UNDERGRADUATE RESEARCH SYMPOSIUM

COLORADO SCHOOL OF MINES
EARTH • ENERGY • ENVIRONMENT

2022 | PROGRAM

04.18.22 &

04.19.22

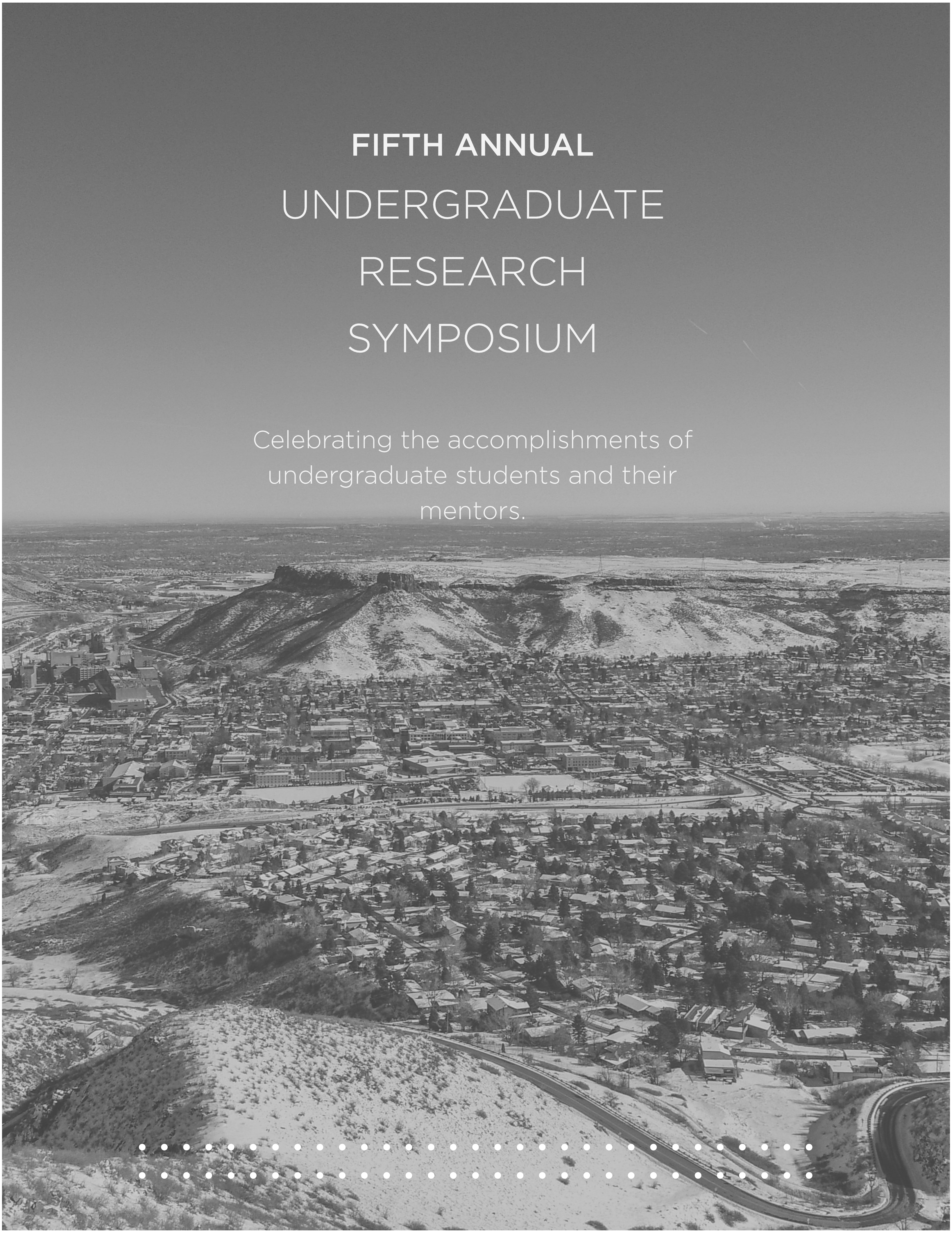
GREEN CENTER

Undergraduate Research Scholars and University Honors and Scholars Programs presents the fifth annual Symposium showcasing undergraduate research from all disciplines across Mines! Oral presentations will take place April 18, 10a-12p. Poster presentations will take place April 19, 10a-12p.

Keynote address, *Reimagining Undergraduate Research for a Post-Pandemic World*, by Jenny Olin Shanahan, Ph.D. on Monday, April 18, 4p in the Student Center, Ballrooms D&E.

FIFTH ANNUAL
UNDERGRADUATE RESEARCH SYMPOSIUM

Celebrating the accomplishments of undergraduate students and their mentors.



UNDERGRADUATE RESEARCH SYMPOSIUM

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WELCOME

Dear Mines Community,

It is with great pleasure the office of Undergraduate Research Scholars and University Honors and Scholars Program, UHSP, invites you to the fifth annual Undergraduate Research Symposium.

The Undergraduate Research Symposium provides a valuable opportunity for our students to disseminate their work in an effective way, thereby advancing their communication skills and engaging them in dialogue with a broader audience. Students from all disciplines are invited to participate. In 2018, at our inaugural symposium, we had 80 unique poster presentations — the breadth and depth of which was outstanding. This year, the Undergraduate Research Symposium is presenting over 100 intellectually stimulating posters and oral presentations. This includes presentations by our largest cohort of first-year student researchers yet.

The 2022 Undergraduate Research Symposium will be held in person on Monday, April 18th, 2022 and Tuesday, April 19th, 2022. Oral presentations will take place in the Green Center, Second Floor on Monday, April 18th from 10a-12p MT. Poster presentations will take place in the Green Center, Friedhoff Hall on Tuesday, April 19th from 10a-12p MT. We are honored to welcome Professor Jenny Olin Shanahan, Assistant Provost for High-Impact Practices at Bridgewater State University, to deliver our Keynote Address, *Re-imagining Undergraduate Research for a Post-Pandemic World*, on Monday, April 18 4p-5p in the Student Center, Ballrooms D&E. On Tuesday, April 19th, from 12p-1:30p, Professor Shanahan will also be hosting a Workshop for Mentors, *Centering Equity and Inclusion in Undergraduate Research Mentoring.*

It goes without saying, the past two years have not been easy for anyone. But, your hunger for knowledge and unwavering curiosity feeds the spirit of research at Mines. We would like to specifically acknowledge the faculty mentors at Mines who embrace inquiry-based learning by engaging undergraduate students in research. Your dedication to undergraduate research and our students' eagerness to engage are what make this symposium possible. Thank you all for your hard-work and thoughtful pursuit of discovery.

