial use, which we were successfully able to generate. This project has shown my much of what it means to be a researcher, and since it was computational research, has shown how research works even outside of your standard laboratory

Development of Aromatic Polymer from Biomass Phenols

Christopher R. Bernard Rodríguez, Department of Chemistry, University of Puerto Rico at Cayey

Adam Brooks, Scott Philips, Department of Chemistry, Penn State University

For years, polymers have been of great interest due to their many applications. Most of the monomers for these polymers are made from petrol-based starting materials and are synthesized using harsh chemical reactions. We wish to develop a polymer with an aromatic backbone from a readily available biomass generated phenol monomer.

Throughout the summer, I spent my time synthesizing a polymer using biological resources. I tested and determined the most efficient way to perform the polymerization. Our results showed that we can obtain both a readily soluble/workable polymer and a resilient insoluble polymer. This research experience has taught me how to better interact with other scientists, it has also helped me improve my lab and English skills. In future graduate studies, I am certain that this experience will be an invaluable one.

Solid-state luminescent cooling in dye-doped polymers

Jeffrey D. Mohan, *Department of Physics & Department of Chemistry, McGill University*
Alex J. Grede, Noel C. Giebink, *Department of Electrical Engineering, The Pennsylvania State University*

Luminescent cooling is the process by which energy is removed from a material – thus lowering its temperature – through the irradiation with light. This technique was used to form the Bose-Einstein Condensate that won the 2001 Nobel Prize in Physics, although the way in which the light cooled the gas is different from the mechanism in the present work. In our system of acrylic doped with the fluorophore Lumogen Red 305 (R305), incident laser photons induce a series of vibronic transitions in R305 molecules that generate higher energy fluorescent photons and ultimately leave the R305 in lower energy states than it started.

With the more developed rare earth-doped glasses, temperatures of 120 K below ambient have been achieved, making practical applications of this technology a real possibility. Luminescent coolers have several advantages over standard thermoelectric coolers and cryogenics, namely they are cryogen-free, contain no moving parts, and organic luminescent coolers specifically are much more appealing because of the abundance, flexibility, and low cost of the raw materials.

I were unable to conclude whether we had cooled or heated our sample under irradiation because we saw both cooling and heating signals in the same samples in different measurements. This interesting result and several others I encountered this summer showed me a very different and important side to being a researcher: that science is a very mercurial process that requires and teaches critical thinking on a level I had not previously encountered. Ultimately, I enjoyed the experience immensely and only want more to make a profession out of research.

The author hard at work

Chemotactic Interactions of Glucose Oxidase and Catalase Based Micromotors

Gabriel I. Vega Bellido, Department of Chemical Engineering, University of Puerto Rico Mayaguez
Erik Jewell, Thomas E. Mallouk, Department of Chemistry, Penn State University

There has been growing interest in the development of autonomous micromotors due to their numerous potential applications as sensors and drug delivery agents. The purpose of this project was to discover the parameters required for an observable chemotactic interaction between different enzyme-functionalized microspheres, in this case glucose oxidase and catalase enzymes. To this end many of these spheres were made, the glucose oxidase beads were assayed using flourometric and spectrophotometric methods, and then both beads were placed in solutions with or without glucose and observed under a microscope for signs of chemotactic interaction.

Throughout the summer I synthesized and studied many sets of particles. I found that the glucose oxidase beads were producing hydrogen peroxide as expected, but the videos of the interaction between the beads were inconclusive in showing chemotaxis. This experience has helped me better understand the workings of a research lab and the process of research. Research is something that requires the ability to tackle a problem from multiple perspectives in order to find a solution, and I look forward to tackling more problems in the future.

