UNDERGRADUATE RESEARCH SYMPOSIUM

COLORADO SCHOOL OF MINES
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2019 | PROGRAM

APRIL 26, 2019
1-3 PM
COORSTEK FOYER

Poster session showcasing research by undergraduate students from all disciplines across Mines.

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SECOND ANNUAL
UNDERGRADUATE RESEARCH SYMPOSIUM

Celebrating accomplishments of our undergraduate student researchers and their mentors.

UNDERGRADUATE RESEARCH SYMPOSIUM

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WELCOME

Dear Mines Community,

It is my pleasure to invite you to the second annual undergraduate research symposium.

Undergraduate research symposium provides an excellent opportunity for our students to present their scholarly work and engage with the Mines community. At our inaugural symposium last year, we had 80 poster presentations, and the breadth and depth of the students' work on display was outstanding. This year you'll witness another intellectually stimulating day as you interact with our student researchers, who are presenting over 115 posters, representing all departments across Mines.

I would like to acknowledge the faculty mentors at Mines who embrace inquiry-based learning by engaging undergraduate students in research. Their unwavering dedication to undergraduate research and our students' eagerness to engage in learning through discovery are what makes today possible.

Mines community is grateful to CoorsTek for sponsoring and participating in the symposium this year!

Congratulations to all the students who are presenting today.

Thank you all for joining us to celebrate our exceptional students and their dedicated faculty mentors.

Lakshmi Krishna
Interim Director of Undergraduate Research

TECHNICAL PROGRAM

APPLIED MATHEMATICS AND STATISTICS

1 Calculus on Discrete Fractional Difference Operators

Author: Michael O'Leary, Senior, Applied Mathematics and Statistics
Faculty Mentor: Kevin Ahrendt, Applied Mathematics and Statistics

We will present results related to the continuous derivatives and integrals with respect to order of discrete fractional difference operators. In particular, we will examine the differentiability of these operators at integer value endpoints. These results also allow us to compare the rates of change of these derivative structures, and additionally can be used to fit these operators to real world data.

2 Using a Mathematical Model to Study Blood Clotting in Hibernating Ground Squirrels

Author: Emily Novak, Senior, Applied Mathematics and Statistics
Faculty Mentor: Karin Leiderman, Applied Mathematics and Statistics

When ground squirrels hibernate, they may sustain body temperatures of approximately 5C for weeks at a time. Along with the decrease in body temperature, other biological changes occur including a decreased heart rate, which decreases blood flow, and a decrease in the production of several plasma proteins important for blood coagulation. Due to the low blood flow, it is thought that hibernating animals would be at higher risk for developing blood clots, since blood stasis is a known contributor of this risk. The goal of this project was to use a mathematical model of flow-mediated coagulation is to investigate how the temperature, flow, and plasma levels of coagulation proteins, each affect blood clotting during hibernation; clotting was assessed by measuring the model's output of the coagulation enzyme, thrombin. We first determined the temperature dependence of the kinetic rate constants involved in coagulation by using the Q10, and the temperature dependent scaling of the diffusion coefficients for the plasma proteins. Next, we verified that our model showed a substantial clotting response under normal conditions and no clotting response under hibernating conditions. Finally, we identified temperature as the most critical factor in determining whether or not a clotting response would occur.

3 Modeling the Synchronization of Cilia Outside a Sphere

Author: Miika Jarvela, Senior, Applied Mathematics and Statistics
Faculty Mentor: Karin Leiderman, Applied Mathematics and Statistics
Faculty Mentor: Forest Mannan, Applied Mathematics and Statistics

Cilia are hair-like appendages attached to microorganisms that allow the organisms to traverse their fluid environment. The algae Volvox are spherical swimmers with potentially thousands of individual cilia on their surface and the cilia coordination is poorly understood. In this work, we developed a mathematical model of cilia on the outer surface of a sphere submerged in a fluid. The goal was to determine if factors related to the spherical shape affected cilia synchronization. We modeled each beating cilium tip as a small rotating sphere, attached to the surface by a spring. This was achieved by using numerical approximations to regularized fundamental solutions of the Stokes equations defined in a region outside of a sphere. Previous models showed synchronization when cilia were attached to a sphere but this was largely because the cilia were beating in the same direction all the way around the sphere. It is known that Volvox cilia beat toward one pole, where some cilia are beating in opposite direction, which somehow helps with directed motion and rotation. By including more biologically realistic assumptions about ciliary beating in our model, we were able to simulate and understand how groups of cilia synchronize to aid in directed motion.

4 Landau Damping

Author: John Corrette, Senior, Applied Mathematics and Statistics
Faculty Mentor: Stephen Pankavich, Applied Mathematics and Statistics

In physics, there is a process in which an instability in a plasma system is resolved exponentially, known as "Landau Damping". In short, when a stable system of plasma is perturbed, the system will return to a stable state in exponential time. In this project, we studied how the different parameters in our perturbation (amplitude, frequency, mean and variance) affected the damping rate of the system. For my part of the project, I studied the case of a "Maxwellian Equilibrium," which is a narrow-tailed distribution similar to that of a normal distribution. To study this equilibrium, we used a numerical "particle-in-cell" method in order to numerically determine the damping rate as described by the Vlasov-Poisson system of partial differential equations. Once we created code for this method, we used the school's supercomputer "Mio" to run numerous simulations in parallel in order to do a process known as global sensitivity analysis in order to determine how sensitive the damping rate of a given sample equilibrium was to the four given parameters. Once this process has been completed, we should be able to analytically determine how a perturbation can affect the process of Landau Damping in a sufficient and numerically accurate manner.

5 Modeling Glycerol Dynamics During an Oral Glucose Tolerance Test

Author: Kate Bubar, Senior, Applied Mathematics and Statistics
Faculty Mentor: Cecilia Diniz Behn, Applied Mathematics and Statistics

In a fasted state when glucose is not readily available, the body undergoes lipolysis, a process in which adipose tissue is broken down to be used as source of energy. Lipolysis results in the release of glycerol and free fatty acids into the bloodstream. Insulin resistance in adipose tissue affects the suppression of lipolysis. Our objectives were to model the glycerol dynamics during an oral glucose tolerance test with a stable glycerol tracer to explore methodologies to quantify adipose insulin resistance. We used a one-compartment model in which the rate of glycerol enrichment is given by a glycerol concentration-dependent clearance and an implicit insulin-dependent rate of appearance. Our model reliably describes our dataset and estimates the glycerol rate of appearance in insulin resistant patients and the control group.

6 A Mathematical Model of Surface-Mediated Enzyme Inhibition Under Flow

Author: Jayde Thompson, Senior, Applied Mathematics and Statistics
Author: Shannon Bride, Senior, Applied Mathematics and Statistics
Faculty Mentor: Karin Leiderman, Applied Mathematics and Statistics

Damage to a blood vessel triggers a cascade of events within the vessel wall. The cascade of events is commonly known as the coagulation cascade. This cascade begins when an integral membrane protein called tissue factor (TF) is exposed and interacts with proteins in the plasma. These interactions produce enzymes that amplify and stabilize the coagulation process. One of these stabilizing processes is called the tissue factor pathway inhibitor (TFPI), and it regulates blood coagulation primarily by inhibiting the enzyme production formed at the injury surface. Previous mathematical models of the coagulation cascade underflow have shown this stabilizing mechanism to be weak in comparison to the removal of enzymes by flow itself. However, these studies were limited to small injury sites, resulting in small TF patches. In this project, we used the finite element method to simulate advection-diffusion-reaction equations that represent the surface-mediated coagulation events. We then investigated how the enzyme production in the presence of TFPI is affected by various injury sizes, flow rates, and densities of the exposed TF.

ARTHUR LAKES LIBRARY

7 Do Researchers Always Cite the True Sources? A Case Study on Citing ResearchGate

Author: Andrea Golden-Lasher, Junior, Computer Science
Faculty Mentor: Emily Bongiovanni, Arthur Lakes Library

Scholarly networking sites provide not only a social network and profile service to connect researchers, but a public repository to share academic work. With millions of scholars utilizing these platforms, major scholarly networking sites such as ResearchGate are changing the digital research information ecosystem. This study examines two behaviors that are connected to the ability to publicly access research through sites like ResearchGate: how scholars are citing work found on ResearchGate and how the copyright integrity of uploaded content is maintained. We investigated how 331 ResearchGate records are cited in external articles and identified whether ResearchGate is the true original source of the content. Of the 304 locatable ResearchGate records, only 19 articles had no identifiable true original source and had a researchGate DOI, indicating they were legitimate citations of ResearchGate. Additionally, 54 copyrighted articles had a full-text version available on ResearchGate without clear acknowledgement of reuse permission. Proper citation and uploading behavior are integral to a healthy research environment through crediting the original source of information, contributing to the citing work's credibility, and providing researcher visibility. These findings provoke consideration of how improper content sharing through ResearchGate can effect a reproducible and credible digital research ecosystem.

CHEMICAL AND BIOLOGICAL ENGINEERING

8 Origin of Replication of Synechococcus so. 7002

Author: Jaclyn Whalen, Sophomore, Chemistry
Author: Gabrielle Griner, Sophomore, Chemical and Biological Engineering
Author: Cameron Sneddon, Sophomore, Biochemistry
Author: Soren Loyland, Sophomore, Chemical and Biological Engineering
Faculty Mentor: Josh Ramey, Chemical and Biological Engineering

This research is attempting to determine the origin of replication on the Paq-1 plasmid of Synechococcus sp. 7002. It is a continuation of research conducted by another group last year. The potential Ori site has been transformed into a TOPO plasmid and it's replicating properties will be tested using growth plates with ampicillin.

9 Molecular Mining for Cadmium

Author: Benjamin costa, Sophomore, Chemical and Biological Engineering
Faculty Mentor: Nanette Boyle, Chemical and Biological Engineering
Faculty Mentor: Josh Ramey, Chemical and Biological Engineering

Heavy metals in soil and groundwaters from former mine sites present a large environmental threat. Cadmium, commonly found at these sites, is detrimental to the surrounding flora, as well as livestock and humans, where it can cause kidney, bone, and lung disease. The goal of this project was to develop a rapid, selective, and sensitive cadmium sensor and binder to determine the concentration and then remove the cadmium present in mine tailings. The sensing gene and promoter (cadC) was sensitized via IDT and placed in a pUCIDT vector. The E. coli cells containing the pUCIDT plasmid were then grown while exposed to cadmium, and the GFP expressed was measured using a plate reader. The binding peptide sequence which mimics a metallothionein was synthesized as an IDT Gene Block, and pMAL was obtained. However, testing revealed that the sensing results did not match literature values and the pMAL inhibited cell growth.

10 Studying Rhodopsin Structure

Author: Brandon Reynolds, Junior, Chemical and Biological Engineering
Author: Tommy Gerson, Junior, Chemical and Biological Engineering
Author: Chandler Seamount, Junior, Chemical and Biological Engineering
Author: Gage Morrison, Junior, Chemical and Biological Engineering
Faculty Mentor: Josh Ramey, Chemical and Biological Engineering

Rhodopsin is an essential protein found in eyes, and it uses a disulfide bridge to stabilize its structure. Using genetic engineering, this disulfide bridge can be interrupted, by changing amino acids in the primary structure and creating a new disulfide bridge in a different place or slightly changing the secondary structure of the protein in such a way that it breaks the disulfide bridge. By introducing changes in the primary structure, we can effectively determine whether or not the disulfide bridge is essential to the structure and function of rhodopsin.

11 Combinatorial Synthesis of $Mg_xZn_{1-x}O$ Thin Films for Use in CdTe Solar Cells

Author: Gavin Yeung, Junior, Chemical and Biological Engineering
Faculty Mentor: Colin Wolden, Chemical and Biological Engineering

CdTe-based solar cells are the leading commercialized thin film photovoltaic technology. This technology has the potential to exceed 30% PV cell efficiency. One strategy to improve efficiency has been to replace the conventional CdS window layer with transparent alternatives. This talk describes our development of alternative window layers by reactive sputtering of metal targets. We have focused our initial work on magnesium zinc oxide (MZO). MZO has been shown to be effective in CdTe solar cells, but there are conflicting reports on what the optimal alloy composition ($Mg_xZn_{1-x}O$) is for this application. First we established optimal power and Ar:O_2 ratio for reactive sputtering of the individual ZnO and MgO thin films. We then developed approaches for the combinatorial synthesis of MZO libraries through reactive co-sputtering. MZO libraries with a band gap variation of more than 0.5 eV across a 3-inch substrate were fabricated, as validated by X-ray diffraction and optical band gap analysis. These libraries were then substituted for CdS and integrated into our standard CdTe solar cell fabrication sequence. Preliminary optimization has yielded devices with >15% efficiency using MZO having a band gap of 3.5 eV, which is correspond to alloy composition of x ~0.12.

12 Yittria Stabilized Zirconia Supported Ru Catalysts for Ammonia Synthesis

Author: Sarah Livingston, Junior, Chemical and Biological Engineering
Faculty Mentor: Douglas Way, Chemical and Biological Engineering
Faculty Mentor: Colin Wolden, Chemical and Biological Engineering

Ammonia (NH_3) is critical to today's society because it serves as the raw material for fertilizer production. Conventionally, NH_3 is produced through the well-known Haber-Bosch process at temperatures and pressures such as 400-500°C and 100-150 bar. Such critical reaction conditions and massive scale production (145 mt of NH_3 in 2014 globally) together make NH_3 synthesis one of the most energy extensive processes in the world, consuming 1-2% of the total energy expense. YSZ is a more active Ru catalyst support than traditionally used supports such as Al_2O_3. Cs as a promoter increases the reaction rate up to an order of magnitude higher by reducing the apparent activation energy from 123 kJ/mol to 75 kJ/mol. This rate enhancement is insensitive to the amount of promoter addition, with Cs outperforming Ba and K by up to 2 times. At low temperatures (< 350°C) the rate becomes inhibited by H_2 absorption, but the use of lower H_2:N_2 ratios enables the rate to remain comparable to what is observed in stoichiometric mixtures at temperatures > 400°C. Relative to a typical ratio of H_2:N_2= 3, operating at an optimized H2:N2 ratio enables a positive pressure dependence of the reaction rate, especially at temperatures < 350°C. The superior performance of the YSZ supported Ru catalyst suggests that it is promising for innovative NH_3 synthesis processes operating at reduced temperatures and pressures.

13 Platelet-Neutrophil Targeting Nanoparticles for DVT Treatment

Author: Nicole Masters, Senior, Chemical and Biological Engineering
Faculty Mentor: Keith Neeves, Chemical and Biological Engineering

Deep vein thrombosis (DVT) is a serious thrombotic event that typically occurs when individuals do not move their legs for extended periods of time, such as sitting on a long airplane ride. Due to the nearly invisible, deep tissue nature of this event in combination with the need to still be able to allow for coagulation, it is advantageous to create a targeted treatment. Nanoparticles coated in platelet and neutrophil targeting peptides present a possible method for targeted treatment. A microfluidic device with a simulated valve pocket of 150° was utilized along with whole blood with Reynolds flow of 10 to compare the results of these targeted nanoparticles to nanoparticles with non-targeting peptides. From these experiments, it became evident that the targeted particles become immeshed within the clots forming in the pockets significantly more than the non-targeted particles, which typically were trapped within the fibrin or dense NET formation. Because the nanoparticles were not tested for therapeutic purposes, the targeted nanoparticles did not always lead to a reduction in platelet accumulation and NET formation. However, the statistically significant difference between the build-up of the targeted as compared to the non-targeted nanoparticles indicates that this method of drug targeting shows promise.

14 Conversion of Lipid Biomass to Liquid Biodiesel over Mesoporous Nickel Oxide Catalysts

Author: Courtney Smoljan, Sophomore, Chemical and Biological Engineering
Faculty Mentor: Moises Carreon, Chemical and Biological Engineering

In the production of lipid biodiesel, lipid biomass is converted to heptadecane during deoxygenation reactions Lipid based diesel fuels have been estimated to provide up 70% reduction in CO_2 compared to conventional petroleum fuels. Good results have been obtained over noble metal catalysts, like zeolite supported platinum in hydrogen atmospheres. However, platinum is nearly 400 times more expensive than nickel. The purpose of our project is to develop an inexpensive, non-noble metal catalyst that can help reduce CO_2 emissions and leverage new bioresources. Currently, we are synthesizing mesoporous nickel-oxide catalysts via solvothermal methods. Our catalysts are exposed to a batch reaction with model fatty acids representing realistic biomass reactants in a hydrogen rich atmosphere. Initial results show a 36 wt% yield to heptadecane. The catalysts are calcined and reused to observe the recyclability.