Congratulations to all the students who are presenting at this year's symposium. And, lastly, thank you all for joining us to celebrate our exceptional students and their dedicated mentors.

Mines Undergraduate Research Scholars
University Honor and Scholars Programs

2022 SCHEDULE OF EVENTS

MONDAY, APRIL 18TH, 2022

Oral Presentations
Green Center, Second Floor, Rooms 200C & 200F
Session 1: 10:00am-11:00am
Session 2: 11:00am-12:00pm

Keynote Address by Dr. Jenny Olin Shanahan
Re-imagining Undergraduate Research for a Post-Pandemic World
Student Center, Ballrooms D&E
4pm - 5pm

TUESDAY, APRIL 19TH, 2022

Poster Presentations
Green Center, Friedhoff Hall
10am -12pm

Workshop for Mentors by Dr. Jenny Olin Shanahan
Centering Equity and Inclusion in Undergraduate Research Mentoring
Green Center, Second Floor, Room 200C
12pm - 1:30pm

MORE ABOUT THE KEYNOTE ADDRESS

Speaker: Jenny Olin Shanahan, PhD
Assistant Provost for High-Impact Practices at Bridgewater State University

Re-imagining Undergraduate Research for a Post-Pandemic World: This keynote address for student-researchers and mentors will focus on three interconnected transformations in Undergraduate Research: why centering equity and inclusion is essential to discovering and creating new knowledge; how the COVID-19 pandemic is prompting long-term changes to research questions and methods; and why flexibility and trust are foundational to the "next normal" of undergraduate research.

ORAL PRESENTATIONS - SESSION 1

MONDAY, APRIL 18TH, 2022

SESSION 1

Green Center, Second Floor

10:00A - 11:00A

Time	Location	Presenters	Project Number and Title
10:00A - 10:15A	**200C**	**Kylee Sheikh**	**58 O: Understanding Engineering Students' Experiences with Perceiving and Rationalizing Meritocracy in the Development of Professional Identity**
10:00A - 10:15A	200F	Jessica Kennedy	55 O: Multiphysics Optimization of GaN-Based Power Transistors for 5G mm-Wave Operation
10:15A - 10:30A	**200C**	**Erik Villar, Jonathan Juaneza**	**91 O: Traceability of Colorado's Frac Sand Supply Chain and Related Emissions**
10:15A - 10:30A	200F	Alexandra D'Aquila	10 O: Technoeconomic Analysis of Catalytic Membrane Reactor Processes for Producing Ammonia based Fuels
10:30A - 10:45A	**200C**	**Marisa Sandoval**	**33 O: Urinary Biomarkers as Personalized Feedback: A More Successful Approach to Weight Loss**
10:30A - 10:45A	200F	Sean Skweres	74 O: Applying Optical Diagnostics and Laser Flash Diffusivity to Characterize Electrolytes
10:45A - 11:00A	**200C**	**Armand Ovanessians**	**50 O: Unveiling Hidden Viral-Host Protein Interactions in COVID -19 for Drug Repurposing**
10:45A - 11:00A	200F	Kayla Andis	77 O: Analysis of Electroplating Bath Composition for III-V Substrate Reuse

ORAL PRESENTATIONS - SESSION 2

MONDAY, APRIL 18TH, 2022

SESSION 2

Green Center, Second Floor

11:00A - 12:00P

Time	Location	Presenters	Project Number and Title
11:00A - 11:15A	**200C**	**Sergio Oscar Nuñez Silva**	**101 O: Systematic Analysis of Low-Energy 7Be Decay Spectra in Superconducting Quantum Sensors for the BeEST Sterile Neutrino Search Experiment**
11:00A - 11:15A	200F	Akshnati Vaishnav	49 O: Proteome-Wide Association Study: Enhanced Linking of Genes and Phenotypes with Machine Learning
11:15A - 11:30A	**200C**	**Finnegan Rush**	**104 O: A Triple-Pinhole Apparatus For the Exploration of Vortex Dynamics**
11:15A - 11:30A	200F	Ashley Galligan	78 O: Influence of Titanium on Pitting Corrosion of 304 Stainless Steel
11:30A - 11:45A	**200C**	**Sara Kim**	**39 O: Electron Microscopy Analysis of Fuel Cell and Battery Electrodes**
11:30A - 11:45A	200F	Natalie Compton, Mason Weems, William Stogdehill	85 O: Robotic Blacksmithing
11:45A - 12:00P	**200C**	**Julia Eiken**	**5 O: Web-Based Application for Mathematical Model of Blood Coagulation**
11:45A - 12:00P	200F	William Lansing	86 O: Development of Consumables for Deposition Rate Additive Manufacturing

TECHNICAL PROGRAM

APPLIED MATHEMATICS AND STATISTICS

Please note, Poster Presentations are noted with a 'P' and Oral Presentations are noted with an 'O'.

1 P **Seasonal and Hourly Variability of Particulate Matter 2.5 in Denver**
Author: Zi Li, Senior, Applied Mathematics and Statistics
Mentor: William Daniels, Applied Mathematics and Statistics
Mentor: Dr. Dorit Hammerling, Applied Mathematics and Statistics

Particulate matter 2.5 (PM 2.5) refers to small particles or droplets in the air that have width less than or equal to 2.5 microns. PM 2.5 is a major air pollutant and can cause diseases in the human respiratory system, and hence, it is of interest to study PM2.5 sources and variability over time. For our analysis, we select the Denver metropolitan area as our study region and use the Purple Air sensor network that records local and real-time air quality data. We randomly select ten sensors within this region that have complete PM 2.5 records from 2019 to 2021 to get a representative sample and conduct exploratory data analysis to analyze how PM 2.5 concentrations change at seasonal and hourly timescales. We observe that not all of the sensors have the same monthly variation due to the impact of local factors and that PM 2.5 peak values typically occur in either July or August. We further hypothesize that wildfires, both local and via long-range atmospheric transport, contribute to the PM 2.5 peak values in summer and use multiple linear regression to investigate this hypothesis.