Physics Department REU “hosts”

Cell Transcription Site Analysis
Using Fluorescence Microscopy

Christopher Pocetti, Department of Physics, Penn State University
Professor Lu Bai, Department of Biochemistry and Molecular Biology, Penn State University

The goal of this project is to provide more evidence to our lab's model of divergent gene pair expression. In order to back up our theories we need to analyze our microscopic images of yeast cells. This analysis should provide data on the amount, location, and intensity of mRNA binding locations throughout our cell samples. Interpretation of this data could lead to new insights into our models of gene pair expression.

To get this data quickly and easily, I was assigned to write a MATLAB application capable of analyzing our multi-channeled microscopic images. This required a long review of MATLAB functionality and morphological operations. The resulting code I came up with proved to work to our lab's needs. It returned data for each cell detected including mRNA transcription site locations, frequency, and intensities. This experience has definitely gotten me interested in both biology and image analysis. After this program I wish to continue to learn about biological mechanisms and improve my ability to write functional code.

Modeling Highly Dense Space-time

Sheel Patel, Department of Physics, Pennsylvania State University
Martin Bojowald, Department of Physics, Penn State University

To understand highly dense areas of our universe, such as black holes and the big bang, we have strived to combine quantum mechanics and relativity to create a quantum theory of gravity. Loop Quantum Gravity (LQG) does just that. It theorizes that space-time is quantized into these loops. A network of these loops joined together resemble the space-time we see. Curvature and other space-time features could be described by the loops that encloses it. This could help us resolve singularities that occur at black holes and even the big bang.

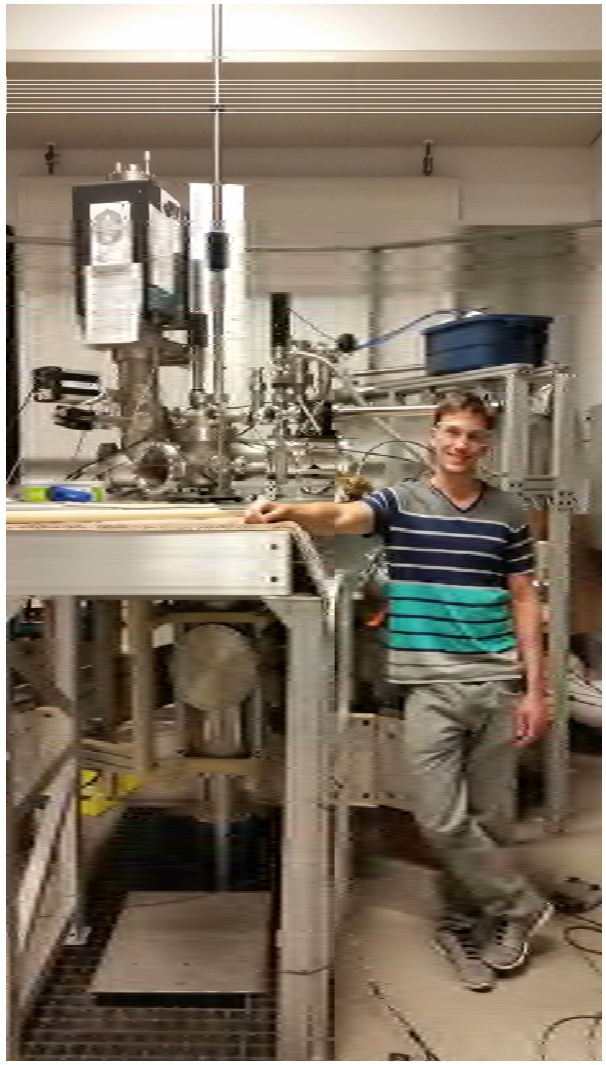
Models in LQG have been constructed to describe the propagation of gravitational waves. I looked at how these waves behaved near the big bang. I took the differential equation that described this propagation and solved it for solutions. These solutions were then fit to specific boundary conditions for continuity purposes. Most of my work was theoretical and dealt with a lot of math. This fell right into my interests as a physics and astronomy double major. I got the opportunity to see how theoretical research is done. I got to work at the forefront of physics in a new field and actually make a contribution. This program provided me with great experience and reminded me why I love physics in the first place.