15 Surface Reactions in Plasma-Assisted Etching with UV-light Enhancement

Author: Jonathan Newcomb, Senior, Chemical and Biological Engineering
Faculty Mentor: Sumit Agarwal, Chemical and Biological Engineering

For solar cells to remain an economically viable clean energy source, the levelized cost of electricity must reach \$0.02-0.03/kWh by the year 2030. Currently high efficiency solar cells such as the interdigitated back contact (IBC) cell are produced in various academic and national labs in a complex and expensive device fabrication sequence that cannot be scaled up to a commercial setting. Processing improvements are needed to drastically lower the overall production cost.

Currently, fabrication of an IBC solar cell requires pattern transfer from a photomask onto the substrate in a process known as photolithography which drives up the cost of the solar cell. Thus, IBCs need to be fabricated without the photolithography step to become competitive. One proposed method relies on selective photo assisted etching and deposition. However, prior to the implementation of photo assisted processing, the underlying surface phenomena needs to be understood. We constructed a reactor complete with a UV-light source and in situ attenuated total reflection Fourier transform infrared spectroscopy (ATR FTIR). From the infrared spectra taken over the course of the etching and deposition process, we can determine the overall surface reactions and effect of the UV-light source on the process.

16 Functionalized Nanoparticles as Effective Gas Hydrate Anti-Agglomerates

Author: Brittany Slupe, Senior, Chemical and Biological Engineering
Faculty Mentor: Ning Wu, Chemical and Biological Engineering

Gas hydrates are water molecule ‘cages’ that trap gas in pipelines at elevated pressure and low temperatures. Their formation and agglomeration in flowlines can result in increased fluid viscosity, large pressure drop, and eventually blockage of the flowline, which will endanger the production. Due to this, there has been extensive research on how to mitigate this risk, and anti-agglomerates (AA) are typically used to create a flowable hydrate slurry. However, AAs are typically quaternary ammonium salts and have negative environmental impacts. Here we are investigating the potential of functionalized nanoparticles (NPs) as a novel class of AA. NPs are of interest because of they can form more stable “Pickering” emulsions to protect hydrate particles and can be easily recycled. To determine if functionalized NPs can be used as AA, we have; (1) synthesized and characterized functionalized NPs, (2) studied the impact of NP hydrophobicity determined the best method for recycling magnetic particles; and (4) imaged the emulsions under optical microscope before, during, and after recycling to prove reusability and emulsion stability. Preliminary results indicate the surface modified NPs stabilize water in-oil emulsion droplets during cyclopentane hydrate formation and dissociation, and the adhesion between droplets is minimal. Also, the magnetic particles have shown to stabilize water-in-oil emulsions and can be recycled through various methods to form new emulsions. This project combines nanoscience with the field of gas hydrates in order to overcome a very important problem in the petroleum industry.

17 Genome Scale Metabolic Modeling of C. zofingiensis

Author: Anthony Nagygyor, Senior, Chemical and Biological Engineering
Faculty Mentor: Nanette Boyle, Chemical and Biological Engineering

Climate change is an extremely large and complex issue, requiring the development of solutions to a multitude of different problems. One such problem is figuring out how to create alternative sources of energy and chemicals that are sustainable over the long term. C. zofingiensis, an alga, can provide part of the solution by being a renewable source of triacylglycerols (TAGs), a biodiesel precursor, and astaxanthin, a value-added nutraceutical. In order to understand C. zofingiensis’s potential for genetic alteration, to enhance the production of these metabolites, a genome scale model can be constructed to accelerate learning about viable pathways. However, genome scale models can be quite laborious to construct from scratch, raising a question of whether there is a quicker way. The Boyle Lab is proposing a method of constructing metabolic models from several donor models, using computational biological tools to curate the combined model.

18 Determining the Effect on Biological Nanosensor Response Characteristics from Varied Lipid Membrane Compositions

Author: Tony Tien, Freshman, Chemical and Biological Engineering
Author: Ashley Chesney, Freshman, Chemical and Biological Engineering
Faculty Mentor: Kevin Cash, Chemical and Biological Engineering

Current methods of measuring analyte concentrations, including molecular sensors and probes, are limited in their selectivity, sensitivity, and invasiveness for use inside biological systems. The creation of polymeric nanosensors for analyte concentration determination in vivo is designed to address the current limitations of molecular sensors and probes, focusing particularly on selective sensitivity to biological analyte ranges. The research at hand aims to investigate the role of varying nanosensor charges in the response characteristics that the nanosensors produce for target analytes. In particular, changes in the nanoparticle zeta potentials are indicative of the stability of these nanosensors, which can be used to match the coagulative interaction levels in solution. The lipid membrane charge ratio is varied with combinations of positive 18:0 TAP, negative 16:0 PG, and neutral DMG-PEG-2000 lipids. Nanosensor zeta potential is measured by zeta phase analysis light scattering (PALS), while nanosensor functionality is measured with fluorescence intensity in response to varying biological analytes of interest, including lithium, potassium, sodium, and calcium ions. With this information, improved methods for biological analyte concentration determination could be used for enhanced biological compatibility and in vivo monitoring capabilities desired by biomedical applications.

19 Investigations of Clathrate Hydrate Slurry Rheological Properties and their Visualization

Author: Jordan Sand, Senior, Chemical and Biological Engineering
Faculty Mentor: Ahmad Majid, Chemical and Biological Engineering
Faculty Mentor: Carolyn Koh, Chemical and Biological Engineering

Gas hydrates are solid inclusion compounds formed when water and gas are under conditions of high pressures and low temperatures. Gas hydrates have the possibly of forming in oil and gas flowlines causing problems relating to safety, the environment, and economics. Hydrates in flow lines are studied by examining pressure drops in pipelines. Pressure drops are caused by increased viscosity of the slurry flowing in the pipeline. This indicates that viscosity is increasing, and the pipeline is susceptible to plugging. Work has been done in applying visualization techniques to anticipate the formation of gas hydrates such as using a standard high-pressure rheometer however due to the physical requirements of the rheometer cell itself, visualization under the constraints of a high-pressure system have proven to be unattainable. The work done here introduces two different types of visualization techniques. The first is a visual clear rheometer cell under the constraints of atmospheric conditions, where gas hydrates are formed at low temperatures using cyclopentane. With this system it is possible to relate the change in viscosity to the visual of slurry flow patterns. The second system uses a Parr cell with a borescope camera to visually examine hydrate formation from an aerial view.

20 Active Motion of Colloids Under AC Electric Fields

Sophia Johnson, Senior, Chemical and Biological Engineering
Faculty Mentor: Ning Wu, Chemical and Biological Engineering

The electrohydrodynamics of different asymmetric particles influence their behavior, from single particle motion to small cluster formation to collective active dynamics. The asymmetrical particles were tested for active motion under low to high frequencies, and their propulsion was recorded on microscope videos under varying electric fields and voltages in order to determine velocity and orientation on ITO electrodes printed onto microscope slides and made into parallel setups. These particles can reverse their propulsion direction at the frequency where their polarizabilty changes sign. This helps people to understand how and why asymmetrical particles propel under a wide frequency regime.

21 Using Molecular Dynamics Simulations to Explore Hydrate Formation

Author: Elise Madonna, Junior, Chemical and Biological Engineering
Author: Kyle Lam, Junior, Chemical and Biological Engineering
Author: Yilin Wu, Junior, Chemical and Biological Engineering
Faculty Mentor: Amadeu Sum, Chemical and Biological Engineering

The main objective of our research is to further understand the conditions that enable the formation of gas hydrates. Until recently, molecular dynamics simulations had not been utilized to explore this phenomenon, which occurs when water molecules form a cage around a gas molecule. This development is common in oil pipelines, and can result in bursting. Therefore, in application, the use of results from molecular dynamics simulations could prevent costly and environmentally detrimental pipeline disasters. At this point, we have focused on how the presence of sodium chloride (NaCl) in a solution of water and methane affects the formation of hydrates. Molecular dynamics simulations have been performed with two different weight percentages of NaCl, and at three different temperature-pressure combinations. One of the temperature-pressure settings was a control, for which we did not expect any hydrate formation, and the other two settings were conditions that we expected to be conducive to hydrates. After conducting these simulations, the output files were visually analyzed to determine whether any hydrate formation had occurred. Although the results of these simulations are not yet conclusive about the formation of hydrates under specific conditions, the power and versatility of molecular simulations is promising for this field of research. In the future, calcium chloride ($CaCl_2$) will be tested under the same pressure temperature conditions in order to further explore the effect of salts on gas hydrate formation.

22 Microbubble Assemblies for Continuous Measurement of Intraocular Pressure

Author: Susie Mallison, Senior, Chemical and Biological Engineering
Author: Ari Solomon, Senior, Chemical and Biological Engineering
Faculty Mentor: Kevin Cash, Chemical and Biological Engineering
Faculty Mentor: Melissa Krebs, Chemical and Biological Engineering

Innovation of a microbubble pressure sensor system has the potential to greatly impact the medical field, specifically in measuring increased intraocular pressure, the only modifiable risk factor for glaucoma. The biocompatible microbubbles contain a perfluorobutane gas core surrounded by a lipid layer, synthesized with Laurdan via sonication. Under applied pressure, the microbubbles decrease in size, changing the fluorescent response of the Laurdan as measured by fluorescence spectroscopy. The microbubbles were analyzed with and without pressure, yielding a consistent cyclic fluorescent response.

23 Scalable Synthesis of Alkali Sulfide Nanocrystals Using a Bubble Column Reactor

Author: Kristen Hietala, Senior, Chemical and Biological Engineering
Faculty Mentor: Colin Wolden, Chemical and Biological Engineering

Renewables such as wind and solar are crucial for our energy future, but their expansion is limited by their intermittency and the need for storage. Lithium ion batteries are the current leaders, but this technology does not have the capacity to address all storage requirements. Next generation batteries can address these challenges, using alkali sulfide nanocrystals (NCs) to make solid-state electrolytes and cathodes. Conventionally produced using energy intensive processes, these materials are prohibitively expensive. Our group has developed a green approach to synthesize these NCs at room temperature by reactive precipitation by contacting hydrogen sulfide (H_2S) gas with organometallic solutions. The industrial waste H_2S is fully abated while generating clean burning hydrogen as a valuable byproduct. My contribution to this research has been to develop bubble column reactors as a scalable platform to synthesize nanocrystals. We developed an innovative 4-phase bubble column, which enabled synthesis and separation of phase-pure, anhydrous Li_2S and Na_2S nanocrystals. Characterization showed that the primary crystal size ranged from 10−40 nm. Li_2S cathodes fabricated from these NCs show promising battery performance, where the capacity approaches the theoretical value and displays good cyclability and rate capability.

24 Dynamics of Graphene Sheets at a Water-Vapor Interface: A Molecular Dynamics Study

Author: Ronghua Bei, Junior, Chemical and Biological Engineering
Faculty Mentor: Joseph Samaniuk, Chemical and Biological Engineering

Understanding the dynamics of particles at fluid-fluid interfaces has attracted considerable research interest over the past several decades as fluid interfaces create an environment where monolayer thin films can be assembled through a 'bottom-up' approach. For example, fluid-fluid interfaces have been used to manufacture highly transparent and electrically conductive thin films of graphene flakes as it has been shown that graphene flakes are thermodynamically favorable at the interface between two immiscible fluids. However, the dynamics of film formation and the interactions between graphene flakes are currently not understood. Furthermore, it has proven difficult to isolate and experimentally probe the dynamics of pristine monolayer graphene flakes at fluid-fluid interfaces. This study aims to address this gap by using computational simulations, which have been shown to reliably estimate real-world experimental scenarios. Molecular dynamics simulations were employed to investigate the lateral interactions and stacking dynamics of mono- and few-layer graphene flakes at a vapor water interface. Applied biasing force (ABF) simulations were used to render potential of mean force profiles and identify different stacking pathways. Additionally, distance versus time profiles were generated for two interacting monolayer flakes and the results were fit according to a power law relation to understand how the interaction pair potential scaled with center-to-center separation distance. Ultimately, this study offers a new perspective into the investigation of interactions between interfacially-bound particles.

CHEMISTRY

25 Biologically-based Hydrogen Production, Storage, and Release

Author: Heather Jacobs, Senior, Chemistry
Faculty Mentor: Tom Gennett, Chemistry
Faculty Mentor: Gayle Bentley, National Renewable Energy Laboratory

As the use of hydrogen as an energy source has continued to develop, there have been some obstacles that must be overcome. One obstacle is how to store and transport the hydrogen gas. The current method that is being used requires gas compression, which can be costly. The aim of this research is to develop a two node solution for hydrogen storage and transportation. Formate can be produced biologically or electrochemically. While we are exploring both options for formate production, biological production is the primary focus of this work. Biological formate production can be achieved by engineering the bacteria Escherichia coli to produce formate under anaerobic fermentation conditions. The resulting formate can be transported safely, and stored until H_2 production is needed. After the formate has reached its destination, a second engineered E. coli strain will then release H_2 from formate. The H_2 will then be used in a fuel cell and the CO_2 will be recycled to aid in formate production from node one. Together, the formate production and H2 release form a cycle which enables a renewable, H_2 production and storage cycle.

26 Oxidatively Remodeled Hydrogels for Biomedical Applications

Author: Gabriel Adriano, Junior, Chemical and Biological Engineering
Faculty Mentor: Dylan Domaille, Chemistry

The long-term goal of the program is to develop "smart" hydrogel materials that deliver therapeutics and diagnostics on-demand only at sites of diseased tissue. To accomplish this, we are developing materials with a new chemical linkage that breaks down only in regions of elevated reactive oxygen species (ROS), which is a chemical marker of inflammation and disease. The first-generation material has been synthesized on a multi gram scale and used to anchor fluorophores to a biocompatible hydrogel. We hypothesize that during the course of organ rejection, elevated levels of ROS will trigger fluorophore release from the gel, where it will be secreted in the patient's urine and alert the patient that their transplant is undergoing rejection. In vivo studies are currently ongoing at Children's Hospital Colorado. Further synthetic work on the second-generation material has also been initiated. We expect that this next-generation linkage will incorporate more rapid dynamics while maintaining the ROS-degradability profile. Current efforts are being made to synthesize this molecule for further kinetic studies concerning oxidative stress and degradation.

27 Exploring the Photochemistry of Flavin Derivatives for their Use as Water Oxidation Catalysts in Hydrogen Storage

Author: Julie DuClos, Junior, Chemical and Biological Engineering
Faculty Mentor: Shubham Vyas, Chemistry

The need for low cost energy storage continues to be a pressing matter for the viability and proliferation of large scale intermittent renewables such as wind and solar. Storing hydrogen from water oxidation is one current method, but catalysts contain costly metals such as rubidium and palladium. Flavinum ions pose a lower cost, organic solution to water oxidizing catalysts, specifically Et-FlOH. However, increasing the photocatalysis properties of flavins is key for their application in industry for water oxidation and hydrogen storage.
We have explored the synthesis of several chlorinated flavin and flavinium ion derivatives for investigation of flavin photochemical activity. Density functional theory (DFT) calculations, UV-Vis spectroscopy and Laser Flash Photolysis (LFP) were employed to study the flavin photochemistry. It has been shown that DFT aligns with experimental absorption spectra.

28 Release of Nile Red via pH Responsive Nanoparticles

Author: Allison Vanderfeen, Junior, Chemical and Biological Engineering
Faculty Mentor: Stephen Boyes, Chemistry

The usage of phosphorus fertilizers causes significant environmental damage, including eutrophication and reduced water quality. Smart polymers and controlled release of fertilizers have become increasingly important in the agriculture industry. Polysuccinimide (PSI), a biodegradable polymer that is stable at acidic and neutral conditions, was synthesized as a pH-responsive polymer. The PSI was functionalized with various nucleophiles in order to obtain a stable copolymer. The copolymers were encapsulated with Nile Red and the release of the dye was monitored over time in different pH solutions. The release of dye simulates the controlled release of fertilizer that is the future for agricultural communities.