2 P **Mathematical Modeling to Investigate Dual-Pathway Inhibition by Anticoagulant Drugs**
Author: Azlan Tubbs, Junior, Applied Mathematics and Statistics
Mentor: Dr. Karin Leiderman, Applied Mathematics and Statistics

The purpose of blood coagulation is to halt blood flow from a damaged vessel for the vessel to heal and repair. Blood coagulation occurs as overlapping enzymatic events, which are strongly regulated by platelet surfaces. Coagulation begins when the wall of the blood vessel is injured and ends when aggregated platelets seal the injury. Dual pathway inhibition, in which both antiplatelet and anticoagulant drugs are used in combination, promises therapies for reducing risks of harmful clot development that may lead to coronary and cerebrovascular ischemia. Although information exists concerning the effectiveness and success of dual pathway inhibition therapies, the mechanism remains ambiguous due to a lack of ability to observe detailed biochemical interactions during the dynamic clotting process. Mathematical modeling allows for efficient simulations of the clotting process and provides access to the dynamic concentrations of all proteins, cells, and interactions within the system under the influence of flow. This project will build on a mechanistic mathematical model of flow-mediated coagulation and platelet deposition. A combination of the antiplatelet aspirin and the anticoagulant rivaroxaban will be considered in the model, and the clotting process will be simulated for various concentrations of drugs and injury types.

3 P **Understanding Energy Dissipation Through Nonlinear Waves on Quantized Vortex Filaments**
Author: Kaleigh Rudge, Senior, Applied Mathematics and Statistics
Mentor: Dr. Scott Strong, Applied Mathematics and Statistics

Vortex filaments are a fundamental structure in quantum fluid dynamics for transferring energy between length scales. Understanding their motion and the relationship between the transfer of energy and the helical patterns of the vortex lines are crucial in understanding the decay of free quantum turbulence. To understand these relationships, we define scaling laws that separate classical and quantum regimes for fluids. Beginning with the Navier-Stokes equation describing a continuum fluid, we define an inverse Madelung transformation to arrive at the Gross Pitaevskii equation modeling a Bose-Einstein condensate. This is done as the Gross-Pitaevskii equation defines the evolution of identical atoms condensed into a single particle wave function describing the hydrodynamic fluid density. Furthermore, we can connect the Gross-Pitaevskii equation into the Biot-Savart law to understand the velocity fields induced by vortex filaments, defined by regions of density depletion within the condensate. The Biot-Savart integral gives us a line integral and allows us to view a vortex filament from a geometric perspective defined by its curvature and torsion.

4 P Differential Dynamics of Insulin Action Models on Glycerol and Glucose in Adolescent Girls with Obesity

Author: Griffin Hampton, Senior, Applied Mathematics and Statistics
Mentor: Dr. Cecilia Diniz Behn, Applied Mathematics and Statistics
Mentor: Dr. Melanie Cree-Green, University of Colorado Anschutz Medical Campus

In response to a glucose challenge, under healthy conditions the pancreas releases insulin which suppresses lipolysis in adipose tissue, decreasing plasma glycerol concentration, and regulates plasma glucose concentration through action in muscle and liver. Insulin resistance (IR) occurs when more insulin is required to achieve the same effect and IR may be tissue-specific. IR emerges during puberty because of high concentrations of growth hormone and is worsened by the rising phenomenon of youth-onset obesity. Gold standard protocols for evaluating IR do not address potential differences in the dynamics of tissue-specific insulin responses. To investigate the dynamics of insulin acting on adipose tissue, we developed a novel differential-equations based model that describes the dynamics of glycerol during an oral glucose tolerance test. We compared these dynamics to the dynamics of glucose and insulin collected under the same protocol. We found that the action of insulin on glycerol peaks earlier and follows the dynamics of plasma insulin more closely compared to insulin action on glucose. These findings suggest that the dynamics of insulin action show tissue-specific differences in female adolescents with obesity and IR, with adipose tissue responding to insulin more quickly compared to muscle and liver.

5 O Web-Based Application for Mathematical Model of Blood Coagulation

Author: Julia Eiken, Senior, Applied Mathematics and Statistics
Mentor: Dr. Karin Leiderman, Applied Mathematics and Statistics

Blood clotting is a natural process to stop bleeding upon injury. It involves coagulation, a complex network of biochemical reactions with positive and negative feedback, all occurring under flow. Due to this complexity, the overall response of the clotting system is difficult to predict. Mathematical modeling is a powerful tool to facilitate such predictions. These predictions are interesting for clinicians to understand and treat clotting disorders, but difficult to access due to complex computational and mathematical formulations. We present a web-based application that displays one such model and its output in a way that is easy to use for clinicians and other researchers, without direct interaction with the model code. The app allows for simple modification of parameters and acquisition and observation of output data, enabling a broader scientific community to utilize the power of mathematical modeling.

6 P Multiscale Analysis and Simulation of In-Host Dynamics of HIV Infection

Author: Cameron Clarke, Junior, Physics
Mentor: Dr. Stephen Pankavich, Applied Mathematics and Statistics

The time course of HIV infection consists of three distinct stages: an initial acute infection, a long asymptomatic period, and a final transition to AIDS. The majority of existing mathematical models provide a useful representation of either the first two stages or the last stage of infection, but only recently has a viable model that captures all three stages been developed. Herein, we provide a complete analysis of this new, three-stage model and categorize the stability properties of the infected and disease-free equilibria. Additionally, as eradication of the virus is not a feasible option due to viral reservoirs, namely secondary cell populations, the maintenance of an undetectable viral load (i.e. less than 50 virions per cubic millimeter) via antiretroviral therapy (or ART) is the optimal outcome for infected individuals. In order to better understand how to achieve reduced virion populations, we perform active subspace decompositions with the time to the onset of AIDS as our variable of interest. Our simulations demonstrate that lengthening the time to AIDS beyond a human lifespan is a practical option to ensure undetectability of the viral population, and the implementation of time-dependent ART is the most effective process to extend the chronic phase of HIV.

CHEMICAL AND BIOLOGICAL ENGINEERING

7 P CO2 Adsorption in Various Metal Organic Frameworks (MOFs)

Author: Candan Erdemir, Junior, Chemical and Biological Engineering
Mentor: Jair Fernando Fajardo Rojas, Chemical and Biological Engineering
Mentor: Dr. Diego Gómez-Gualdrón, Chemical and Biological Engineering

Ordered, tunable nanoporous materials such as metal-organic frameworks (MOFs) have the potential to be optimized for energy-efficient capture of CO_2 from multiple sources, ranging from flue gas mixtures to air itself. One challenge is that MOF tunability also gives rise to millions of possible materials, making it difficult to find the very best MOF for capturing CO_2 at a given set of conditions. Molecular simulation is being used as a means to more rapidly screen the CO_2 capture properties of a large number of candidate MOF structures in the computer instead of in the lab. While simulation is generally faster than experiments, this is not necessarily true when the simulations involves significant (ye undesired) co-adsorption of H_2O: a compound present both in flue gas and air at concentrations comparable or larger than the CO_2 one wants to capture. Here, we propose a hierarchical screening approach, where first a random pore sampling approach (Widom insertion) is used to learn the average energetics of interaction of H_2O, CO_2 and N_2 with a large number of MOFs, which is encoded by the so-called adsorption Henry's constant. This approach should allow the most hydrophobic MOFs to be easily detected at low computational cost, while also providing insights into what makes a MOF hydrophobic. Subsequently, the smaller set of hydrophobic MOF can go through a screening stage focusing on the co-adsorption of CO_2 and N_2, safely neglecting H_2O effects.