Noise Characterization of a PTC-cooled Scanning Tunneling Microscope (STM)

Kostantinos Morfesis, Physics, Penn State
Lavish Pabbi, Riju Banearji, Dr. Ivan Skachko , Dr. E.W. Hudson
Department of Physics, Penn State University

The purpose of this project was to determine whether acoustic coupling or mechanical coupling from the PTC(refrigerator) causes the greatest decrease in resolution of the STM. The results indicated mechanical coupling is the greatest source of noise. With this, we can now focus on improving mechanical vibration isolation of the STM. Once improved, the STM will have better resolution for observing microscopic phenomena

My participation in the project consisted of: taking measurements of noise in the STM, and developing/implementing a way of separating acoustic from mechanical noise. The project has increased my interest in physics and helped in deciding graduate school plans.



Search for Jointly Emitting Ultra-High Energy Cosmic Ray and High Energy Neutrino Sources

George Filippatos, Department of Physics, Penn State University
Stephane Coutu, Department of Physics, Penn State University

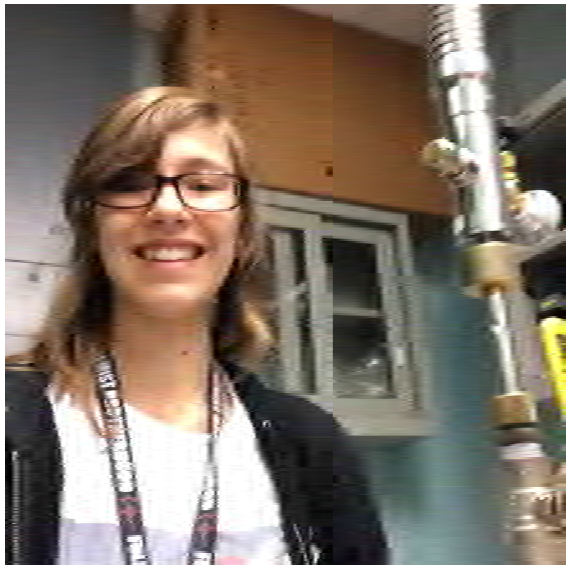
Ultra-high energy cosmic rays (UHECRs) have the highest energy density of any particles in the known universe. They are particles with energies above 10^{18} eV. For reference this is about a million times more energetic than the particles observed at the Large Hadron Collider. The source of these particles is not known, but they are likely to also produce high energy neutrinos.

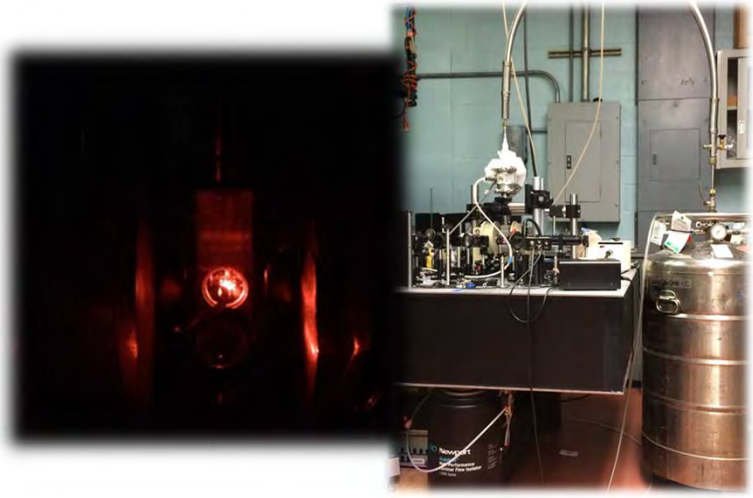
In order to learn more about the origins of these particles we searched for sources emitting both UHECRs and high energy neutrinos. I searched the archival data of the Pierre Auger and IceCube Observatories, detecting UHECRs and neutrinos respectively. After finding only 2 pairs correlated in both time and space in 27,000 events, I preformed the search again on randomized data and found that 2 pairs were statistically likely given the sample size. Therefore it is most likely that these pairs did not originate from the same source.