29 Mesoporous Silica Nanoparticles for Drug Delivery

Author: Hadley Thomas, Sophomore, Chemistry
Faculty Mentor: Bryan Trewyn, Chemistry

Our team aimed to use mesoporous silica nanoparticles as a targeted drug delivery system. These nanoparticles will be loaded with a drug, in our project this is fluorescein. The particles are then coated with starch. The starch is broken down by enzymes produced in saliva, which allows the drug to transfuse across the oral mucousal membranes. This technology has additional applicability in several different industries including cosmetics and the food industry. Our team has synthesized the nanoparticles and functionalized them. Currently, we are loading the drug and testing the release of the drug under lab simulated conditions that mimic the oral mucosal membranes.

30 Analysis of Solid State Batteries

Author: Olivia Bird, Sophomore, Chemistry
Faculty Mentor: Svitlana Pylypenko, Chemistry

This research has been studying solid state lithium batteries, specifically those using an LPS solid electrolyte. Lithium metal anodes are desirable because they allow for good current flow and higher energy density than any currently commercially available batteries. Among other uses, this highly energy dense batteries would be critical in making electric vehicles more available and widespread. In liquid electrolytes lithium metal can not be used as it forms dendrites which will short circuit a battery. Solid state electrolytes are much more resistant to these dendrites, and also can function at a much broader range of temperatures than liquid electrolytes. There are still a variety of problems with the viability which this experiment has sought to analyze. A combination of voids in the LPS microstructure and the lithium dendrite growth previously mentioned can still lead to failure of the solid state battery. This research has been utilize X-ray tomography to analyze the microstructure of sample batteries in order to gain a better understanding of failure mechanisms and their relation to current density.

CIVIL AND ENVIRONMENTAL ENGINEERING

31 Microbial Responses to Environmental Perturbations in Engineered Treatment Wetlands

Author: Evelyn Lundeen, Senior, Environmental Engineering
Faculty Mentor: Jonathan Sharp, Civil and Environmental Engineering

Shallow, open-water treatment wetlands have demonstrated the capacity to reduce freshwater nitrogen loading through microbial processes, offering a low-energy supplement to traditional treatment systems through a benthic biomat. A demonstration-scale wetland in California actively treats river water impaired by secondarily treated wastewater effluent, but ongoing studies suggest that wetlands may be suitable for the treatment of other impaired waters (e.g., mining waters or fracking waste). These wetlands are subject to fluctuations in influent water quality, variable flow, and other environmental perturbations that may impact their performanc and efficiency with respect to nitrogen removal. Previous bench scale experimentation has demonstrated that the biomat can remove ammonium from hydraulic fracturing produced water, but questions remain regarding how specific solutes (i.e., salinity, metals) influence the functionality of the system. In parallel, ongoing efforts are investigating the potential for biomat metal immobilization from artisanal mining impaired waters. The purpose of this study is to understand how geochemical gradients relevant to various impaired source waters impact biomat nitrogen attenuation while exploring the potential for metal immobilization. Understanding how these wetlands might respond to various source waters and environmental perturbations at the lab scale will provide mechanistic insight into their applicability at larger scales in future efforts.

32 Wood Composite Material Properties Under High Temperature

Author: Noah Ottum, Junior, Engineering Physics
Faculty Mentor: Shiling Pei, Civil and Environmental Engineering

This study is part of a research project examining fire risk in cross laminated timber (CLT) structures. "Delamination", a major concern for CLT fire safety, occurs when the adhesive bond fails within a panel before it chars, exposing additional fuel for fire regrowth. Understanding the mechanical properties of the adhesive bond line at elevated temperatures is a fundamental step towards understanding delamination. The material properties of wood and wood adhesive bonds were studied at various temperatures below the char temperature of wood (300°C) to characterize the strength and stiffness as a function of temperature. Four adhesives, three of which are commonly used in CLT production, were studied: two formulations made from polyurethane, one made from melamine formaldehyde, and one made from phenol-resorcinol formaldehyde Tests were performed in a half-lap shear joint and compared against a specimen with identical geometry made from a solid piece of wood with no joint. The phenol-resorcinol formaldehyde joint had approximately the same shear strength as solid wood at all temperatures, whereas the other adhesives had noticeable reduction in strength at high temperatures. The method used in this study is unique among other CLT adhesive tests as it measures the performance of the adhesive under load.

33 Moisture Performance of Mass Timber Building in Colorado Climate

Author: Jake Stogdill, Junior, Civil Engineering
Author: Jacob Woods, Junior, Civil Engineering
Faculty Mentor: Shiling Pei, Civil and Environmental Engineering

This research project focuses on obtaining moisture content data within the cross laminated timber of a mass timber building located in downtown Denver. These readings will not only benefit the owner of the building but it will provide insight on how the wood reacts to the climate of Colorado. These observations could possibly be used to update building codes and ultimately increase the use of the mass timber within the United States.

34 Designing a Low Cost Method to Control DO for Wastewater Microbial Communities

Author: Sarena Nguyen, Sophomore, Chemical and Biological Engineering
Faculty Mentor: Junko Munakata Marr, Civil and Environmental Engineering
Faculty Mentor: Gary Vanzin, Civil and Environmental Engineering

Rare earth elements (REE) play a significant role in the manufacturing of many common electronics and technologies today. Some examples include wind turbines, electric car batteries, and x-ray technologies. Due to their rapid popularity surge and use, there has not been much research conducted about their environmental effects, especially concerning wastewater microbial communities. The overall aim of this project is to test the effects of lanthanides on both aerobic and anaerobic systems, with a current focus on gadolinium and yttrium.

However, the dissolved oxygen (DO) levels of the aerobic bioreactors has not been able to remain constant throughout each cycling period, making it difficult to obtain accurate readings on the direct effects of the lanthanides. Thus, efforts have been made to keep this factor consistent, taking microbial digestion and media influxes in mind. The design of a low cost system to control the aeration has been considered and developed. The system is currently able to read dissolved oxygen readings from a probe and control the aeration pumps to keep the DO constant for distilled water. Future efforts will be made to control the DO of a biological system that consumes oxygen before implementing it on the bioreactors.

35 Enhancing Floc Settleability of Activated Sludge

Author: Megan Freytag, Senior, Environmental Engineering
Faculty Mentor: Rudy Maltos, Civil and Environmental Engineering

In the U.S., 70-75% of wastewater treatment plants (WWTP) are conventional activated sludge (CAS) systems. While this is an effective treatment method, one problem that exists is sludge bulking due to the presence of filamentous bacteria that reduce the microbial floc settling rates. In order to maintain a constant sludge volume index (SVI), research conducted at the Mines Park Water Reclamation Facility (MPWRF) utilizes methods to increase settling rates and reduce bulking in CAS systems. This can be done with hydraulic selector technology developed at the Colorado School of Mines, which uses hydrodynamic forces to remove poorly settling floc. A hydraulic selector made with a 3D printer has been installed in the bioreactor of a bench scale system to produce a denser floc that will settle faster. The system was operated for 141 days and tested with entrance flow rates of 1,2,3 & 4 L/min to find to optimal velocity. The experiment started at the lowest entrance velocity and was raised over time. In order to test the settleability of sludge produced by the hydraulic selector, floc diameter, zeta potential, sludge settling velocity, and influent and effluent water quality parameters were measured. Over the course of the experiment, faster settling velocities were measured and increased particle diameter. The starting settling velocity of the sludge from BR1 and BR2, respectively, were 6.7 cm/s and 0.7 cm/s. At the peak of the experiment the settling velocities were 6.7 cm/s and 29 cm/s for BR1 and BR2, respectively. Faster influent flow rates will lead to faster wastewater processing, which would reduce the need for facility expansion and furthermore reduce operating cost.

36 Conserving Energy through Anaerobic Wastewater Treatment

Author: Nicole Holland, Senior, Environmental Engineering
Author: Emily Phaneuf, Freshman, Environmental Engineering
Faculty Mentor: Junko Munakata Marr, Civil and Environmental Engineering

Most modern municipal wastewater treatment systems are aerobic systems that consume energy in order to remove solids and organics. The goal of this research is to create an energy positive system to treat raw domestic wastewater by studying an anaerobic baffled reactor (ABR) coupled with an anaerobic fixed film reactor (AFFR). The microbial communities used by this system break down organic carbon in the influent wastewater, producing methane and carbon dioxide. Capturing this biogas for energy recovery allows for the overall system to be energy positive. This system is unique because it treats wastewater from an on-campus apartment complex, opposed to many studies that use synthetic wastewater for research. Samples are collected weekly to test for biological oxygen demand, total and volatile suspended solids, and chemical oxygen demand. Thus far, the project has achieved its goal of a low energy requirement and creating energy-rich biogas. It also approaches EPA secondary standards of 30 mg/L for the aforementioned water quality parameters. Continued development of this system will allow for further improvement to the water quality, such as removal of nitrogen that remains in the anaerobic effluent.

37 A Case Study of CLT Application to Residential Building in Flood Zone

Author: Lindsey Whittington, Senior, Civil Engineering
Faculty Mentor: Hongyan Liu, Civil and Environmental Engineering

This project analyzes the effectiveness of CLT in flood prone zones by conducting a cost versus benefit analysis of flood damage. The goal was to determine whether or not CLT is viable alternative for traditional Light-Frame Timber construction in flood prone areas. Using a cost analysis method developed by Mason Taggart and floor plan layouts by Brad Burback, simulations were run with under a flood condition to determine total damage and component damage costs.

38 Rock Powered Life

Author: Abigail Osburn, Sophomore, Chemical and Biological Engineering
Faculty Mentor: John Spear, Civil and Environmental Engineering

We have worked on culturing anaerobic microorganisms from the subsurface of Oman that are not normally samples as they come from extremophile regions. My main focus was to create/alter a media which we then used to continue culturing the samples. We have also begun DNA extraction from some of our vialed samples and have worked on starting sample extraction from Omani rock cores. The end goal of the project is to identify and classify all organisms from this extremophile environment, with our main study on how they survive in such harsh conditions.

COMPUTER SCIENCE

39 Attention Please: Your Attention Check Questions in Survey Studies Can Be Automatically Answered

Author: Arthur Mayer, Senior, Computer Science
Faculty Mentor: Chuan Yue, Computer Science

Attention check questions have become commonly used in online surveys as a key mechanism to filter out inattentive respondents and improve the data quality. However, little research considers the vulnerabilities of this mechanism, which can allow attackers to automatically answer such questions and bypass that quality control. In this project, we performed the first study to investigate such vulnerabilities, and demonstrated that attackers can leverage deep learning techniques to pass attention check questions automatically. We designed AC-EasyPass, an attack framework that combines convolutional neural network and weighted feature reconstruction to easily pass attention check questions. We constructed the first attention check question dataset that consists of both original and augmented questions and showed that AC-EasyPass achieves 84% mean average precision (MAP) and mean reciprocal rank (MRR) on both the original and augmented datasets. Finally, we explored two simple defense methods, adding adversarial sentences and adding typos, for survey designers to mitigate the risks posed by AC-EasyPass. We hope that our work will raise sufficient attention of the research community towards developing more robust attention check mechanisms, and to prompt the CSCW research community to more seriously consider the emerging security risks posed by the malicious use of artificial intelligence techniques.

40 The Analysis of Armospheric Pressure in Mobile Devices to Determine Relative Position in a Vehicle

Author: Hayden Sather, Junior, Computer Science
Faculty Mentor: Dejun Yang, Computer Science

Distracted driving causes thousands of accidents each year. Some phone providers offer an application which turns the phone into a “Driver Mode” whenever the phone is detected to be in a vehicle, but it does not distinguish between the driver’s and the passenger’s position. This research is focused around analyzing the changes in atmospheric pressure that the mobile device feels, along with the vehicle dynamics to determine the location in the vehicle that the device is located in.

41 Deploying Adversarial Machine Learning Attacks with a Projector

Author: Andrew Harelson, Junior, Computer Science
Faculty Mentor: Chuan Yue, Computer Science

Research in adversarial machine learning thus far has been limited to performing attack digitally or with some kind of print media. Being able to deploy these attacks with a projector would give an attacker more flexibility as they could turn the attack on and off remotely. Our project explores the practicality of deploying such an attack. We compare the robustness of a variety of adversarial methods when subject to the distortions inherent to projected images. We also study how light level, distance, and viewing angle affect the robustness.

42 Mixed Reality Deictic Gesture for Multi-Modal Robot Communication

Author: Elizabeth Boyle, Senior, Computer Science
Faculty Mentor: Tom Williams, Computer Science

Our research explores the use of augmented reality as an interface for human-robotic communication. Specifically, we are examining the use of Augmented Reality visualizations as a replacement for deictic gestures, such as pointing, which cannot always be performed by robots since they may be remote from their human teammate or may not have movable arms. As reported in our paper, presented at the 14th ACM/IEEE International Conference on Human-Robot Interaction, we have conducted experiments, through simulated robotic communication, demonstrating that having Augmented Reality visualizations does increase human robotic communication efficiency. Moreover, I have been developing 3D visualizations and orientation mapping functionality in Unity to be used on the Microsoft Hololens for future in-person experiments.

43 Robotic Swarm Autonomy for Emergency Response

Author: Gazi Mahbub Morshed, Senior, Computer Science
Faculty Mentor: Hao Zhang, Computer Science

Autonomous Robotic Swarm poses vast application in Emergency Situations which are either too dangerous or inaccessible for human. Long term mobile autonomous robot needs to maneuver in an unknown environment. Thus, visual place recognition becomes an essential part of its autonomy as the robots must understand its location as well as apprehend other robots' location in the search and rescue environment. Visual place recognition is a challenging problem because of the appearance of the real-world can vary extensively. A place recognition algorithm must address problems like; multiple places in an environment may look very similar, same places in an environment may look drastically different because of vegetation, weather or season change, and places may not always be revisited from the same viewpoint and position as before. In my research, I explored a newly proposed method called SRAL (Shared Representative appearance learning) which autonomously learns representative features that are shared in all scenes, and then fuses the features together to represent the long-term appearance of environments observed by a robot during its life time. I focused on implementing this method in a robot recognizable programming language in an optimal way so that a robot can carry out this model by itself.

44 Effective Visualization of Sparse Machine Learning Results Applied to Brain Imaging Modalities Derived from the TADPOLE Challenge

Author: Lauren Baker, Freshman, Computer Science
Faculty Mentor: Hua Wang, Computer Science

MRI and PET scans are commonly used for diagnosing Alzheimer's disease (AD) because they are non-invasive and widely available. These scans can show brain atrophies that are solidly linked to cognitive decline and help physicians make an accurate diagnosis. Researchers run machine learning algorithms on MRI and PET scans to isolate regions of interest (ROI) in the brain most associated with an Alzheimer's disease diagnosis. Taking this brain data and effectively visualizing it is important for interpreting results and seeing if machine learning results contradict or confirm prior medical understanding. Visualizations also bridge the gap between the medical communities and the public by making the data easier to understand. For example, hearing that a region of the brain is affected vs seeing that region, or related regions of the brain, is lit up. Brain visualizations allow for quick and effective communication of the results of machine learning algorithms.

45 Visualizing Learned Genetic Predictors of Drug Sensitivity from the GDSC Data Set

Author: Madeline McKune, Junior, Computer Science
Faculty Mentor: Hua Wang, Computer Science

Many anticancer treatments are only effective for a small subset of patients. For those resistant to common therapies, doctors must deduce a drug's efficacy by looking at each patient's tumor. Open-access datasets, like the Genomics of Drug Sensitivity in Cancer, paired with novel machine learning models, can provide much-needed clinical insights. The GDSC dataset contains 664 cell lines with corresponding sensitivity results for 138 different drugs. By applying our machine learning model, we identify which genetic biomarkers are more sensitive to a specific therapeutic treatment: the output returns the 50 most expressed genetic biomarkers for a subset of drugs. Thereby, we face the challenge of how to visually relate drug response to bioinformatic data. We anticipate that effectively visualizing learned drug efficacy will bridge the medical and computational communities, as well as, uncover novel genetic mechanisms that make a cancer cell susceptible to treatment.

46 Communication in Robotic Swarms

Author: Ryan Buck, Senior, Computer Science
Author: Simon Reisig, Sophomore, Computer Science
Faculty Mentor: Neil Dantam, Computer Science

Our project covers two aspects of controlling a Schunk robot arm: the calculations needed to move from user-inputted commands to move the end effector in a 3D workspace to individual joint movements, and the communication of those commands to their respective joints using CAN BUS protocols. We make use of inverse Jacobians and rigid-body transformations to take a desired velocity for the end effector and use it to calculate the velocities of each individual joint in the robot. Once these velocities are calculated, we use RS485 serial communication to command and communicate with various parts of the robot arm, gripper, and sensors. After all communication libraries are made and ready for implementation, we will be using them in conjunction with the ACH IPC Library, and other supporting libraries, to control robot planning and action.