8 P Direct Air Capture of Methane by Engineered Microbial Consortium

Author: Evan Okolovitch, Sophomore, Chemical and Biological Engineering
Mentor: Darrian Newman, Chemical and Biological Engineering
Mentor: Dr. Nanette Boyle, Chemical and Biological Engineering

Since pre-industrial times, atmospheric methane has more than doubled, reaching 1,800 ppb. Although there is only a single molecule of methane for every 200-400 molecules of carbon dioxide, methane serves as a greater contributor to the greenhouse effect due to its higher number of vibrational nodes that facilitate IR absorption. Due to dilute atmospheric concentration, traditional methane sequestration methods require substantial energy inputs. We seek to take advantage of biological methane capture and usage by designing an engineered microbial consortium consisting of a genetically engineering glucose-secreting cyanobacterial strain, Synechococcus elongatus UTEX 2973, and a methane-consuming bacteria, Methylomonas sp. strain 761M. The use of UTEX 2973 as an additional energy resource through glucose production would ideally offset the high energy costs associated with the biological capture of methane. Here, the design and creation of the glucose-secreting strain will use synthetic biology (Golden Gate cloning, Cyanogate, and the MoClo Kit) on UTEX 2973. In the future, further characterization of the methanotroph will be required, as well as an assessment of its capability to grow alongside the mutant cyanobacterial strain. Sustainability and feasibility assessments of this consortium will potentially lead to a negative emission pathway to produce high-value products like biofuels.

9 P Polymeric Gene Therapy: A Literature Review of Delivery Challenges

Author: Aryelle Wright, Junior, Chemical and Biological Engineering
Mentor: Dr. Ramya Kumar, Chemical and Biological Engineering

Following the central dogma of molecular biology, problems arise with abnormal protein function. Gene therapy aims to prevent these problems by targeting specific DNA sequences of diseases. Using polymers, genetic payloads (messenger-RNA, short interference-RNA, plasmid-DNA, and ribonucleoproteins) can rectify mutated DNA in patients, thereby curing diseases of genetic origins. Even with its benefits, gene therapy poses several delivery challenges. Currently, research is trying to replace adeno-associated viruses in clinical gene therapy. This is because individuals have previous immunity to viruses, while there are also safety concerns and questions of costliness. Synthetic materials, polymers, can resolve the financial and manufacturing challenges presented by viral vectors. Polymers provide numerous innate properties, such as versatility of structural

conformations, biodegradability, and ease of synthesis. These polymer complexes determine the efficacy of gene transfection. This poster provides a review of the delivery challenges in gene therapy, while highlighting the advantages of polymers and disadvantages of viral vectors.

10 O Technoeconomic Analysis of Catalytic Membrane Reactor Processes for Producing Ammonia based Fuels

Author: Alexandra D'Aquila, Junior, Chemical and Biological Engineering
Mentor: Rok Sitarx, Chemical and Biological Engineering
Mentor: Dr. John Jechura, Chemical and Biological Engineering
Mentor: Dr. Collin Wolden, Chemical and Biological Engineering

Catalytic membrane reactors (CMR) are reactor units which have been impregnated with a catalyst and paired with a highly selective membrane. This research aims to evaluate the technological efficiency and economic feasibility of a CMR process for producing ammonia based alternative fuels. The techno-economic portion of this research project is being conducted through the process modeling software Aspen Plus using experimental data from physical prototypes. The process produces a high pressure blend of hydrogen and ammonia which can then be used as fuel. Analysis of this process as well as the fuel product indicates that the CMR produces a purer product than the traditional Haber-Bosch process which does not remove nitrogen from the product and thus produces more toxic NOx when burned. The product of the CMR process burns with similar efficiency to a natural gas which indicates that it could reasonably serve as a carbon free replacement fuel wherever natural gas is used. Additionally, the infrastructure required to utilize this ammonia based fuel already exists around the world and many engines and motors could burn this fuel with minor modifications; these factors demonstrate a feasible application for this CMR process and its product as a carbon free fuel source.

11 P Microwheel Propulsion at an Air-Water Interface

Author: Logan Yeager, Junior, Chemical and Biological Engineering
Mentor: Dr. David Marr, Chemical and Biological Engineering

Cystic fibrosis is a genetic disease caused by the malfunction of cystic fibrosis transmembrane regulator (CFTR). This causes the buildup of mucus within digestive organs and more troublingly the lungs as well. Current therapeutics simply mitigate symptoms, and site active therapeutics are limited by transport through mucus. Microbots: magnetically actuated aggregates of magnetic microparticles, are a novel solution to this problem. They are able to effectively increase concentrations at fibrous fronts and mechanically actuate the recanalization of channels, in this case bronchioles and alveolar spaces [1]. The goal of this work is to characterize the propulsion of Dynabead aggregates known as Microwheels near the air-water interface. In conjunction with mucus rheology, this work aims to find remedies to cystic fibrosis and lung cancers via aerosolized targeted drug delivery. An in vitro assay of sub-micellular concentration SDS was used to create an air-water interface. This aims to model the dynamics within lungs: a naturally occurring air-water interface within the body where surfactant is present. From this, it was found that the Microwheels are able to translate on the air-water interface; however, in a counterintuitive manner. Additionally, the characteristic velocity of the wheels is not predictable simply based on radius as compared to previous work. It is believed that wheel geometry plays a role in their ability to translate, and preliminary data indicates that translation rate and circularity may be related in some manner. [1] Disharoon, D, Marr, DWM, Neeves, KB. Engineered microparticles and nanoparticles for fibrinolysis. J Thromb Haemost. 2019; 17: 2004– 2015. https://doi.org/10.1111/jth.14637