Photocurrent Generated by Circularly Polarized Light on Topological Insulators

Brittany L. Grimm, Department of Physics, Penn State University
Yu Pan, Dr. Nitin Samarth, Department of Physics, Penn State University

Three dimensional topological insulators (TI) host spin-textured helical surface states within their band gap. The spin momentum locking of the surface states has been probed by using a circularly polarized optical excitation to impart helicity-dependent directionality to a charge photocurrent. Surface electrons in the helical surface states of a topological insulator carry pure spins. By illuminating a sample of TI with a circularly polarized beam, a photocurrent was produced due to the imbalance of photon absorption between electrons with opposite spins. For this experiment, Cr doped (Bi,Sb)2Te3 was explored in hopes of studying the magnetically induced photocurrent on TI at different temperatures. It was observed that with an induced magnetic field, the photocurrent of TI is amplified due to the contribution of photocurrent from the bulk of the material, in addition to the surface contribution, and that this bulk contribution has a temperature dependence such that the contribution increased as temperature decreased. It was concluded that this contribution was due to the breaking of the inversion symmetry in the bulk.





I aligned the optics for use in measuring the photocurrent of the sample, managed the lock-in and electro-magnet, cooled down the sample using liquid helium and a cryostat, ran the programs which took the data and analyzed the data. The PSU REU program made a huge impact on my skills in experimental physics, research practice and ethics, as well as broadened my understanding of modern interdisciplinary research. My hopes are that with the skills I gained here in the REU program, I can get into grad school and be able to continue doing research in physics with the tools I need to succeed. It is my hope that someday I can make a career out of research in physics and begin sharing my passion for the field with other future students and individuals.

Title of Research Project

Zhiyu Yin, Name of Physics, Penn State University
Prof. Stephane Coutu, Sai im, Tyler Anderson, Department of Physics, Penn State University

Description of project and the work performed (shorten your abstract):

The project for me is to carry out a design analysis and proposal for HELIX program, especially to find properties of aerogel blocks and investigate methods to characterize the physical properties of aerogel. And I also help test for ISS-CREAM hardware.

First of all, I refurbished an existing clean room. I also studied the literature about aerogel and to find related issues which are useful for my experiment. Then I designed the project and related experiments. The goals for such experiments is to contribute original ideas on the design and operation of the metrology methods, and assess their accuracy and reliability prior to acquiring expensive equipment, and to determine the availability of needed components, including experimental difficulties and funding limits.

For the other part of my project, test for ISS-CREAM hardware, I have learned Linux and ROOT for the purpose of data analysis. Besides that, I made use of all kinds of tools to manufacture and clean hardware. At the same time, I used software combined with physics knowledge to test the availability of the hardware.

Certain DNA Features Dictate REB1–DNA Binding

Domenick Braccia, Department of Physics & Department of BMB, Penn State University
Lu Bai, Department of Physics & Department of BMB, Penn State University

When conditions are correct, naked DNA in an organism's cell binds to transcription factors (TF) to regulate the expression of genes. One major condition for TF–DNA binding is the contact surface between DNA and that protein, which is determined by its sequence. REB1 one is a well studied transcription factor in yeast, and is known to be a regulator in the RNA pol II pathway. This work focused on determining what nearby, sequence specific content is present in true REB1 binding sites as compared to false REB1 binding sites *in vitro*. By discerning what sequence specific factors are enriched in true REB1 binding sites and tying them to physical changes in DNA conformation, this work has shed light on the mystery surrounding TF-DNA binding preferences in yeast.