47 Graph Embedding

Author: Savannah Paul, Senior, Computer Science
Faculty Mentor: Hao Zhang, Computer Science

Drone swarms are a collection of individual robots that function as a uniform system; swarms are used to aid humans in solving large, complex problems ranging from military reconnaissance and defense to item deliveries. Sub-swarms are created when the swarm size and task complexity increase in order to efficiently execute multiple tasks simultaneously by the group, however many factors can affect how to divide the swarm making it difficult to do manually. Graphs are capable of representing a variety of physical scenarios and different types of entities, such as drone swarms. We have proposed graph embedding techniques as a method to analyze the features and interactions within swarms. Graph embedding is designed to take a graph, or set of graphs, and represent it in a low dimensional vector space by creating a vector representing of each node. Using various embedding techniques on a set of graphs provides insight into how to best optimize and divide the swarm it is representing.

48 Vibration-Based Keystroke Snooping

Author: Azam Abidjanov, Senior, Computer Science
Faculty Mentor: Dejun Yang, Computer Science

Keystroke snooping, i.e. inferring a user’s typed inputs, is a serious threat to user privacy. The adversary can learn user’s sensitive information such as usernames, passwords, credit card numbers, SSNs and confidential documents. The goal of this project is to show that one can exploit subtle vibration patterns to infer keystroke accurately and reliably. We also plan to design simple but effective defense techniques. Through this project, we also aim to raise awareness of such attacks.

49 Human Interaction with Robotic Wheelchair in VR Simulation

Author: Taewoo Kim, Senior, Computer Science
Faculty Mentor: Thomas Williams, Computer Science

Virtual Reality allows new ways of safely studying human-robot interactions without the need for bulky hardware and provides a new tool for designing interactive robots. Accordingly, our laboratory is using VR technologies to experimentally measure the factors impacting human-robot trust, in cases where a user must cede her navigational autonomy to the robot. A prime example of this is a self-driving car or robotic wheelchair where the robot controls navigation, rather than the user. In our experimental work, we are specifically using VR to study human interaction with robotic wheelchairs. Our experiment provides various fetch tasks to participants which they must complete by giving voice commands to their wheelchair. This experiment uses the “Wizard of Oz” paradigm in which a “wizard” controls the wheelchair from a remote location, unbeknownst to the participant, who will feel like an actual robot is responding to her commands. Throughout this task, we assessed participant trust in the robot through periodic surveys.

ECONOMICS AND BUSINESS

50 Public Knowledge and Support of Oil and Gas Production

Author: Melanie Pincus, Sophomore, Economics and Business
Faculty Mentor: Peter Maniloff, Economics and Business

This research project investigates the interaction between public opinion and the operation of the petroleum industry. This project has been conducted through research surveys, notably through the social media platform Twitter. Utilizing GIS and R technology, we are exploring the similarities and discrepancies between individuals in Weld County on their knowledge on the oil and gas industries.

ELECTRICAL ENGINEERING

51 Improving Understanding of Sociotechnical Thinking in Engineering Education - Mixed Methods Research

Author: Alyssa Boll, Senior, Electrical Engineering
Faculty Mentor: Kathryn Johnson, Electrical Engineering

This NSF-funded research project analyzes undergraduate engineering students’ perceptions of the intersection between social and technical dimensions of engineering. This project includes distributing a survey to undergraduate engineering students and analyzing the data through both quantitative and qualitative techniques. Free response questions in the survey were coded and analyzed to determine overarching themes. In addition, the team has developed classroom intervention assignments to give students the opportunity to practice sociotechnical thinking in the classroom. Intervention classes occur across two departments at two universities. The incorporation of sociotechnical thinking in engineering courses is contrasted sharply with the decontextualized, technical problems that existing curriculum prioritizes. This research finds that many students believe that social and technical topics are separated and that engineering should prioritize the technical dimensions of problem solving. Students in intervention courses exhibit stronger sociotechnical integration, including stakeholder consideration, engineering ethics, sustainable development, and societal impacts of engineering products. Developing undergraduate students’ engineering habits of mind and sociotechnical thinking skills better prepares the next generation of engineers to tackle engineering challenges in the workplace, where social and technical impacts of engineering projects are interdependent and inseparable.

52 Errors Analysis of Subgridding when Modeling Multiscale Structures Using the Finite-Difference Time-Domain Method

Author: Madison Le, Senior, Electrical Engineering
Faculty Mentor: Mohammed Hadi, Electrical Engineering
Faculty Mentor: Atef Elsherbeni, Electrical Engineering

One of the most common approaches to analyze electromagnetic wave phenomena is the finite-difference time-domain (FDTD) method. Problems of interest include modeling wave propagation through urban infrastructures, wireless communications, radio-frequency identification (RFID), and antenna designs. FDTD subgridding methods have become increasingly necessary as the operating frequency of modern electronic devices have risen and thus creating electrically large computational spaces. For example, an 8 by 12 antenna array would require approximately 300 GB of computational memory, which would require powerful computer processing. By separating the problem space into fine meshes around the objects with fine details and then coarse meshes elsewhere, or subgridding, the memory usage could be reduced to under 30GB, which could be done on a single computer. Subgridding purportedly allows these electrically large domains to be analyzed accurately without the need for large allocations of memory and resources. Under these circumstances subgrid regions become electrically large themselves. FDTD simulations in 1D and 2D spaces are used with varying subgrid sizes to expose the accumulating errors with a contrast ratio of 1:3. 1D and 2D FDTD simulations indicate a direct correlation between the subgrid electrical size and the cumulative errors incurred on the propagated waves.

53 Chipless RFID Tag Design

Author: Spencer Hutchinson, Sophomore, Electrical Engineering
Faculty Mentor: Atef Elsherbeni, Electrical Engineering

Radio-frequency identification (RFID) is an identification technology in which each tag stores data that is then wirelessly transmitted to the tag reader. RFID is generally more functional than barcodes as it operates without line-of-sight. However, due to the semiconductor-based electronics on each RFID tag, barcodes will likely always be less expensive. Chipless RFID provides a cheaper alternative to conventional RFID as it operates without an integrated circuit on each tag. Some chipless RFID systems encode data in the tag's frequency-domain response when excited by an incident electromagnetic wave. Multiple resonant elements are used to produce dips in the spectral response that each encode a bit. This research project seeks to expand on existing frequency-domain techniques by increasing the data stored in a given tag area and bandwidth. To achieve this, a specific resonant structure was investigated. This structure was a cross-shaped ring that was first modeled on a substrate with a ground plane. Simulations performed with HFSS showed that the structure produced a dip in the monostatic radar cross-section (RCS) at specific frequencies. A tag with five cross-ring structures was simulated and shown to produce five dips in the RCS. This tag encodes five bits in a 2.5x2.5cm area.

54 Frequency Dispersive Soil Analysis for Oil and Gas Bore-Hole Exploration

Author: Andres Velasco, Junior, Engineering Physics
Faculty Mentor: Mohammed Hadi, Electrical Engineering
Faculty Mentor: Atef Elsherbeni, Electrical Engineering

The determination of soils' frequency dispersive properties is explored for further implementation in electromagnetic simulations using the finite-difference time-domain (FDTD) method. When performing such simulations for bore-hole studies, a cylindrical model is adapted where a radial source of varying frequencies is used. These electromagnetic properties of soils will change as the frequency of the source varies. Soils that follow this property are characterized as dispersive soils. Unlike frequency-domain solvers, FDTD allows simulating such frequency variations within a single run. For bore-hole analysis, the frequency range of interest is a wideband covering 10-100 Hz for wireless telemetry along the entire depth of the borehole to 100-500 MHz for surrounding rock formation imaging and reflectometry.

Soil electrical properties from the data collected so far were formatted and interpolated between 300 MHz and 1.5 GHz to provide a set of data for the complex permittivity of the soil as a function of frequency. With this achieved the Debye model for dispersive media was constructed, and a numerical method was applied to find the Debye terms for a three-pole expansion, which would serve as a fit for the frequency dependent complex permittivity data. The Debye model fit for the analyzed soil types matched up closely with the collected raw soil data, thus showing the validity of the numerical Debye model builder. The obtained Debye model coefficients are then used via an auxiliary differential equation (ADE) to extend the capabilities of our in-house developed cylindrical FDTD simulator.

55 Image Recognition Using the Finite Difference Time Domain Method

Author: Allison Tanner, Junior, Electrical Engineering
Faculty Mentor: Atef Elsherbeni, Electrical Engineering

The finite-difference time-domain (FDTD) method for modeling of electromagnetic wave propagation is an attractive method to apply to the problem of medical imaging because of its ability to accurately model dispersive materials. Modeling capabilities of the FDTD method can be improved when applied to time reversal. Time reversal describes a method of computation in which time-based expressions are replaced with their negative value, creating a model of reverse motion, or backwards propagation of time. This has been shown to increase accuracy and precision of material modelling when using the FDTD method, translating to greater potential identification of tumors, cleaner detection of breaks or tears in tissues, and sharper models of biological materials. Time reversal of the FDTD method can be achieved by using resultant electric and magnetic field outputs of a simulation as inputs to a new “backwards” simulation. The described backwards simulation is derived by coding the FDTD method to solve for field components one time-step behind the present instead of future field components. The use of resultant fields as inputs causes the reverse simulation fields to propagate in the opposite direction of the forward wave and converge upon the original source point.

56 Improving Understanding of Sociotechnical Thinking In Engineering Education

Author: Jacquelene Walter, Junior, Electrical Engineering
Faculty Mentor: Kathryn Johnson, Electrical Engineering

This research project focuses on the socio-technical thinking aspects of engineering students in engineering classes at two universities. In order to fully grasp engineering practice, it is important that the social and technical aspects are not separated. This project utilizes mixed-methods research which means there are various quantitative and qualitative analyses performed on various data sets. This allows for various perspectives and observations. The main objective is to gain a better understanding of how students perceive the social within the technical aspects of engineering, and how to improve their understanding of it. Through assignments, reflection logs, focus groups, and surveys, we are able to perceive how students view socio-technical thinking in their engineering education.

57 Signal Processing Demonstrations For Inspiring K-12 Students To Pursue STEM Careers and Education

Author: Alexi Drgac, Senior, Electrical Engineering
Faculty Mentor: Michael Wakin, Electrical Engineering

To strengthen the scientific community, it is crucial to get kids interested in the Science, Technology, Engineering and Math (STEM) fields at a young age. The problem with engaging students in these fields, is that many of the fundamental theorems and ideas regarding STEM course are vastly beyond anything that can presented to younger students without creating immense confusion. The challenge of this project will involve capturing these scientific concepts and distilling them down to a level in which will be interesting and engaging for the desired age levels. Future applications for this project would involve fitting the created lesson plans for Teach Engineering, which is a website designed for k-12 teachers to have easy access to STEM lesson plans.

ENGINEERING, DESIGN & SOCIETY

58 Beyond the “Public Good”: Broadening Engineering Students’ Views of Stakeholders through CSR

Author: Cassidy Grady, Junior, Geological Engineering
Faculty Mentor: Jessica Smith, Engineering, Design & Society
Faculty Mentor: Greg Rulifson, Engineering, Design & Society

How does instruction in corporate social responsibility (CSR) affect how engineering students identify stakeholders and techniques to harness engineering to benefit stakeholders? This poster reports findings from a statistical analysis of pre- and post-module survey responses of about 450 students in targeted mining engineering, petroleum engineering, and liberal arts courses. These courses took place from the Fall 2016 to Spring 2018 semester at the Colorado School of Mines, Virginia Tech, Marietta College, and South Dakota School of Mines & Technology. We focus on two groups of questions: one that asked students to identify stakeholders and the other that asked them to rate examples of potential CSR projects. We conducted a paired t test, a Wilcoxon test, and effect size tests to determine if the changes in student-by-student responses observed over the course of the modules were statistically significant. The most significant changes among the sophomores were found in the field session. Students overall were most likely to consider prioritizing local hires to be a good example of CSR. We offer preliminary assessments of why student learning varies across courses, including content and context, instructor background, and length and depth of the CSR modules.

GEOLOGY AND GEOLOGICAL ENGINEERING

59 Calcite and Pyrite Weathering Profiles in Variably Metamorphosed Shales, East River CO

Author: Clara Bewley, Junior, Geological Engineering
Faculty Mentor: Alexis Sitchler, Geology and Geological Engineering

The objective of this project was to quantify depth of weathering in the Mancos Shale near East River Valley, CO. The Mancos Shale has been variably metamorphosed in this area resulting in unique problems with effects on watershed properties. Furthermore, modeling the depth of weathering will ultimately allow for hydrological and geochemical properties to be better understood. X-ray fluorescence spectroscopy was used to determine the elemental composition of a sample of core at a resolution of four feet. Analysis of the core was focused on the major constituents of calcium, magnesium and potassium, as well as the minor constituents of aluminum, sulfur, silicon and iron. Analyzing concentration versus depth as well as correlation among pairs of constituents will allow for the depth of weathering of calcite and pyrite to be quantified. Furthermore, understanding the correlation between various elemental constituents may ultimately allow for the development of models that can be used to predict how nutrient and solute transport affect watershed properties.

60 An Approach to Measure Rock Joint Roughness Using Repeated LiDar Scanning

Author: William Busath, Junior, Geological Engineering
Faculty Mentor: Gabe Walton, Geology and Geological Engineering

The quantification of rock joint roughness is a critical aspect of rock mass characterization, as it affects the hydraulic and shear strength properties of rock masses. While many approaches exist most require the measurement and digitization of joint topology. There have been many studies devoted to measuring roughness in rock joints yet existing methods all have limitations related to accuracy, equipment cost, or time. One common limitation is that many of the existing methods utilize equipment designed for use at laboratory scale cannot be applied in the field. In this study, we propose a new approach. The main advantage is that the measurement device used (a LiDAR scanner) can be used for applications other than joint roughness digitization and can also be easily scaled to large rock joints in the field. Our method uses the average of many 3D LiDAR scans to increase precision in topology digitization, achieving precisions of approximately 100 μm in one hour of collection time. We tested different sample orientations relative to the scanner, number of surfaces scanned at one time, scanner distances, and scanner settings to determine their effect on overall accuracy. Additionally, we present a novel method to quantitatively evaluate scan alignment quality.

61 Unbrecciated Cumulate Eucrite NWA 11001: a Record of Fractional Crystallization and High-Temperature Annealing Within the Crust of 4 Vesta

Author: Lauren Marie Martin, Freshman, Mining Engineering
Faculty Mentor: Richard Palin, Geology and Geological Engineering

NWA 11001 is a cumulate eucrite meteorite from the asteroid 4 Vesta, the second largest asteroid body within the solar system. The sample's bulk-rock mineralogy (collected with a TECSCAN-VEGA-3) shows the eucrite to contain mainly clinopyroxene, anorthite, and quartz with trace amounts of Fe-oxides, ilmenite, spinel, iron metal, and apatite. More testing with an electron microprobe (JEOL 8230/8530), was conducted and the first parts of the mineral data was modeled using THERMOCALC software and the collected data from the automatedn mineralogy and EPMA compositions. As the data from NWA 11001 is still being processed, this project aims to construct more phase diagrams from the collected data. Once these models have been created, the history of the eucrite's formation within 4 Vesta can be examined.

62 Joint Analysis of the Mount Evans 7.5' Minute Quadrangle, Central Colorado

Author: Lauren Miller, Junior, Geological Engineering
Faculty Mentor: Yvette Kuiper, Geology and Geological Engineering

The goal of this project was to investigate brittle structures, predominately joints, in the northern half of the Mount Evans 7.5' minute quadrangle in central Colorado as a complement to the structural analysis completed last year in the southern half of the same quadrangle to synthesize a complete quadrangle joint analysis. Joints generally form parallel to σ_1 orientations and normal to σ_3. The data collected showed some spatial variation throughout the quadrangle, that can be roughly divided into domains, though it remains difficult to correlate these variations with larger scale tectonism. The joints in the northern half of the quadrangle, as in the southern half, are most likely related to the Late Cretaceous-Eocene Laramide orogeny and the Oligocene and younger Rio Grande Rift. However, due to extensive lithological anisotropy in the region and the heterogeneity of Laramide paleostress orientations, it is difficult to discern a relationship between the joint orientations observed and specific known tectonic events.