12 P Synthesis & Characterization of a Metal Ionomer Composite for Electrochemical Application

Author: Joshua Cedillos, Junior, Chemical and Biological Engineering
Mentor: Jed LaCoste, Chemical and Biological Engineering
Mentor: Dr. Andrew Herring, Chemical and Biological Engineering

Fuel cell application is an extremely complex and important industry, requiring the development of proton exchange membrane (PEMs) solutions for a multitude of different sectors. As of right now, there are commercial standards for proton exchange membrane (Nafion) but need to be improved. One of the high-value materials used in fuel cell application is proton exchange membrane. PEMs are capable of high-power density proton conductivity. Fuel cell application usually creates peroxide formation which leads to low density and conductivity. Agents such as cerium and manganese counterattack peroxide formation but do not stay in the initial area due to diffusion and dissolution. In this work, advancement in PEM properties with additives has the potential to operate efficiently with light-duty fuel cell vehicles and high duty fuel cell vehicles for commercialization usage. This project focuses on the chemically bonded ionomer of perfluorinated sulfonic acid (PFSA) and ionomer membrane. Proton conductivity is organized into two intensive properties of temperature and relative humidity. Methods regarding water uptake and ionomer membrane permeability properties with electrochemical impedance spectroscopy (EIS) and fourier transform infrared spectroscopy (FTIS).

13 P Mechanisms of β-cell Death in Type 1 Diabetes

Author: Drake Hampton, Junior, Chemical and Biological Engineering
Mentor: Dr. Nikki Farnsworth, Chemical and Biological Engineering

Type 1 diabetes (T1D) is characterized by a progressive loss of insulin-producing β-cells in pancreatic islets due to high levels of pro-inflammatory cytokines which are secreted by infiltrating immune cells. We have shown that pro-inflammatory cytokines alter islet function via protein kinase C δ (PKCδ) dependent mechanisms. PKCdelta has been implicated in many important cellular processes, including regulation of apoptotic cell death, and previous studies have suggested a role for PKCδ in mediating β-cell death in T1D. However, little is known about the role of PKCδ in T1D. We hypothesize that increased levels of β-cell death will correlate with increasing prevalence of PKCdelta. MATLAB is used to correlate variation in PKCδ prevalence to immune cell location and β-cell death in the islet to confirm the role of PKCδ in mediating β-cell death in T1D.

14 P Metabolite Flux Across Bacterial Protein Shells

Author: Cosette McLaughlin, Junior, Chemistry
Mentor: Dr. Alexander Pak, Chemical and Biological Engineering

Bacteria use bacterial microcompartments (BMC) to separate metabolic reactions within the cell. BMCs are encompassed by a protein shell. The protein shell allows specific compounds into and out of the BMC, but the mechanistic basis for selectivity across the protein shell remains unknown. In Salmonella, the so-called Pdu BMC serves to catalyze the reaction of 1,2-propanediol and to prevent the escape of toxic intermediates. Two shell proteins, PduA and PduT, were selected to study selective permeability. Using molecular dynamics simulations, the diffusive behavior of three ligands, 1,2-propanediol, propionaldehyde (the toxic intermediate), and 1-propanol (the product), around the shell proteins was studied. In the future, umbrella sampling simulations will be performed to quantify potential of mean forces, thereby allowing explicit identification of key interactions between ligands and protein residues during permeation. This will allow for a better understanding of the selective permeability of these BMCs which have applications as catalytic bionanoreactors to aid in bioremediation, water treatment, or various other fields.

15 P Monitoring the Exchange of Ions Via Fluorescent Nanosensors

Author: Sydney Isbell, Sophomore, Chemical and Biological Engineering
Mentor: Adrian Mendonsa, Chemical and Biological Engineering
Mentor: Dr. Kevin Cash, Chemical and Biological Engineering

The ability to detect and effectively quantify analytes is desirable in the field of biosciences. Current methods, while effective, are either invasive, require extensive training or expensive technology. Our method utilizes ratiometric fluorescent nanosensors to achieve this goal. These nanosensors operate on the principle of ion-exchange analogous to that of ion-selective electrodes. Our sensors have a charge balancing additive, a fluorescent transducer, and an ion detection moiety (ionophore) encapsulated in a hydrophobic polymer (PVC) matrix. The sensor's optical properties (absorbance and fluorescence) change with respect to the surrounding ionic activity. In this work, we developed sensors that are selective and sensitive to calcium ions and pH. The calcium sensors were able to detect calcium concentrations as low as 100 μM and showed an affinity towards Ca^{2+} over other ions (Na^+, K^+, Mg^{2+}). The pH sensors were able to detect pH changes ranging from pH 5 - 9, which encompases most biological systems, and was selective to H^+ ions over the aforementioned competing ions. We aim to deploy these sensors into hornworms (Maduca sexta) to study physiological processes as they progress through each instar.

16 P Environmental Microbiology in the Lab – Nanosensors to Monitor Capillary-Based Systems

Author: Mara Fink, Sophomore, Chemical and Biological Engineering
Mentor: Tyler Sodia, Quantitative Bioscience and Engineering
Mentor: Dr. Kevin Cash, Chemical and Biological Engineering

Soil is full of microbial communities that break down and recycle nutrients and foreign chemicals. These microbes are interdependent on one another. The goal of this project is to test nanosensors developed by the Cash lab to adequately measure interrelated metabolism in a spatially and temporally defined manner. Testing these nanosensors determines their capabilities to image the presence of elements in vitro with the goal to use them in complex microbial systems in the future. Using an in vitro system the facultative anaerobic bacteria Pseudomonas Aeruginosa to set up a single dimension model. Oxygen is measured using fluorescent nanosensors in a capillary based system. The tests indicate that oxygen nanosensors work in this in vitro system and that Pseudomonas Aeruginosa is good at creating oxygen gradients - with highly oxygenated cells at the top and deoxygenated cells at the bottom of the capillary tube. Tests with other nanosensors, like pH are inconclusive and more testing is required as part of future work. The preliminary results from working with the oxygen nanosensors are promising and suggest many next steps. These steps include testing additional sensors, incorporating other types of bacteria and using square capillaries to get images on a confocal microscope.