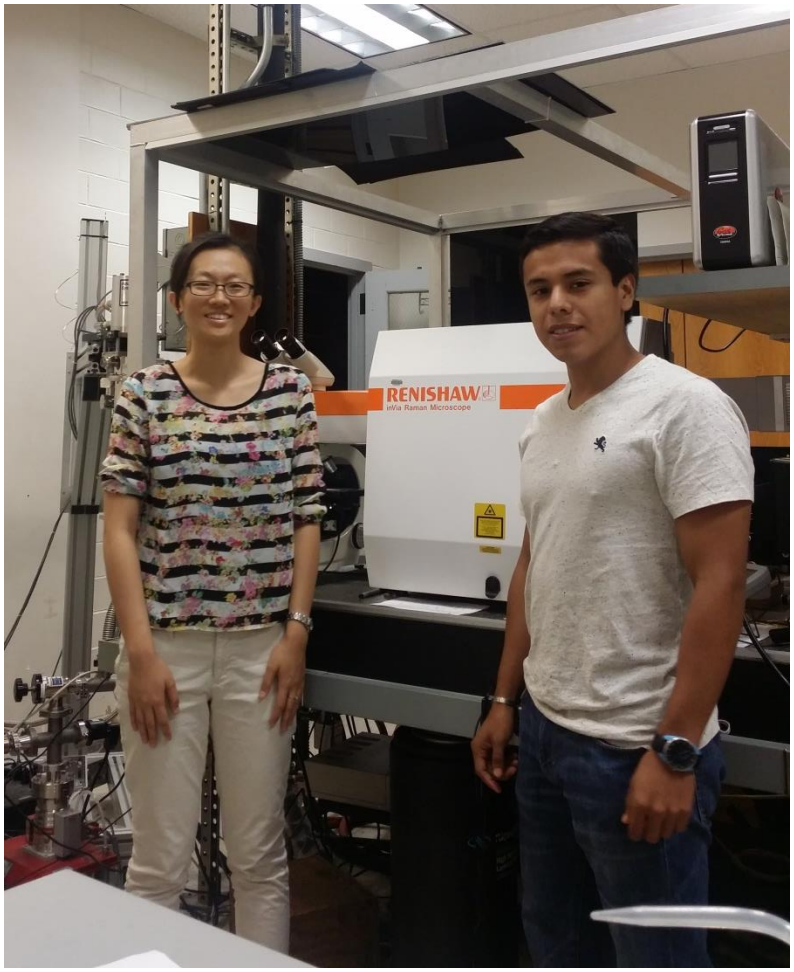
With guidance from mentor Lu Bai, I lead the investigation, performed all of the calculations and created all of the figures in my presentation and poster with the exception of the dinucleotide heat map.

Carbon Nanotube Enhanced Oxide Macroscopic hybrid Film by Bar Coating Method

Armando Moncayo[1], Yu Lei[4] , Kazunori Fujisawa[2,4] and Dr. Mauricio Terrones[2,34]

[1]Department of Physics and Math, Iberian-American University, Mexico; *[2]Department of Physics, [3]Departament of Chemistry, [4]Department of Material Science and Engineering, The Pennsilvanya State University, USA.*

Graphene Oxide has become an attractive bridge for fabricating graphene-based functional materials since it is relatively easy to reduce Graphene Oxide (GO) into Graphene, and moreover it can be produced in bulk quantities. The attributes of two allotrope structures of carbon were fused in one hybrid material, five varieties of Carbon Nanotubes (CNT's) were dissolved in aqueous solution of GO at different concentrations, in order to create a carbon nanotube network over the GO matrix.

The optical, electrical, mechanical and morphological proprieties of the hybrid film were characterized. It was possible to dissolve CNT's avoiding the use of a surfactant that can affect the mechanical properties of the film, the carbon nanotubes were effectively dispersed in aqueous solution by ultrasonication and attached to the GO films forming a network; the resulting solution has the proper characteristics to form big area films by Dry Film Scrolling method.

Not only has the REU experience given me a wider view of the mechanisms that rules science research but it has also encouraged me to cotinue my studies in grad school.