63 Hydroclimate Zones of the Paleocene-Eocene Transition

Author: Leland Spangler, Senior, Geological Engineering
Faculty Mentor: Piret Plink-Björklund, Geology and Geological Engineering

The Paleocene-Eocene Thermal Maximum hyperthermal event (PETM) is widely regarded as the closest historical partial analogue to anthropogenic climate change, characterized by an increase in atmospheric carbon dioxide coeval with a rapid increase in terrestrial temperature from 5-9 degrees C. A significant body of previous research has identified the PETM as a period of dramatic hydroclimate extremes, however the spatial relationships of these studies and their findings are poorly understood. Here, we present a synthesis of PETM hydrological proxy data, interpreted and categorized into four distinct hydroclimate zones that vary with respect to paleolatitude. Preliminary results indicate a drastically different hydroclimate regime than today, which we illustrate further using analogies to modern Köppen-Geiger climate zones. Though concrete links to anthropogenic climate change cannot be made at this time, the dataset lends itself to many trends that may serve as a forecasting mechanism for the future of Earth's hydrologic cycle.

64 Climatic vs. Tectonic Controls on the Formation and Size of Fluvial Fans

Author: Julia Payne, Senior, Geological Engineering
Faculty Mentor: Mark Hansford, Geology and Geological Engineering
Faculty Mentor: Piret Plink-Björklund, Geology and Geological Engineering

Is the size of fluvial fans controlled by the tectonic setting they occur in or their climatic setting? There is a spectrum of depositional sedimentary fans that occur on land and two end members have been distinguished by Ventra and Clarke (2018) who propose that alluvial fans can "have radii of several tens of kilometers… up to a few hundred kilometers" with "higher gradients," whereas fluvial fans "maintain low gradients within restricted ranges of fractions of a degree" and "have radii of several tens of kilometers and up to a few hundred kilometers". Alluvial fans have been well defined and are understood in the literature (Blair and McPherson, 1994) whereas fluvial fans are a newer concept and are yet, not fully understood (Leier et al., 2005; Hartley et al., 2010; Weissmann et al., 2010). The process of fan formation is imperative to understand as it has implications for a multitude of other disciplines beyond sedimentology, including flood prevention, reservoir characterization, and paleoclimate modeling. Currently, there is not an extensive interpretation of the controls behind fluvial fan formation, size, or internal architecture. Fans have been investigated individually, but the first order controls on the formation and preservation of fluvial fans are not fully understood. Here, to address this issue, we used satellite imagery from Google Earth to measure the outlines of the 415 fluvial fans identified by Hartley et. al (2010). We also measured channel width at the apex and toe of each fan and calculated the gradient. For each fan, the tectonic and climatic setting was identified. We investigated the scaling relationships between these variables and are accessing possible trends and controls exerted by the tectonic and climatic settings. Early results indicate that fan sizes may be controlled by a combination of both the tectonic and climatic settings. Careful investigation will be needed to further decipher the validity of this result, and to eliminate commingled controls.

65 Petrologic Characterization of Metasediments at the Kansanshi Mine, Zambia

Author: Stephen Piurkowsky, Senior, Geological Engineering
Faculty Mentor: Alex Gysi, Geology and Geological Engineering

The Kansanshi Cu-Au mine in the metamorphosed Domes region of the North-Western Province of Zambia is the largest copper mine in Africa. Recent deep drilling penetrated a nearly complete sequence of Katangan metasedimentary rocks providing an opportunity to characterize the sequence from the basal Mindola Clastics through the Nguba Group, including talc-kyanite "whiteschists," and alteration related to Cu-Au mineralization. Rocks were investigated using traditional thin section petrography, FE-SEM, and TESCAN Integrated Mineral Analyzer (TIMA) automated mineralogy. Results show a sequence of lower-amphibolite facies metasediments with an abundance of Mg-, Na-, and Ca-rich phases suggestive of metasomatism by saline, carbonate-rich metamorphic fluids. The deepest Roan Group metasediments commonly contain albite, phlogopite, Mg-chlorite, and scapolite. At the top of the sequence, Nguba Group interlayered schists and phyllites display a quartz carbonate-biotite-muscovite-(garnet) mineral assemblage with local development of scapolite and large, randomly oriented hornblende porphyroblasts. Alteration minerals associated with chalcopyrite bearing veins and in siliciclastic metasedimentary rocks include Fe-carbonate, albite, white mica, rutile, apatite, green mica-V, and occasionally scapolite. In carbonate/evaporitic rocks, alteration associated with copper mineralization consists of recrystallized carbonate minerals, albite, and rutile. Overall, rocks at Kansanshi underwent Mg metasomatism and localized Na-Ca alteration, with pervasive alteration occuring in the deepest rocks.

66 Automation of Photogrammetry and Slope Deformation Change Detection

Author: Brian Gray, Senior, Geological Engineering
Faculty Mentor: Gabriel Walton, Geology and Geological Engineering
Faculty Mentor: Ryan Kromer, Geology and Geological Engineering

Monitoring of rock slopes is critical to ensure safety of people and infrastructure that could be affected by slopedeformation events, such as rock fall. Photogrammetry is a relatively low cost, compact, and non-invasive method of 3D-imaging and modelling surfaces, such as cliffs and slopes. With repeated modelling, comparison algorithms can detect changes between these models, allowing for evaluation of rock fall and debris hazards. The research purpose is to optimize automation procedures for the generation of 3D slope models and detection of slope deformation processes. This research could increase the practicality of photogrammetric remote sensing techniques and maximize budgeting for risk evaluation of rock slopes. Results indicate the optimal method of point cloud construction for the purpose of volumetric change detection is alignment of an initial point cloud to a high accuracy LiDAR data set, and align each future model to the preceding. Most optimal results were obtained by treating each image as a separate camera for purposes of parameter calibration during point cloud construction. Further analysis of this data remains to be completed regarding impacts of weather and lighting, seasonal influences, and examination of pre-failure deformation rates to produce forecasts of rock fall prior to events.

GEOPHYSICS

67 Summarized Findings from the 2011 Geophysical Survey of the Crestone Crater

Author: Kaden Nostrom, Senior, Geophysical Engineering
Faculty Mentor: Andrei Swidinski, Geophysics

A group of senior undergraduate geophysics students from the Colorado School of Mines conducted a geophysical survey of the Crestone Crater near the Great Sand Dunes National Park, Colorado. They implemented a magnetics, DC resistivity, and a gravity survey to determine the physical properties of the crater, detect subsurface structures, and detect any differentiations from any regional trends. They corrected the gravity data for topography and the Bouguer anomaly, ran 2D and 3D inversions for the DC data, and did 2D interpolations and a 3D inversion of the magnetic data.

68 Imaging the Crestone Crater Using Direct Current Resistivity

Author: Zachary Zyla, Senior, Geophysical Engineering
Faculty Mentor: Andrei Swidinsky, Geophysics

As a part of a senior design project on Crestone Crater, five Colorado School of Mines students performed various geophysical surveys in order to geologically characterize and determine the origin of the crater. The crater is the largest of many similar topographic impressions, located in the Sand Dunes National Park near the northern boundary, and to the south of the town Crestone, Colorado. One of the methods used was direct current (DC) resistivity. This method was used for its ability to collect two dimensional cross sections over the crater along with its near-surface, high data resolution capabilities. The survey consisted of one 400 meter line moving west to east and was performed using the ABEM Terrameter LS 2 Resistivity Meter and the data collected was processed using ABEM's processing software. Once processed and inverted, the data collected will provide resistivity values on a finer scale which can be used in conjunction with other data sets in order to support the various hypotheses on the crater's origin.

69 Geologic Characterization Using Transient Electromagnetics

Author: Samuel Chambers, Senior, Geophysical Engineering
Faculty Mentor: Andrei Swidinsky, Geophysics

A Time Domain Electromagnetic (TDEM) survey was conducted over the Crestone Crater located south of the town of Crestone, Colorado in order to find the depth to the Precambrian basement. The USGS has the depth to basement for the surrounding areas, either from well logs or other methods. However, over the crater like features close to the Sangre de Christo mountains there is no information of the basement depth. Before acquisition, forward models were constructed using IX1D software provided by the Colorado School of Mines. The resistivities and depths were interpreted from well logs of the closest wells (BACA1 and BACA2), as well as from several papers on the geology of the basin. There was a total of 5 TDEM soundings conducted over the crater in the shape of a plus oriented to magnetic north.

The 5 soundings were conducted using the Geonics EM57, and Protem Receiver. The transmitting coil dimensions were set to 100m by 100m, and the receiving loop was synchronized through a reference cable and placed in the center of the transmitting loop. The recovered depth will hopefully be in the range of 300 to 400 meters. The 5 soundings will be inverted, and compared to existing well logs near the site, in order to determine layers, and basement depth. The newfound depth to basement, and other formations in the subsurface will allow for further geological interpretations from existing or new geophysical studies over the crater.

HUMANITIES AND SOCIAL SCIENCES

70 A Comparison of Ethics and Ethical Programs Across U.S. Universities

Author: Connor Price, Senior, Computer Science
Faculty Mentor: Qin Zhu, Humanities and Social Sciences
Faculty Mentor: Sandy Woodson, Humanities and Social Sciences

This research project has focused on the gathering and subsequent analysis of data regarding the teaching and status of programs dedicated to the field of ethical study across U.S. collegiate institutions of similar or related caliber to our own at Mines. It has compared everything from the number of credits required to be dedicated to Humanities and Social Science classes, to the number and variation of ethics related majors offered, to the types of classes and fundamental programs dedicated to ethics in each institution. Three categories of schools: Colorado, peer-based, and aspiration institutions were compared with Mines. After months of research, my mentors and I have concluded that ethics at Colorado School of Mines does not have the same firmly established and wide-reaching foundation that our counterpart schools possess. That being said, I also conclude that while our school may not seriously compare to other STEM minded institutions now, it should in no way deter us from branching out and expanding our own ethics program in the future.

MECHANICAL ENGINEERING

71 Pressurized Fuel Cell Stack Testing

Author: James Frazar, Senior, Mechanical Engineering
Faculty Mentor: Neal Sullivan, Mechanical Engineering
Faculty Mentor: Christopher Cadigan, Mechanical Engineering

The purpose of this research is to develop and demonstrate a novel hybrid stationary power system comprised of an intermediate temperature (600°C) pressurized solid oxide fuel cell (SOFC) stack integrated with a high efficiency stationary internal combustion engine. Here at the Colorado School of Mines, the Colorado Fuel Cell Center has been designing and building the required equipment to evaluate a 5 kW SOFC's energy efficiency when pressurized. Experimental data from the pressurized SOFC will be used to accurately model the overall hybrid power system and yield a high efficiency, low cost energy solution.

72 Automating the Analysis of 3D Printed Metals Microstructures

Author: Marcelo Gonzales, Senior, Mechanical Engineering
Faculty Mentor: Aaron Stebner, Mechanical Engineering
Faculty Mentor: Branden Kappes, Mechanical Engineering

This project is related to developing a high throughput characterizations of 3D printed metals to support building a database sufficient for training machine learning models to use for real-time process optimization. In other words, the impact of this project is related toward automating the ability for scientists to collect large amounts of high pedigree metals characterization data and improving the the ability to be able to discern deformities such as porosity. This all means that we need to process images much faster than the microscope allows. For example, to get an image at 2000x magnification it would take a few hours compared to what it would take to get the same image at 200x. Once collection of data is concluded, a python code package was developed in order to test a model from a research paper titled, "Optical Image Scaling Using Pixel Classification," by Dr. Bouman from Purdue University. In this method, the pixel being interpolated is classified based on a neighborhood of surrounding pixels. Thus, the high-resolution pixel is obtained using the coefficients that were gathered during the training process. This approach is based on stochastic model that assumes that pixels can fall into a variety of classes such as edges, smooth textures or different orientations. Finally, this whole program package is completed it will speed up the process of looking at a metal specimen. A process that use to take several hours will now will be possible in a much more shorter time.

73 Magnetic Needle Guiding System

Author: Robin Evans, Senior, Mechanical Engineering
Faculty Mentor: Andrew Petruska, Mechanical Engineering

The surgery for Parkinson's disease at the moment is very rudimentary. The patient is strapped to a rigid apparatus and stiff metal rods are stuck into the brain to to deliver an electrical shock to different locations of the brain. In order to minimize the impact from jamming a metal rod through the brain, a magnetic needle guiding system is being developed. The guiding system uses a Helmholtz coil to create an even magnetic field. It has been my job this year to create an accurate indexing system to place a magnetometer to test the magnetic field at precise locations of the work space. Along with this, I was also in charge of creating the camera calibration plate.

74 Investigation of Flow Through Porous Media

Author: Noah Pelsmaeker, Senior, Mechanical Engineering
Faculty Mentor: Nils Tilton, Mechanical Engineering

This research serves to investigate the rarely studied flow through porous media. Common practical applications include flow in oil and gas reservoirs, ground water aquifers, and blood flow through kidneys. The geometries of these systems are more complex and thus the flow through them is described in an averaged sense rather than on the scale of individual pores. This research is an effort to model the flow on the pore scale and compare it to experimental data of the averaged flow. Steady flow in this domain is relatively understood, but unsteady flow is not. To model these flows, a modified version of Darcy's law, known as the Forchheimer equation, was used. Additionally, this research used an additional term to account for unsteady flow. The validity of this equation was checked with collection of pressure and flow rate measurements to find the permeability and Forchheimer coefficient for a variety of pore sizes with steady flows. Pressure and water height versus time data was collected for unsteady flows using a U-tube with oscillating water. The collected data was used to fit the Forchheimer equation for the tested porous media and determine the unsteady term.

75 Designing a Fuel Cell Test Stand Including High Pressure and Compression Capabilities

Author: Christopher Chmura, Senior, Mechanical Engineering
Faculty Mentor: Neal Sullivan, Mechanical Engineering

In this project I am designing a new test stand for fuel cell testing. This test stand uses compression and high pressure. The compression is used to help create a tight seal around the fuel cell which decreases the likelihood of test failure. High pressure in the system is used to help facilitate the chemical reactions happening through the fuel cell. It is hoped that by using this test stand there can be a greater understanding of fuel cells which could be used to increase their overall effectiveness. This test and the use of state of the art materials such as proton-conducting fuel cell ceramics can be used to convert renewable electricity into high-value chemicals such as hydrogen, hydrocarbons and ammonia. This can help address the intermittent nature of renewable electricity, making renewable energy more efficient and cost effective. The current project is in the design iteration phase and is planned to be finalized by the end of the semester.

76 Advanced Manufacturing of Solid Oxide Fuel Cell Systems

Author: Jewel Newman, Freshman, Mechanical Engineering
Faculty Mentor: Neal Sullivan, Mechanical Engineering

In my research project, I prepare ceramic and metallic materials for careful imaging and analysis using Scanning Electron Microscopy and Energy-Dispersive X-Ray Analysis. These analyses enable the research team to understand the microstructure and morphology of next-generation energy-storage electrochemical cells now under development at Colorado School of Mines. The broader goal of the research team is to harness proton conducting ceramics and use them in solid oxide fuel cell systems to convert renewable energies into high-value chemicals. This presents a new method to store intermittent renewable energies like solar and wind and promote wider usage of renewable energies.

77 Renewable Energy Storeage Through Electr-ceramics

Author: Michelle Butler, Junior, Mechanical Engineering
Faculty Mentor: Neal Sullivan, Mechanical Engineering
Faculty Mentor: Carolina Herradon, Mechanical Engineering

The purpose of this project is to design, create, and commission a test stand that will convert renewable electricity into stable, valuable liquid fuels. The energy community seeks technology to enable long-term storage of the intermittent electricity generated from wind and solar power. In this project, we use renewable electricity to drive electrochemical and thermochemical reactions to produce ammonia. Ammonia has great promise as a clean energy carrier: it is "carbon neutral", forming no greenhouse gases when combusted; it is easily transported due to its liquid phase; and it contains a large amount of hydrogen for clean energy production. In this research, we will exploit the unique properties of proton-conducting ceramics developed at CSM to "electrochemically synthesize" ammonia from nitrogen, water vapor, and renewable electricity feedstocks. Both productivity and efficiency of electrochemical synthesis increase as temperature and pressures are increased. Higher temperatures drive electrochemistry by increasing the electrochemical reaction sites, while higher pressures move equilibrium to form more ammonia. In order to support higher temperatures and pressures for this test, we are commissioning a pressurized test stand that we designed to analyze ammonia synthesis using proton-conducting ceramics. The work is supported by the Department of Energy, Advanced Research Projects Agency – Energy (Contract DE-AR0000808).