17 P Porous Organic Cage (POC) Membranes for Olefin/Paraffin Separation

Author: Ashley Potter, Sophomore, Chemical and Biological Engineering
Mentor: Keerthana Krishnan, Chemical and Biological Engineering
Mentor: Dr. Moises Carreon, Chemical and Biological Engineering

Separating olefins from paraffins is one of the most challenging and energy intensive industrial processes. Olefins are key chemicals in the chemical and petroleum industries due to their wide use as platform raw materials for many important commercial products. For instance, ethylene is the platform raw material for the synthesis of plastics, fibers, synthetic rubber, synthetic resins, styrene, ethylene oxide, acetaldehyde, acetic acid, among others. In the petrochemical industry olefins are always accompanied by a considerable amount of paraffins. Therefore, to produce pure olefin for further utilization, the paraffin needs to be removed. We propose to develop microporous crystalline molecular sieve membranes having the potential to effectively separate olefin/paraffin mixtures (relevant to hydrocarbon separations).The benchmark technology for these separations gases is cryogenic distillation, which is an energy intensive process. The membrane technology proposed here could play a key role in making these separations less energy intensive. In this project it is proposed the development of crystalline molecular sieve membranes that can effective separate olefins from paraffins via size exclusion.

18 P Zwitterionic-nanoparticle Dressing Targeting Inflammation and Reactive Oxygen Species in Diabetic Wounds

Author: Alexandra Raichart, Senior, Chemical and Biological Engineering
Mentor: Michael Stager, Chemical and Biological Engineering
Mentor: Dr. Melissa Krebs, Chemical and Biological Engineering

Diabetic patients have a lack of insulin which results in increased inflammation and restricted blood flow and, when left untreated, this can inhibit wound healing. Currently, diabetic ulcers on these patients are treated with antibacterial ointments and gauze, which do not address the underlying disease. To treat these wounds a zwitterionic hydrogel was designed to provide a malleable, surface-covering bandage that could release biological factors to reduce chronic inflammation and improve healing. The hydrogel would be a one-time application as compared with current treatment methods that include a topical application that needs to be applied multiple times a day. This research has been focused on how the gels can be consistently fabricated, how their mechanical properties can be measured, and characterizing their ability to control the delivery of drugs over time. A wide range of physical characteristics were achieved by varying the zwitterionic monomer, co-monomer, and total polymer concentrations. Having this variety made it easy to narrow down on the most desirable hydrogels that could serve as wound healing dressings.

19 P Metal Organic Frameworks for the Removal of Contaminants from Water

Author: Amit Sela, Freshman, Chemical and Biological Engineering
Mentor: James Crawford, Chemical and Biological Engineering
Mentor: Dr. Moises Carreon, Chemical and Biological Engineering

Perfluorooctanoic acid, PFOA, is a perfluorinated carboxylic acid that persists in our environment and has proven to result in adverse health effects in humans. Research has shown that high levels of exposure to PFOA may cause kidney cancer, problems to fetuses, liver damage, thyroid disease, and more. Therefore, to remove this harmful fluoride-based compound from water, we propose the use of zinc and cobalt-based metal organic frameworks. We hypothesize that PFOAs can be removed from water via size exclusion and selective adsorption on the surface of the metal organic frameworks, MOFs. Thus, ZIF-8, a zinc MOF, ZIF-67, a cobalt MOF, and a mixed MOF were synthesized. These MOFs were used as adsorbents in a solution of water and the perfluorooctanoic acid. X-ray diffraction was employed to determine the crystalline structure of the synthesized MOFs, and to assess their structural stability after PFOA exposure. Nuclear Magnetic Resonance spectroscopy was utilized to determine the concentration of the PFOA over time. Our preliminary results suggest that both ZIFs are promising materials for PFOA removal.

20 P Catalytic Membrane Reactors for Green Hydrogen Production by Decomposition of Ammonia

Author: Caleb Coatney, Junior, Chemical and Biological Engineering
Mentor: Dr. Doug Way, Chemical and Biological Engineering

This project focused on the use of catalytic membrane reactors (CMRs) to produce hydrogen gas via ammonia decomposition. The goal of research in this area is to develop a CMR that can provide high purity hydrogen product under relatively mild temperatures of around 300-400℃. Improving the efficiency of this process is essential to attaining a scalable means of hydrogen production that is less resource-intensive than traditional steam reformation or electrolysis. This year, research primarily focused on the ceramic supports of the membrane reactors to better understand factors affecting conversion/purity and reaction rate. A dive into the literature provided a foundation for understanding the effects of catalyst size, shape, loading, and dispersion, along with support material and the presence of promoters. The porous nature of the ceramic supports and membranes allows for gas to permeate through the reactor. In the lab, alumina supports were placed in various treatments of aqua regia before loading with ruthenium catalyst. Nitrogen leak rate tests were conducted using a bubble flow meter to measure how permeability was affected. Leak rates were normalized by surface area, pressure, and thickness to compare data across different tests.

21 P Characterizing Image Diversity in Undergraduate Anatomy and Physiology Textbooks

Author: Kevin Huang, Senior, Chemical and Biological Engineering
Author: Sonny Nguyen, Senior, Chemical and Biological Engineering
Mentor: Dr. Justin Shaffer, Chemical and Biological Engineering

Previous research studies have suggested that physician and medical students' biases in the United States against patients of socially marginalized characteristics negatively influence the attention, decision making, and quality of care provided to them, despite already significant or growing volume of interactions with these populations in a medical setting. These characteristics include sex, obesity, race, sexuality, being of low income, age, and the many intersections between two or more such groups. This study aimed to determine if there was limited exposure or inaccurate demographics of patient populations within undergraduate human anatomy and physiology (A&P) textbooks. This study examined 423 figures depicting human bodies across three popular undergraduate human A&P textbooks in the United States published since 2017. The results were consistent with previous studies that the overwhelmingly dominant characteristics depicted were toned body type, white, adult, and male. This is in contrast to characteristics of actual hospitalized patients, which consist of significantly more obese, female, and Hispanic patients. Furthermore, when compared to undergraduate A&P textbooks, the medical school anatomy textbooks were found to be even less diverse in sex, race, body type, and age. Early exposure to medical professionals through these textbooks, which contain inaccurate representations of patient populations in the United States, could provide insight for future research into a source of biases against certain patient populations.

22 P Multiphase Flow Characterization Using a Benchtop Setup

Author: Ryan Mehrabian, Junior, Chemical and Biological Engineering
Mentor: Dr. Amadeu Sum, Chemical and Biological Engineering

Multiphase flow is essential in the production of oil and gas, and to better understand the impact of solids in the multiphase flow of gas/liquid system, we have designed and built a benchtop setup that closely captures the mixing and dispersion of phases. We are using this experimental system to map the flow conditions in the setup to actual pipe flow by doing image processing of the mixing and dispersion of the phases including gas, liquid, and solids.