78 A Building Energy Simulation of Weaver Towers

Author: Juno Padilla, Junior, Mechanical Engineering
Faculty Mentor: Paulo Tabares, Mechanical Engineering

According to the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), Golden, Colorado is within climate zone 5B, meaning it is susceptible to cool and dry conditions. In this study, the authors utilized OpenStudio to design and validate energy usage in Weaver Towers at Colorado School of Mines in Golden, Colorado. Weaver Towers is a suite-style dorm capable of housing 225 students every school year. To consider ways the housing structure can best adapt to this climate for optimum energy usage, construction drawings of the dorm were used to create the geometry and set-up of the heating, ventilation, and air conditioning (HVAC) system in OpenStudio. The software allows users to perform building energy analysis via EnergyPlus, a simultaneous integrated solver. By providing variables such as weather data, sunlight exposure, plug load usage, and the distribution of air within a given building, EnergyPlus completes a zone thermal balance to find out how much energy is required to heat or cool designated thermal zones. The results from the building simulation on OpenStudio were validated via energy.

79 Infrared Spectroscopic Study of the Thermal Stability of Alkyl Carbonate Electrolytes

Author: Anna Christiansen, Sophomore, Mechanical Engineering
Author: Mason Hightower, Junior, Mechanical Engineering
Faculty Mentor: Jason Porter, Mechanical Engineering

Decomposition of ethylene carbonate (EC) in lithium-ion batteries leads to battery swelling, off- gassing, and thermal runaway. Ethylene carbonate decomposes electrochemically by reduction at the anode or chemically in the bulk electrolyte at elevated temperature. The formation of a solid electrolyte interface (SEI) on the anode limits electrochemical decomposition. While neat ethylene carbonate is thermally stable at temperatures exceeding 150°C, EC-based electrolytes containing lithium hexafluorophosphate ($LiPF_6$) salt are known to chemically react at temperatures as low as 50°C. Trace contaminants, especially moisture, have also been shown to strongly affect electrolyte stability. In this work, the chemical stability of EC at elevated temperature is studied using infrared spectroscopy. Electrolyte samples are heated on an attenuated total reflection (ATR) stage using both liquid samples and in operating half and full cell batteries. Liquid samples were prepared in an argon glove box with varying concentrations of $LiPF_6$ salt, H_2O, and in CO_2 gas environments (to simulate cathode off-gassing). Operando spectroscopic measurements of electrolyte stability in graphite half cells, lithium cobalt oxide ($LiCoO_2$) half cells, and lithium-ion full cells were also collected. Reaction rates and activation energies are also reported using time-resolved infrared spectroscopy.

METALLURGICAL AND MATERIALS ENGINEERING

80 Mapping of Silicon Carbide with Raman Spectroscopy

Author: Jack Kleikamp, Senior, Metallurgical & Materials Engineering
Faculty Mentor: Brian Gorman, Metallurgical and Materials Engineering
Faculty Mentor: Corinne Packard, Metallurgical and Materials Engineering

This project for the International Center for Multiscale Characterization (ICMC) studies how doping and microstructure affect the results of silicon carbide spectroscopy. Samples of lab-grown (CVD) silicon carbide are mapped using a Raman spectrometer, recording the different spectra across the samples. Differences in the lattice strain and peak broadening across the sample can lead to a better understanding of the microstructure of a sample, the chemical properties, the effect of doping, and the overall growth behavior of silicon carbide. Examples of microstructure findings include stacking fault behavior and preferred orientation during growth. The project also studies connections between Raman and photoluminescence (PL) spectroscopy. The importance of such findings lies in further details about the usefulness of doping, the economics of Raman versus PL spectroscopy, and the effect of microstructure on the properties of silicon carbide.

81 Next Generation Automobile Conductors

Author: Chad Haunschild, Junior, Metallurgical & Materials Engineering
Faculty Mentor: Terry Lowe, Metallurgical and Materials Engineering

The goal of this project is to develop nanostructured variants of aluminum that have electrical conductivity and strength high enough to enable nano-aluminum wires to replace copper wires in future automobiles. This project is interesting because it creates a massive shift in the automobile industry, helping to usher in the era of all electric vehicles. Nanostructured aluminum wires can reduce the weight, environmental impact, and cost of automobiles while increasing fuel efficiency. Today every car has over 1 mile of wiring, having a weight on the order of 100 pounds. Cars of the future with nanostructured aluminum will have less than half the weight of conductors. Also, the cost per amp delivered by automobile wiring is at least 6 times less for aluminum compared to copper.

82 Mechanical Deformation of Copper Metal Prior to Thermal Oxidation and its Impact on Nanowire Growth Behavior

Author: Melissa Dangler, Senior, Metallurgical & Materials Engineering
Faculty Mentor: David Diercks, Metallurgical and Materials Engineering

The formation of copper oxide nanowires via thermal oxidation is a well-documented occurrence. Several studies have attempted to analyze the growth behavior under a variety of heat profiles and conditions, but here only one heat profile was used. The primary focus of this report is to show the change in growth behavior after the introduction of physical defects and through cyclic oxidation and reduction steps. Electrodeposited copper foils were thermally oxidized in air at 675°C for 2 hours. Prior to oxidation, half of the samples were mechanically deformed (MD) in a planetary mill while the other half remained undeformed (UD). Each group was then divided into 3 subgroups: Oxidized Only (OO), Oxidized and Reduced (OR), and finally Oxidized-Reduced-Oxidized (ORO). Growth of nanowires was observed for all of the copper foils tested. For UD samples the growth was restricted primarily to the edges of the foils while for the MD samples, surface growth was also present. A substantial difference in the latter group was the development of surface ridges which may have contributed to the shift. Across all 6 subgroups, several morphological changes occurred with respect to the ridges, the underlying surface, and the nanowires themselves.

83 Dancy Pants

Author: Allison Bateman, Senior, Mechanical Engineering
Faculty Mentor: Terry Lowe, Metallurgical and Materials Engineering

I, along with the Transdisciplinary Nanostructured Materials Research Team, am attempting to design and analyze a new method to inexpensively fabricate micro-impact lattices from stainless steel wires that can be used in padding to reduce personal injury from impact. This project can have many applications, but currently is intended to help dancers mitigate their injuries from their profession.

84 Development OF 3-D Printed Radiation Shielding

Author: Jesus Mendoza, Senior, Engineering Physics
Faculty Mentor: Jeffrey King, Metallurgical and Materials Engineering

This project evaluates the potential of additively manufactured neutron radiation shielding produced using consumer-level 3-D printers. Plastics used in printing can come in the form of pellets of a typical plastic (ABS, PLA, etc.) and are put into a filament extruder along with a neutron absorbing material. Shielding material will be simulated in MCNP to determine the neutron energy moderation, absorption, and scattering which will provide the material's theoretical effectiveness. Manufactured test filaments will be put in front of a radiation source and the intensity of the radiation passing through the shielding plug will be measured. Relating the radiation intensity to the thickness of the shielding material yields an experimentally derived radiation attenuation coefficient which will serve to validate the simulation results. The printing and structural properties of the resulting materials will also be evaluated. The shielding properties of the resulting materials, considered along with the ease of printing, will determine whether or not a given material combination shows promise as a 3-D printed shielding material.

85 The Effect of Tempering on Hydrogen Induced Cracking in an X65 Thermomechanically Processed Pipeline Steel

Author: Zoey Huey, Senior, Metallurgical & Materials Engineering
Faculty Mentor: Kip Findley, Metallurgical and Materials Engineering

In the oil and gas industry, sour service pipelines containing hydrogen sulfide (H2S) gas are susceptible to hydrogen-induced cracking (HIC). The goal of this project is to examine and understand the processing and microstructure of a thermomechanically processed X65 steel alloy as it relates to HIC. Specimens of X65 steel underwent NACE TM0284 testing, exposing them to H2S. These specimens were then sectioned, polished, and etched using a 2 pct nital solution. They were imaged using light optical microscopy and scanning electron microscopy to study the amount of cracking and its microstructural interaction. This analysis indicated a microconstituent, believed to contain martensite/austenite (M/A), that influenced cracking. The as-received steel samples were tempered at a range of temperatures to decompose the microconstituent, and then subjected to the NACE TM0284 test. The amount of cracking was reduced in all samples as compared to the non-tempered sample. Among the tempered samples, 500 °C resulted in the least amount of HIC, while 400 °C exhibited the greatest amount of cracking. The interaction of HIC with the tempered microstructures was also evaluated.

86 Integration of Piezoelectric Devices into Fabric

Author: Melanie Breckenridge, Freshman, Metallurgical & Materials Engineering
Faculty Mentor: Geoff Brennecka, Metallurgical and Materials Engineering

Piezoelectric devices emit a voltage when undergoing physical deformation proportional to the amount of pressure applied. By integrating a network of these devices into fabric, one might create a suit of them which would continuously output data about an individual's surroundings. This has applications in particularly hazardous environments, in which data about the exact location, radius, and intensity of physical trauma might be given to medical professionals immediately to give aid to workers. It might also be used for impact testing. Thus far, tests have been done on several types of devices to find the best one to integrate. In the next phase of testing, the chosen device will be tested with several trauma sources such as explosions to create "impact" maps.

87 Fatigue of High Strength Steels

Author: Christina Baker, Sophomore, Geological Engineering
Faculty Mentor: Kip Findley, Metallurgical and Materials Engineering

Steels used in chassis components experience fatigue during service, which can be made more damaging in the presence of sheared edges produced during part fabrication. This project was initiated to evaluate the fatigue performance of two steel alloys used in chassis applications: CP800HR and XPF800HR. The objective of the project is to compare the fatigue performance of the alloys in the presence of sheared edges. Holes were punched in each specimen to act as a stress concentrator. Half of each alloy were heat treated for the purpose of removing residual stress. For both steels, stress-amplitude versus fatigue life curves were generated. The CP800HR heat treated samples reached the endurance limit before the as-punched condition. The XPF800HR conditions exhibited similar resistances for the as-punched verses heat treated, and both reached an endurance limit at a similar stress amplitude. Overall, CP800HR heat treated had the highest endurance limit with a local stress amplitude at 325 MPa. XPF800HR as punched had the lowest endurance limit with a local stress amplitude at 175 MPa. It is possible that the heat treatment of the CP800HR condition released some residual stress resulting from the punching process and improved the fatigue life.

MINING ENGINEERING

88 Artisanal Small-Scale Gold Mining In Latin America

Author: Matthew Fedyk, Sophomore, Engineering Physics
Faculty Mentor: Nicole Smith, Mining Engineering

For the purpose of making informed decisions to benefit the artisanal small-scale gold mining (ASGM) communities in Latin America, a clear summary of past international interventions is necessary. Attempts have been made to improve the technology, financial stability, and quality of life for these communities, some attempts succeed while most others fail. The goal of this research is to surmise the interventions and elaborate on their failures. To accomplish this, published journals such as ScienceDirect, government publications, and non-profit organizations were used in this review to demonstrate the effectiveness of interventions in ASGM. Primarily this review is focused on, but not limited to, interventions that have directly acted to reduce mercury emissions from artisanal gold mining.

89 Dynamic Indicators For Assessing Mining's Contributions Sustainability

Author: Aurora Waclawski, Junior, Environmental Engineering
Faculty Mentor: Nicole Smith, Mining Engineering
Faculty Mentor: Sebnem Duzgun, Mining Engineering

Sustainability of mining operations has been a subject of increasing concern in recent years as mining companies seek to balance the competing demands of governments, local citizens, investors, and environmentalists. One challenge in implementing and communicating sustainability initiatives is the lack of adequate indicators for measuring the success of these efforts, especially due to the dynamic nature of mining operations. This research identifies the sustainability indicators used from 2012-2016 by eight large mining companies in diverse markets as reported in their annual sustainability reports. It then compares these indicators to criteria outlined in the academic literature and in the Global Reporting Initiative (GRI), the most ubiquitous sustainability reporting system in use. Our findings demonstrate that there are areas of sustainability that mining companies are paying more attention to, such as incident reporting and material consumption, as well as areas where there appears to be a blind spot, such as impact reporting and transportation. These findings are important for contributing to the conversation on the ways in which mining companies can operate more sustainably and make more significant contributions to sustainable development in the areas where they operate.

90 Development of Virtual Reality for Edgar Mine

Author: Daghan Yigitbas, Junior, Mechanical Engineering
Faculty Mentor: Sebnem Duzgun, Mining Engineering

Virtual reality (VR) is the use of computer technology to create a simulated environment. VR is popularly perceived to enhance video games, yet it can serve many other purposes as well. For example, VR can be used in specialized fields from education to medicine. It is becoming a new tool to train medical practitioners or professions in any other field. In terms of engineering, we can test design principles and structures for safety, maintenance, stresses, and strains. The possibilities of virtual reality seem endless and proves to be a technology of the future. For this project, VR was used to model the Edgar Mine located in Idaho Springs, Colorado. This mine is being used by the Colorado School of Mines to train students in the field of mining engineering. Particularly, this study was conducted to create a virtual environment for use in education, training, decision making, and visualization. Blender and AGIsoft were used to create various models that are commonly used in mining processes. Some of these models include a quadcopter, hard hat, valve, backpack, boom drill, and mine truck. Moreover, data visualization were developed through ParaView to represent limestone and methane content with the walls of the mine.

91 Computer Simulations

Author: Joseph Duebner, Junior, Mechanical Engineering
Faculty Mentor: Eunhye Kim, Mining Engineering

In this project, particle flow code is used to simulate different types of testing for rock samples. Brazilian tensile strength and uniaxial compressive strength tests give parameters to be modeled within the code. Rock parameters are inputted to simulate a sample. This is useful for larger modelling efforts and can help to examine the micro properties of the rock samples in question.

92 VR Development for the Edgar Mine

Author: Nicholas Bellusci, Junior, Mining Engineering
Faculty Mentor: Sebnem Duzgun, Mining Engineering

Virtual reality, or simply VR, allows interactions between a controller and a simulated environment, to create a realistic sense of acting in said environment. VR is a rapidly expanding technology which has assisted numerous industries in a wide variety of applications. Particularly in mining, VR has provided another means of conducting safety and task training procedures, as well as for decision making and engineering purposes. In this study, VR is in development for the Edgar Experimental Mine, located in Idaho Springs, Colorado. The Edgar Mine historically produced commodities such as gold and silver in the late 19th century and is now used by the Colorado School of Mines to educate and train individuals in the various practices of mining engineering. This study aims to use VR as a means of decision making and effective design. Modelling and animation sequences were constructed using programs such as Blender and Unity to mimic common activities that occur at a mining operation. Models included a load, haul, dump machine (LHD), fire extinguisher, mining boot, and Octorotor drone. Animations included the initiation sequence of the drone, movement of the drone over uneven terrain, and LHD operations.

93 Advanced Rock Tunneling Techniques

Author: Jaume Martinez Calvo, Sophomore, Mining Engineering
Faculty Mentor: Rennie Kaunda, Mining Engineering

This experiment further investigated the relationship between rock strength and microwave exposure time through P-wave velocity testing of core samples before and after heating process. With the new results a clear correlation was derived; as microwave exposure time increased the P-wave velocity through the rock sample decreased.

94 Rock Fracture Under Various Environmental Conditions

Author: William Huber, Senior, Mechanical Engineering
Faculty Mentor: Eunhye Kim, Mining Engineering

Under various exposure to environmental effects such as moisture and temperature, the mechanical properties of a rock may change. In this research, samples of Indiana limestone were exposed to various water and NaOH saturations as well as a frozen condition. Using digitital image correlation, strain data is obtained and used in conjunction with force data to study and understand the effect of the saturation and freezing on the fracture behavior of the Indiana limestone.

PETROLEUM ENGINEERING

95 Measuring Mass of Gas in-Place in Cores

Author: Siradon Prateepswangwong, Senior, Petroleum Engineering
Faculty Mentor: Xiaolong Yin, Petroleum Engineering

The objective of this project is to prove the validity of a novel oscillation-based method to directly measure gas in-place (GIP) in conventional rocks. Based on the theory of harmonic oscillation, the effective mass of a core with GIP can be obtained using the frequency of oscillation of a spring-mass system. The mass tested is a weight holder containing the rock, suspended in a pressurized vessel with a spring. The oscillations are triggered and measured by a solenoid connected to a battery pack and an oscilloscope. The effective mass from oscillation is the sum of the mass of the rock, GIP, and the mass of gas co-accelerated outside the rock. The mass of the rock was measured using a precise weight scale. The mass of co-accelerated gas outside the rock was measured using non-porous aluminum cores that have the same cross-sectional area as the rock sample. The GIP was then obtained by subtracting the actual mass of the rock and the mass of co-accelerated gas outside from the effective mass. Experiment results show that GIP measured from this novel method agrees with that measured using a fluid saturation method, proving that the oscillation-based method is effective and accurate.