23 P 3D Printed Perfusable Scaffolds for Glaucoma Modeling

Author: Prasanga Barakoti, Freshman, Chemical and Biological Engineering
Mentor: Bikram Adhikari, Chemical and Biological Engineering
Mentor: Dr. Melissa Krebs, Chemical and Biological Engineering
Mentor: Dr. Mina Pantcheva, University of Colorado Denver School of Medicine

Glaucoma is a progressive eye disease characterized by loss of peripheral vision and eventual, irreversible blindness. The leading cause of primary open-angle glaucoma (POAG), the most common type of glaucoma, is an increase in intraocular pressure (IOP), which is primarily induced by poor outflow of aqueous humor through the trabecular meshwork (TM). Current in vitro approaches for modeling the TM use flat, 2D culture systems that do not capture the complex morphology of the actual three-dimensional microenvironment. To develop a more accurate model, we performed human TM (hTM) cell studies on 3D printed Gelatin Methacrylate (GelMA) scaffolds, cultured in continuous media circulating system. Our group has previously shown that GelMA hydrogels allow cell proliferation and expression of important marker genes in hTM cultures. Here, we successfully bioprinted multilayered GelMA scaffolds and studied cell viability. We also tested perfusability (i.e., the hydrogels' ability to withstand continuous media flow) for up to 72 hours, with and without hTM cells embedded within the structure. We have shown hTM cells to grow/survive within 3D printed GelMA hydrogels in both static and dynamic 3D cultures. This work is helpful in antiglaucoma therapeutics research by providing a cost-effective method of studying the TM.

24 P Measuring the Surface Roughness of Metal Pipe to Better Understand Its Effect on Gas Hydrate-Solid Adhesion

Author: Bella Chase, Freshman, Chemical and Biological Engineering
Mentor: Dr. Christopher Brock, Chemical and Biological Engineering
Mentor: Dr. Carolyn Koh, Chemical and Biological Engineering

Gas hydrates are ice-like solids that occur when a small, nonpolar gas such as methane/CO2 is trapped within a crystalline structure of water molecules under conditions of low temperature and high pressure. These conditions exist in subsea gas flowlines and the aggregation/deposition of hydrates leads to blockages, preventing oil and natural gas transportation. We are analyzing the inner surface of these subsea pipes to understand better how hydrates adhere and block these flowlines. By quantifying the surface roughness of these pipes using profilometry measurements, we can better understand its effect on hydrate/solid adhesion and can implement coatings to better prevent adhesion of hydrates to pipeline surfaces.

25 P Investigating n-Butanol Production on Titania Surfaces for Renewable Fuel Source Additive Development

Author: Kacey Kim, Junior, Chemical and Biological Engineering
Mentor: Dr. Stephanie Kwon, Chemical and Biological Engineering

The need for renewable resources to replace fossil fuels has been a growing concern across industries. The beneficial fuel additive n-butanol became more favorable than ethanol as the compound provided higher energy densities and lower vapor pressures. However, to prevent the presence of formation of undesired ethyl acetate gas molecules, selectivity towards production of n-butanol has been studied through the development of catalysts. The project aimed to investigate the reactivity and selectivity of n-butanol production through aldol condensation on TiO2(101) surfaces. Theoretical analysis of the reactivity of each pathway was conducted using cutting-edge density-functional theory (DFT) calculations within Vienna Abinitio Simulation Package (VASP). Generalized gradient approximation of Perdew–Burke–Ernzerhof (PBE) functional was used to illustrate electron exchange correlations while projected augmented wave (PAW) pseudopotentials were used to represent core. The van der Waals interactions present in the geometries were analyzed through Grimme's D2 methods. Through these computational simulations, the free energies of all plausible enolate-derived species on TiO2 surfaces and of intermediates and transition states involved in their reactions with ethanal or ethanol were successfully calculated. The results of this study are expected to ultimately allow us to design a catalytic system for ethanol upgrading processes for n-butanol production.

26 P Investigation of Novel Catalyst-Ionomer Ink Compositions Toward Single-Cell Alkaline Water Electrolysis Performance

Author: Morgan Ezell, Senior, Chemical and Biological Engineering
Mentor: Dr. Andrew Herring, Chemical and Biological Engineering

Water electrolysis is crucial in allowing hydrogen to become a viable renewable energy source of the future, but improved ionomer and catalyst materials are needed for widespread adoption of the technology . Our lab has developed a highly conductive and durable polyethylene-based ionomer and anion exchange membrane system. In this study, the performance of these materials in an alkaline single-cell water electrolyzer was investigated. Specifically, anodes with varying cobalt-ionomer catalyst ink compositions were used in combination with platinum-ionomer cathodes and a custom polyethylene-based anion exchange membrane. Various anode catalyst-to-ionomer ratios (0, 3.2, 5, 10) were tested and the impact of our ionomer/membrane compared to a commercial standard membrane (Fumasep FAS 50) was explored. The performance of electrolysis trials was primarily evaluated through polarization curves, in which voltage was desired to be low at high currents (less than two volts at one amp). The overall impact of different anode compositions is yet to be determined, but it is suggested that larger amounts of ionomer relative to the cobalt catalyst resulted in improved performance .

27 P Synthesis and Assembly of Anisotropic Particles

Author: Benjamin Hanson, Senior, Physics
Mentor: Dr. Ning Wu, Chemical and Biological Engineering

Self-assembly of anisotropic particles to create colloidal structures at the micro-scale is rich with potential in the field of chemical and biochemical engineering. One of the common mechanisms for self-assembly relies on asymmetric electrohydrodynamic (EHD) flow created by an external electric field. My research has studied this phenomenon in two different applications: first, the assembly of particles into chiral clusters, and second, the fabrication of lithium-ion battery electrodes. The first project involves synthesizing particles that are micron-scale, polystyrene dimers with asymmetric lobes, coated by magnetic particles. The formation and reversible switch between two chirality are caused by asymmetric EHD and dipolar interaction. The purpose for asymmetry is to create microstructures that are actuated by external magnetic fields, for the use of metamaterials. The second project focuses on developing lithium-ion battery electrodes that are fast-charging and high-energy. The process involves aligning the electrode material (graphite and NMC particles) via an AC electric field to create column-like structures with vertical channels. The channels allow less inhibited electron travel, increasing the efficiency of the charging process and the energy density able to be held by the battery.