96 Preliminary Modeling Evaluation of Water Ice Extraction from Lunar Permanently Shadowed Craters by Direct Heating of Icy Regolith

Author: Emilio Gonzalez Marroquin, Senior, Petroleum Engineering
Faculty Mentor: Luis Zerpa, Petroleum Engineering

Nearly a decade ago, the presence of water ice on the Moon's surface was confirmed by scientists using data from NASA's Moon Mineralogy Mapper (M3). M3's spectrometers collected reflective data, some data had properties similar to that of water ice. Lunar water would be an invaluable resource for space programs; water could be extracted for hydration, irrigation, and even propulsion purposes.

Recognizing the interest in lunar water extraction, this research focuses on evaluating direct heating of the icy regolith as a water extraction method. Through direct heating, sublimation will allow water vapor to migrate up the wellbore and be captured at the surface.

Recognizing that the simulator was intended for terrestrial purposes, the inputs, including temperature and pressure, were as close to the actual lunar conditions as the simulator allowed. With the simulator, changes in ice, liquid, and gas saturation, as well as changes in temperature, were analyzed over time.

Results have yielded positive results; lunar ice near the heat source sublimates, allowing gas to travel up the wellbore for collection. Difficulties arise when attempting to collect lunar water at greater depths, the migrating gas can cool into a solid form, preventing lunar water from being collected at the surface.

PHYSICS

97 Vortex Dynamics in Superconductors at High Vortex Densities

Author: Sarah Jones, Junior, Engineering Physics
Faculty Mentor: Serena Eley, Physics

This project is focused on understanding how nanoparticle inclusions in superconducting films affect a sample's measured current carrying capacity. Samples analyzed in this project are all 900 nm thick (Y,Gd)$Ba_2Cu_3O_7$ films which were grown with different nanoparticle inclusions. Inclusions in these samples are rare earth oxides (naturally occurring during growth), BaHfO, and BaSnO (intentionally included during growth). Nanoparticles in type-II superconductors have been observed to pin vortices and prevent their dissipation, which increases the current carrying capacity of the superconductor. This project aims to further understand these vortex nanoparticle interactions by analysis of the critical current and vortex creep of samples under influence of static magnetic fields up to 35 T. Future work will include the search for signatures of nanoparticles which pin multiple vortices under high magnetization. Correlations between nanoparticle density, size vs. coherence length, and non-monotonicity in current capacity will also be characterized.

98 Fastest Quantum Gate in a Fully Connected Quantum Computer

Author: Kyle Clark, Junior, Engineering Physics
Faculty Mentor: Zhexuan Gong, Physics

Quantum computing can offer promising speedup over classical computers using the quantum mechanical phenomena of entanglement. Two-qubit CNOT gates can generate the desired entangled state the fastest, but currently take thousands of times longer to complete than single qubit gates. Using only two qubits for this gate, the theoretical interaction cost for this gate is $\varpi/4$. However, by using more qubits in a fully connected system, we are able to decrease this interaction cost. Using a three qubit system, we were able to lower this interaction cost to only $\varpi/8$, indicating that the addition of qubits to a fully connected system will result in an increase in gate speed.

99 Computational Modelling of the Photo-Field Effect

Author: William Schenken, Junior, Engineering Physics
Faculty Mentor: Reuben Collins, Physics

The photoresponse of a thin film transistor depends on the mode of operation the transistor is in, in an effect known as the photo-field effect. The extent of this effect then depends on the properties of material composing the transistor. This intensity and state dependent photoresponse is explored in amorphous silicon (a-Si) thin film transistors (TFTs) with computational modelling. Results of the numerical simulation agree with observed experimental results. Possible sources of the effect are analyzed and related to parameters in the model. The results from a-Si TFTs are then related to experimental results of TFTs consisting of a-Si embedded with nanocrystalline silicon (nc-Si) quantum dots (the composite material denoted as a/nc-Si), and future work involving a more explicit relationship between the parameters in the model and the properties of a/nc-Si is discussed.

100 Correlation of Conformations with Fibrinolytic Activity of Matrix Metalloprotease-1

Author: Danielle Forristall, Senior, Engineering Physics
Faculty Mentor: Susanta Sarkar, Physics

Protein conformational dynamics is considered as important for catalysis, but it is often difficult to distinguish the catalytically important conformational changes because proteins are inherently flexible biomolecules. This proposal posits that the conformations-catalysis connection of protein function can be defined using single molecule conformational dynamics. We have chosen matrix metalloprotease-1 (MMP1) as a model system because MMP1 displays dramatic substrate promiscuity and temperature-dependent activity. MMPs are cell secreted zinc- and calcium-dependent enzymes that degrade and regulate various structural components of the extracellular matrix (ECM). MMP1 is known to degrade type-1 collagen, but we found that it can also attack a wide range of other protein and non-protein substrates including crosslinked fibrin and alginate. Single point mutation at the active site of MMP1 not only inhibits the catalytic activity on different substrates, but also changes the conformational dynamics. Our hypothesis is that catalytically important conformational changes can be identified within the single molecule conformational dynamics of MMP1; mutations and ligands can be identified to influence the relative distribution of conformations for catalytic engineering for a specific substrate. Using single molecule conformational dynamics measurements using Forster Resonance Energy Transfer (FRET), stochastic simulations, and molecular dynamics (MD), we correlate MMP1 conformations with catalysis. Conformational dynamics on diverse substrates across a broad range of time scales will provide insights into the mechanism of MMP1 promiscuity.

101 Correlation of Conformations with Collagen Degradation Activity of Matrix Metalloprotease-1

Author: Chase Harms, Senior, Engineering Physics
Faculty Mentor: Susanta Sarkar, Physics

Water-soluble triple-helical collagen monomers self-assemble into water-insoluble large collagen fibrils, which provide a scaffold for resident cells to maintain integrity of extracellular matrix (ECM). Degradation of collagen fibrils by cell-secreted matrix metalloproteases (MMPs) is an essential part of tissue remodeling and is involved in many diseases, including cancer, inflammation and tissue injury. Both, specific and nonspecific binding sites exist on fibrils but have not been fully characterized because binding kinetics and degradation mechanisms of fibrils are inaccessible to ensemble biochemical and biophysical methods. MMP1 stands out in the 25-member MMP family because it degrades triple-helical and most abundant type-1 collagen, has crystal structures, and its interaction with collagen monomers is well-studied. Using single molecule tracking of labeled MMP1 on native type-1 collagen fibrils, we showed that MMP1 initiates fibril degradation at specific sites spaced apart every 1 um and diffusive motion of MMP1 constitutes more than 90% of its time on the fibril leading to a significant reduction of the overall catalytic rate. Subsequently, we showed that fibrils also play a role in MMP1 activity due to vulnerable sites on fibrils caused by strain-induced spontaneous periodic buckling. Moreover, the MMP1 catalytic domain alone cannot cleave triple-helical collagen monomers; both the hemopexin and catalytic domains are needed for collagen degradation suggesting role of conformational changes. These results led to our hypothesis that the overall catalytic rate of MMP1 depends not only on active site catalysis, but also on diffusive motion, substrate properties, and conformational dynamics. Our preliminary single molecule Forster Resonance Energy Transfer (smFRET) experiments using fluorescently labeled active and catalytically inactive MMP1 show significant differences in inter-domain motions, which suggest an allosteric mechanism.

102 Industrial Scale Up of Matrix Metalloprotease-1 Production

Author: Sumaer Kamboj, Senior, Chemical and Biological Engineering
Faculty Mentor: Susanta Sarkar, Physics

Collagen is the most abundant protein in the human body and the collagen degrading enzyme, human matrix metalloprotease-1 (MMP1), is critical for normal cell functioning and in disease states such as cancer. It also has biotechnological applications in broad-spectrum degradation of tissue components for cell isolation used in cell biology research and disease applications involving aberrant collagen depositions. However, the prohibitive cost (~$250 for 10 ug of MMP1) limits its usage and therefore, an analogous enzyme, bacterial collagenase, produced by the bacteria Clostridium histolyticum is currently used for cell isolation, treatment of Dupuytren's and Peyronie diseases (FDA-approved Xiaflex injection), and to promote wound healing (FDA-approved Santyl cream). The major drawback of the bacterial enzyme is the triggering of an immune response, an adverse side effect that is less likely to occur with human MMP1. We have reduced the cost of human MMP1 by an innovative purification method without chromatography (patent filed) that produces ~1000 times less expensive and ~2.5 times more active protein compared to the commercially available MMP1. We present industrial scale up of MMP1 production for commercialization.

103 Modulating Cellular Phenotype and Genotype of E. coli

Author: Avery Tyndall, Freshman, Chemical and Biological Engineering
Author: Logan Cummings, Freshman, Mechanical Engineering
Faculty Mentor: Susanta Sarkar, Physics

The working hypothesis is that proper functioning of the replication and post-replication mechanisms in cells can be affected by force, and some cells will survive via adaptive mutations leading to new genotypes and phenotypes. In an initial feasibility test, we have used E. coli production of beta-galactosidase that turns colonies blue. Upon application of force using a cell breaker for 2 hr, colonies changed morphology and became white, suggesting that as a minimum the beta-galactosidase gene was modified. Based on these encouraging results, we propose to define the genotype changes of E. coli cells under defined mechanical forces.

104 Fabrication of Quantum Dots in Silicon

Author: Bradley Lloyd, Senior, Engineering Physics
Faculty Mentor: Meenakshi Singh, Physics

The variety of uses for quantum dots has proliferated in recent years, ranging from photovoltaics to quantum computing. This work is focused on developing electrostatically defined quantum dots for applications in neuromorphic computing. The foremost among these applications is the use of quantum dot devices as artificial synapses. We begin by outlining the model of an artificial synapse and its required behavior. Then, we present a quantum dot architecture in which this functionality can be obtained. Finally, the fabrication and parameters of the electrostatically defined quantum dots is outlined.

105 Visualizing Material Dynamics Resulting from Heating with Single-Shot Diffractive Imaging: Using Patterns of Scattered Light to Monitor Surface and Plume Dynamics

Author: Morgan Trexler, Freshman, Mechanical Engineering
Faculty Mentor: Jeff Squier, Physics
Faculty Mentor: Daniel Adams, Physics

Current additive manufacturing (AM) techniques struggle to provide feedback on part quality in-situ. As a result, AM parts require extensive post process testing for certification. In many AM processes, a plume forms during layer fusion. Our goal is to image the plume in three dimensions, providing feedback to optimize print quality in real time. Single-shot diffractive imaging offers a promising solution to monitoring parts during printing and certifying parts after printing. In diffractive imaging, the pattern of light scattered from the plume is recorded on a detector far from the plume region. The scattering patterns are passed into an advanced algorithm that produces an image of the material surface, electron density profile in the plume, and precise height information as the part is printed. By providing more extensive feedback during the printing process, diffractive imaging could eventually detect printing failures and part properties minimizing optimization times.

106 Open-Source XPS Simulator: Creation and Application in Differentially Charged Binaries

Author: Sergey Koryakin, Senior, Engineering Physics
Faculty Mentor: Xerxes Steirer, Physics

A numerical simulator for X-Ray Photoelectron Spectroscopy (XPS) is presented that enables study of differential charging in surfaces. The XPS simulator improves upon other available XPS simulation software by including surface charge effects on spectra, a user-friendly interface and collaborative availability with open source code. The python code based simulator is aimed to help teach a wider range of students the experimental solid state physics of XPS. This presentations will demonstrate the capabilities of the simulation with a charged binary compound and discuss the physics of differential charge buildup.

107 Simulation of Thermal Conduction in a Superconducting Nanowire System

Author: Zachary Parrott, Junior, Engineering Physics
Faculty Mentor: Meenakshi Singh, Physics

Superconductor-ferromagnetic hybrid systems are predicted to have strong thermoelectric effects at cryogenic temperatures with potential nanoscale cooling applications. In order to experimentally measure the Seebeck coefficient of these fabricated nanowire based systems, proper understanding of the scale of thermal transport expected is necessary. This project seeks to simulate temperature gradient across a nanowire normal to on chip heater through the heat equation in three dimensions. The need to take into account highly temperature dependent thermal conductivities and cooling ability of the dilution refrigerator utilized, a numerical solution is necessary. Simulation has been developed in the commercial software FlexPDE, a scripted finite element solution environment for partial differential equations. In addition to quantifying temperature gradient of nanowires provides additional ability to investigate other experiment parameters including optimal heater and sensor placement. Through this effort further areas of study have been identified concerning the need for experimental measurement of thermal conductivity at low temperature for nanoscale systems.

108 Structural Analysis of the p4/nmm Space Group Ternary Compounds

Author: Erik Bensen, Sophomore, Engineering Physics
Faculty Mentor: Eric Toberer, Physics

This project began by searching the Zn-V-Sb phase space for new thermoelectric materials. Through this exploration process, we confirmed the existence of the compound ZnVSb previously discovered but not explored by Zhu et al. Then we solved for the ZnVSb crystal structure and conducted low temperature magnetic measurements as well as band structure calculations. The crystal structure was determined to be in the P4/nmm space group composed of a square net lattice surrounding a rock salt like bilayer of atoms. Inspired by this work with ZnVSb, we searched the literature and found that the P4/nmm space group holds a wide variety of layered ternary compounds in the PbClF, CaGaN, ZrSSi, and Cu2Sb structure types. These structure types are crystallographically restricted such that only one parameter, the skew, is free to change between compounds. Additionally, these compounds comprise a wide variety of properties including: antiferromagnetic, superconducting, thermoelectric and optical materials which appear to be correlated with the magnitude of the skew and are a result of long range symmetry, short range bonding, and chemical composition. We developed an algorithm to pick the ordering of the elements in the layers with 95% accuracy and are using machine learning techniques including the K-Nearest Neighbor algorithm to model the skew given the electronegativities and ionic radii of the elements in the compound. This model will allow us to start refining our search for new new materials by using the model to predict properties of ternary compounds in this space group before synthesis.

109 Mysterious Flashes Observed High in the Atmosphere by the Pierre Auger Cosmic Ray Observatory

Author: Austin Latham, Sophomore, Engineering Physics
Faculty Mentor: Lawrence Wiencke, Physics

This research investigates unexplained optical flashes observed by the Pierre Auger Cosmic Ray Observatory (Auger) when looking for a specific transient luminous event above thunderstorms, known as elves. Auger is a hybrid detector that uses a surface detector (SD) and a fluorescence detector (FD) to observe high-energy atmospheric events. As the detection of the unexplained flashes in the FD of Auger coincides with elves, we were able to determine that these two events come from the same source. With a correlation between the locations of these shared events and the locations of lightning provided by the World Wide Lightning Location Network (WWLLN), we determined that the cause of the flashes is the same lightning that causes elves. Simulations suggest that these flashes that the observatory is recording may be generated by a phenomenon known as terrestrial gamma ray flashes (TGFs). New data that records signals over a longer time period is currently being analyzed to study the full shape and duration of the flashes.

110 The Use of SHINERS for Raman Spectroscopy

Author: Gordon Gouger, Junior, Engineering Physics
Faculty Mentor: Thomas Furtak, Physics

The objective for this experiment was to be able to detect a mono-layer of otherwise hard to detect molecules on any preexisting surface. Raman spectroscopy is used to study the different frequency modes of materials. This is done through the measurement of the small percentage of light that is scattered. By measuring the change in energy of the outgoing photons as well as the how many photons have that energy delta we can determine how much energy went into vibrations of the molecules. Shell isolated Nano-particles are used since the amount scattered light is so small it is undetectable by itself. These Nano-particles act as antennae amplifying the signal. We worked specifically with carbon coated silver Nano-particles. The use of gold Nano-particles coated with silica have been used for about 8 years. However, theoretically silver nanoparticles should produce a large amplification and carbon was used as it is easier to work with then silica. The end goal was to be able to detect a very small amount of PETN which has been used in terrorist bombings in the past. By being able to detect a small amount of this material on any surface, possible further attacks can be stopped.

RESEARCH CONDUCTED BY MINES STUDENTS WITH OFF-CAMPUS MENTORS:

111 Microstructure Characterization and Image Processing Techniques

Author: Henry Collis, Junior, Mechanical Engineering
Faculty Mentor: Dan Stefan Bolintineanu, Sandia National Labs

Image processing of material micro-graphs can yield significant properties that relate to material performance. Three material classes that we are currently researching are polymer foams, energetics, and thermal spray materials. Analyzing micro-scale images of these materials have lead us to significant properties. They include and are not limited to: porosity, spatial distributions, percolation, anisotropy, and tortuosity. These properties are useful in understanding different material microstructures and ongoing efforts in correlating microstructural features to macroscale material properties.

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112 Applications of Random Walks Utilizing Neuromorphic Computing

Author: Leah Reeder, Junior, Applied Mathematics & Statistics
Faculty Mentor: William Severa, Sandia National Labs

Neuromorphic computing has many promises in the future of computing due to its energy efficient and scalable implementation. Here we present an extension to a neural algorithm that is able to solve the diffusion PDE by implementing random walks on neuromorphic hardware. Additionally, we introduce four random walk applications that use this spiking neural algorithm. The four applications currently implemented are: generating a random walk to replicate an image, finding a path between two nodes, finding triangles in a graph, and partitioning a graph into two sections. We then made these four applications available to be implemented on software using a graphical user interface (GUI).

Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

113 Quantifying the role of Heterogeneity in Aging Demographics, Late-life Mortality Plateau, and High Early-life Mortality

Author: Anthony Sun, Sophomore, Applied Mathematics & Statistics

High early life mortality (HELM) and Late-life mortality plateau (LLMP) are significant deviations from Gompertzian mortality observed in many biological populations. However, the correspondence between these population-level deviations and the intrinsic mortality trajectories in biological aging has yet to be determined. An attractive explanation is that mortality heterogeneity in Gompertzian population may result in these population-level deviations. Here we show that both HELM and LLMP can be derived from genetic and environmental heterogeneity. Using computational models of a heterogeneous Gompertzian population, we show that LLMP and HELM can arise from heterogeneity in Gompertzian parameters and is sensitive to the mean value of these parameters. For a diverse set of organisms (D. melanogaster, C. elegans, H. sapiens, H. glaber), we determine the contribution of heterogeneity to LLMP and HELM. We provide the first method for quantifying the contribution of heterogeneity to species-specific deviations from Gompertzian mortality.

NOTES

ABOUT MURF

MINES UNDERGRADUATE RESEARCH FELLOWSHIP (MURF)

The objective of this program is to enhance the education of undergraduate students with an opportunity to work as research assistants on faculty-led research projects. This will broaden and deepen the educational experience of students by exposing them to the research enterprise. Engaging in research could turn into a journey of self-discovery for students as it may help them identify their own career or research aspirations.

Research funded by this program cannot earn research credit or count towards senior design/capstone credit. Participating faculty members are encouraged to increase the research participation of qualified female students and students from under-represented ethnic backgrounds.

ELIGIBILITY AND STIPEND INFORMATION

The program is competitive and open to all undergraduate students at Mines.

- MURF recipients receive an annual stipend of $1500, disbursed in two equal installments in fall and spring semesters.
- Renewals for a second year are allowable upon demonstration of adequate progress and have to be applied for through the next solicitation.

REQUIREMENTS

Students who receive the fellowship must fullfil the following requirements:

- Provide a 1-2 page summary of the research work at the end of fall semester.
- Participate in the undergraduate students learning outcomes survey conducted twice during the academic year.
- Present a poster or give a talk at the annual undergraduate research symposium held in spring semester (April).

The student application deadline for 2019 MURF is June 3rd.

You can learn about MURF, browse available research projects, and submit an application here:
https://www.mines.edu/undergraduate-research/undergraduate-research-fellowship/

CONGRATULATIONS!

2018-2019 MURF RECIPIENTS

Applied Mathematics and Statistics
Michael O'Leary
Jayde Thompson
Kate Bubar
Miika Jarvela
John Corrette

Chemical and Biological Engineering
Anthony Nagygyor
Courtney Smoljan
Jonathan Newcomb
Yilin Wu
Kristen Hietala
Sarah Livingston
Carla Osuna
Elisa Madonna
Gavin Yeung
Sophia Johnson
Shurraya Polunci
Jordan Sand
Brittany Slupe
Ronghua Bei
Allison Vanderfeen
Christopher Sands
Thomas Crowe
Gabriel Adriano
Sumaer Kamboj
Abigail Osburn
Amara Hazlewood
Chemistry
Mariah Papac
Riley Hansen
Hadley Thomas
Olivia Bird
Allison Vanderfeen
Isabella Rios

Civil and Environmental Engineering
Megan Freytag
Jake Stogdill
Nicole Holland
Sarena Nguyen
Lindsey Whittington
Jacob Woods
Aurora Waclawski

Computer Science
Arthur Mayer
Ryan Buck
Joseph Zeng
Taewoo Kim
Elizabeth Boyle
Savannah Paul
Simon Reisig
Azam Abidjanov
Stephen New
Gazi Mahbub Morshed
Matthew Miller
Daniel Winternitz
Connor Price
Madeline McKune
Jordan Newport

Economics and Business
Warren Marshall
Melanie Pincus

Electrical Engineering
Jacob Johnson
Alyssa Boll
Alexi Drgac
Jacquelene Walter
Jeffrey Stenerson
Madison Le
Spencer Hutchinson
Adam Sandstedt
Allison Tanner
Louis Haddad
Sunsheng Liu
Mandy Whitaker

Geology and Geological Engineering
Cassidy Grady
Clara Bewley
Lauren Miller
Julia Payne
Jacob Tarpley
William Busath
Carissa Anderson
Leland Spangler
Brian Gray
Caleb Ring
Geophysics
Katherine Cohen
Daniel Choi
Nick Wagner
Aspen Davis

Mechanical Engineering
Luke Bowersox
Ali Artzberger
Allison Bateman
Charles Ramey
Connor McLean
James Frazar
Gabriel DeSouza
Meredith Wirth
Robin Evans
Marcelo Gonzales
Mason Hightower
Nicholas Gertie
Christopher Chmura
Michelle Butler
Juno Padilla
Noah Pelsmaeker
Daniel Dickason
William Huber
Joseph Duebner
Daghan Yigitbas
Benjamin Butler

Metallurgical and Materials Engineering
Michael Thuis
Melissa Dangler
Chad Haunschild
Madeleine Johnson
Anyka Bergeson-Keller
Brionna Dumlao
Luc Hagen
Christina Baker
Zoey Huey

Mining Engineering
Jaume Martinez Calvo
Nicholas Bellusci
Tyler Acheson

Petroleum Engineering
Youjun Lee
Siradon Prateepswangwong
Emilio Gonzalez Marroquin

Physics
Aaron Denning
Patrick Losique
Austin Latham
Kyle Crack
Erik Bensen
Bradley Lloyd
Zachary Parrott
Sergey Koryakin
Gordon Gouger
Noah Ottum
Matthew Fedyk
Sarah Jones
Andres Velasco

ABOUT FIRST

FRESHMAN INNOVATION AND RESEARCH SCHOLAR TRAINING (FIRST) FELLOWSHIP

The Freshman Innovation and Research Scholar Training (FIRST) Fellowship offers an opportunity for highly motivated first-year students to participate in original research experiences coupled with a focus on innovation. FIRST fellowship recipients are awarded $1000, disbursed in two installments, to compensate for their time spent on research.

FIRST FELLOWSHIP STRUCTURE

- In the fall semester, students enroll for a 1- credit course that will introduce them to academic research and provide tools needed to navigate the complex landscape of research.
- Students will identify a faculty mentor during the fall semester and work with the mentor to distinguish a research topic, formulate a hypothesis and ascertain objectives by the end of the semester.
- In the spring semester, students participate in faculty-mentored research and conduct hands-on research work in a lab setting.
- At the conclusion of the spring semester, selected students may receive funding to continue working with the faculty mentor and participate in the innovation workshop.
- Students conclude their fellowship by presenting their research and innovation project during the summer semester research Symposium.

You can learn about FIRST fellowship here: **https://www.mines.edu/undergraduate-research/first/**

2018-2019 FIRST SCHOLARS COHORT

Emily Phaneuf (Faculty Mentor: Junko Munakata-Marr)
Cindy Rodriguez-Ornelas (Faculty Mentor: Judith Klein)
Tony Tien (Faculty Mentor: Kevin Cash)
Jewel Newman (Faculty Mentor: Neal Sullivan)
Gabriela Reguerio (Faculty Mentor: Kathryn Johnson)
Logan Cummings (Faculty Mentor: Susanta Sarkar)
Avery Tyndall (Faculty Mentor: Susanta Sarkar)
Lauren Zoe Baker (Faculty Mentor: Hua Wang)
Melanie Breckenridge (Faculty Mentor: Geoff Brennecka)
Gabriela Blanchard (Faculty Mentor: Carolyn Koh)
Jack Chmura (Faculty Mentor: Atef Elsherbeni)
Miriam Garza (Faculty Mentor: Xiaoli Zhang)
Emma Lilly (Faculty Mentor: Kamini Singh)
Madeline Kizziar (Faculty Mentor: Zane Jobe)
Lauren Martin (Faculty Mentor: Richard Palin)
Nicholas Redhorse (Faculty Mentor: Chuan Yue)
Anna Christiansen (Faculty Mentor: Jason Porter)
Jamison Hubbard (Faculty Mentor: Branden Kappes)
Jason Wolfe (Faculty Mentor: Andrew Petruska)

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2019 FACULTY MENTORS

MENTEE'S POSTER NUMBERS ARE INCLUDED IN THE PARENTHESIS.

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Mannan, Forest [3]
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Adams, Daniel [105]
Steirer, Xerxes [106]
Toberer, Eric [108]
Wiencke, Lawrence [109]
Furtak, Thomas [110]

Thank you to all the mentors for your commitment to undergraduate research!

2019 STUDENT PRESENTERS

POSTER NUMBER INCLUDED IN THE PARENTHESIS.

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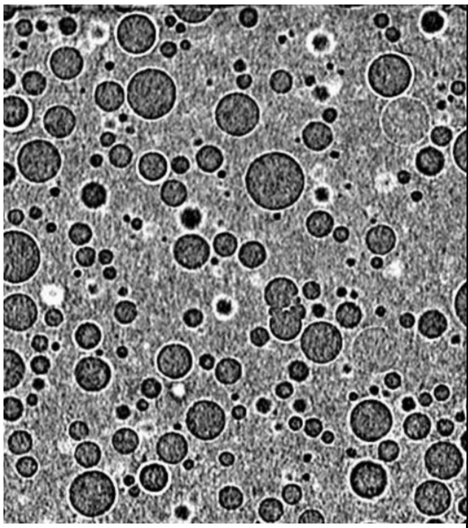

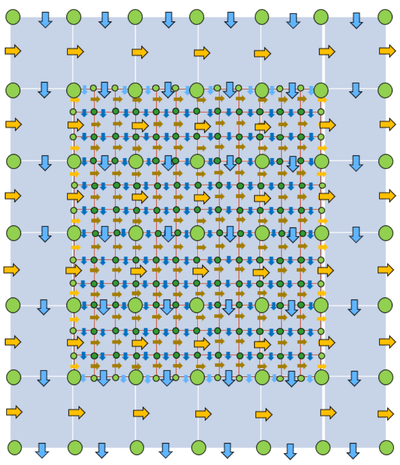

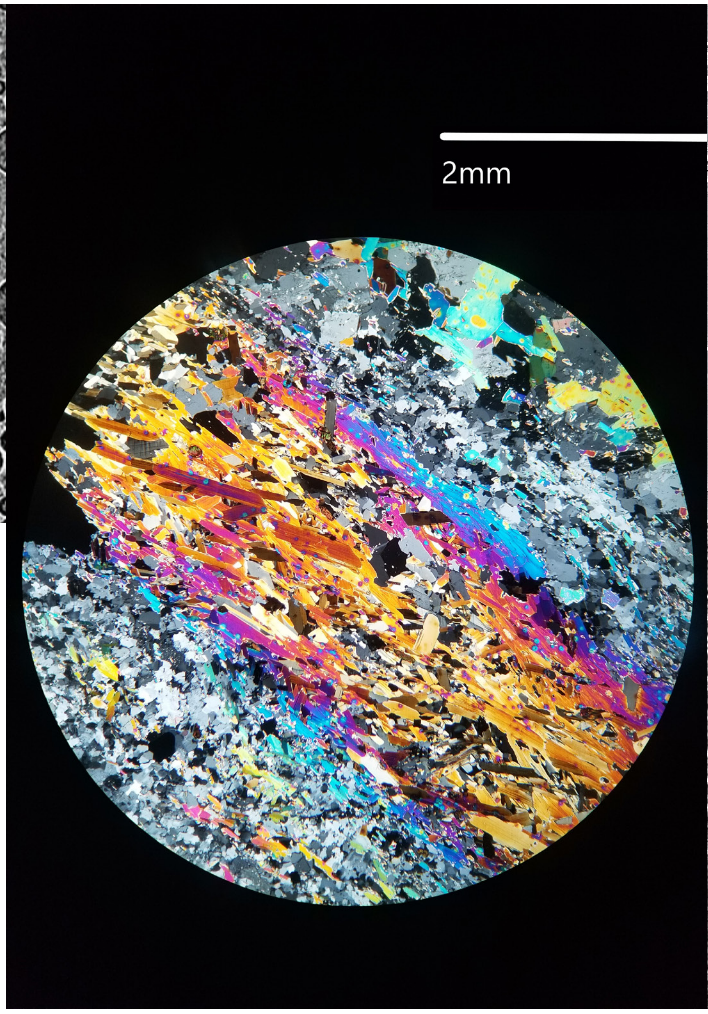

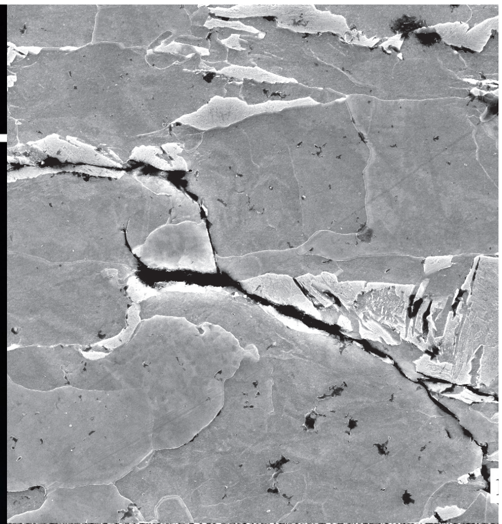

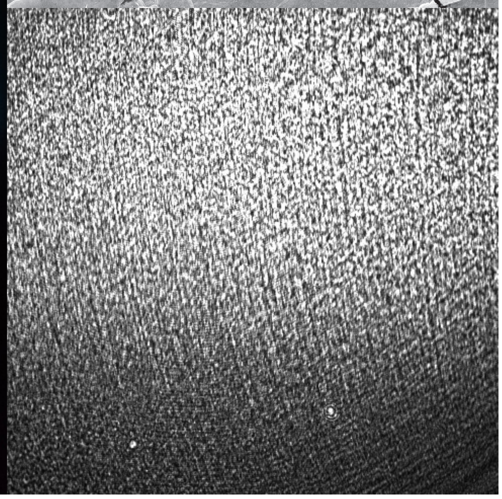

Top left: Polymer foam microstructure infused with GMBs (glass beads) prior to compression test.
Author: Henry Collins, Junior, Mechanical Engineering

Bottom left: Fine grid superimposed with a coarse grid to show subgridding layout for the finite-difference time-domain.
Author: Madison Le, Electrical Engineering

Center: Polarized light microscope image (40x magnification, crossed polarizers) of phlogopite (Mg-biotite) porphyroblasts in a metamorphosed evaporite breccia.
Author: Stephen Piurkowsky, Senior, Geological Engineering

Top right: SEM micrograph of hydrogen cracking in pipeline steel, bordered by a light-colored microconstituent believed to contain martensite/austenite.
Author: Zoey Huey, Senior, Metallurgical and Materials Engineering

Bottom right: BAM image heptane deposited on water subphase.
Author: Michael Thuis, Junior, Metallurgical and Materials Engineering

“If I have seen further, it is by standing on the shoulders of giants.”

- Isaac Newton