CHEMISTRY

28 P Electrochemistry: Synthesis and Characterization of N-Doped Carbon-Based Materials for Energy Application

Author: Isabella Lambardia, Sophomore, Chemical and Biological Engineering
Mentor: Margaret Fitzgerald, Chemistry
Mentor: Dr. Svitlana Pylypenko, Chemistry

Climate change has demonstrated the need for clean, carbon free energy. One way to produce energy without carbon emission is through polymer electrolyte membrane fuel cells (PEMFCs). However, the oxygen reduction reaction (ORR) occurring at the cathode is relatively slow, reducing the overall efficiency of the fuel cell. To combat this, fuel cells use a platinum catalyst supported on carbon to improve the kinetics of the ORR. However, the interactions between the platinum and carbon support are limited, which worsens the dispersion and stability of Pt nanoparticles, and in turn, the efficacy of the expensive Pt catalyst. In order to enhance the platinum-support interactions, the carbon support can be altered by doping with nitrogen. To test the impact of nitrogen-doping, four samples were tested, each with different nitrogen chemistries of doped carbons. The nitrogen-doped carbons were synthesized with varying amounts of pyridinic, and graphitic nitrogen based on pyrolyzation temperature. The doped carbon spheres pyrolyzed at 600 °C had a higher pyridinic nitrogen content, while the doped carbon spheres pyrolyzed at 800 °C had a slightly higher graphitic nitrogen content. These samples were electrochemically cycled from 0.6V to 0.95V to test the stability of the nanoparticles on similar nitrogen doped carbons with different nitrogen chemistries. The samples were imaged using identical location transmission electron microscopy (IL-TEM) with no cycling, and then imaged again after 100, 1000, and 10,000 cycles. The IL-TEM images were utilized to identify migration, dissolution and re-deposition of platinum particles after each set of cycling. The nitrogen-doped carbons synthesized at 600°C showed more platinum migration throughout aging, while the nitrogen-doped carbon spheres synthesized at 800 °C showed a more platinum dissolution. In conclusion, nitrogen-doped carbon spheres synthesized at 800 °C demonstrated the best stability, indicating that a slightly higher graphitic nitrogen content is the most ideal N-doping chemistry for Pt nanoparticle catalyst supports.

29 P Using Styrene Oxide and Epoxy Cross-Linkers for Efficient Plastic Scintillators

Author: John Fein-Ashley, Junior, Chemical and Biological Engineering
Mentor: Caled Chandler, Chemistry
Mentor: Dr. Alan Sellinger, Chemistry

Plastic scintillators are commonly used as detectors for nuclear materials in radiation portal monitoring and other applications. Plastic scintillators are commonly composed of a matrix, consisting of polymerized monomer and cross-linker, and a fluorophore as a dopant. A secondary dopant is often included as a wavelength shifter to prevent concentration quenching of light output from the primary dopant. Desirable properties in a plastic scintillator include high light output, mechanical stability, and gamma-ray/neutron radiation differentiation. This work uses styrene oxide as a monomer with bisphenol-a-diglycidyl ether (BPADGE) and trimethylolpropane triglycidyl ether (TMPTGE) cross-linkers as a matrix material. Dopant and matrix materials were mixed and photocured with a cationic photoinitiator under ultraviolet light. The matrix material and initiator amounts were optimized to increase hardness curing speed. Several different combinations of dopants were tested, and it was found that red-shifted dopants performed better in this matrix than traditional blue-emitting dopants. Dopants were also modified to increase desirable properties, including synthesizing 2,7-distyryl-9,9-dihexyl-9H-fluorene to increase solubility compared to previously used 2,7-distyryl-9,9-dimethyl-9H-fluorene and functionalizing a perylene based dye to red-shift light output. The matrix was found to have promising mechanical properties and potential for stereolithography (SLA) 3d printing.

30 P Using Oxidative Stress to Release Molecular Cargo

Author: Ryan Pfeffer, Junior, Chemical and Biological Engineering
Mentor: Gun Su Han, Chemistry
Mentor: Dr. Dylan Domaille, Chemistry

Non-communicable diseases (NCDs) are responsible for more than 70% of all deaths globally and more than 80% of premature deaths in developing countries. Many NCDs, including asthma, cancer, and rheumatoid arthritis, are complicated by chronic inflammatory responses and exhibit high levels of reactive oxygen species (ROS), which are oxygen metabolites formed as an immune response. Emerging efforts have sought to use ROS as diagnostic and/or signals that trigger localized therapeutic delivery. The goal of this project is to develop hydrogels that release molecular 'cargo' in response to ROS. Research was focused on two major components: formulation of the hydrogel and design of the cargo release functionality. A novel polyethylene glycol (PEG) hydrogel was formulated. The hydrogel was labeled with a fluorescent dye to track its aqueous stability. Separately, an ROS-responsive cargo release functionality was explored and optimized. A variety of amines were explored as cargoes, and 1H NMR analysis revealed H2O2 could trigger the release of amine cargoes with concomitant formation of a p-quinone methide. In some instances, the released amine reacts with the p-quinone methide to form an undesirable side product. A survey of derivatives revealed that the side-product formation is governed by the pKa of the released amine. Future work will focus on merging the ROS-responsive functionality with the hydrogel scaffolds.

31 P Developing Novel Organic Super-Reductant Catalyst Systems

Author: Luke Wideman, Senior, Chemical and Biological Engineering
Mentor: Dr. Shubham Vyas, Chemistry

Flavins and flavinium derivatives are bio-inspired organic compounds that catalyzes a variety of chemical reactions by using atmospheric molecular oxygen including the oxidation of water. A derivative of flavin, known as deazaflavin obtained by replacing a nitrogen atom with a carbon atom in the base skeleton, was recently reported to catalyze reductive chemical transformation using a sacrificial hydrogen donor compound. In this work, we examined the fundamental catalytic pathways for the operation of deazaflavin derivatives using density functional theory (DFT) calculations and time-dependent DFT calculations. Previous work have shown that the functionalization at the C7 and C8 positions for flavins can significantly impact the photocatalytic activity, therefore, we also evaluated the impact of functionalization on the fundamental photochemical scaffold of deazaflavin. Based on the difference density plots and excited state geometry optimizations, it was found that the nature of the excited state scaffolds remain unaltered with some exception while one can tune the wavelength of absorption. The results herein serves as a basis for further research both computationally and experimentally.

32 P Doorways to Lithium Separation

Author: Johnathan Klein, Junior, Chemistry
Mentor: Dr. Mark Jensen, Chemistry

Lithium has become a critical resource in these early days of clean energy, and the recycling of lithium from what would otherwise be waste will become increasingly important . Naturally, lithium exists as water-soluble salts, and being able to separate these lithium salts from other water-soluble salts is important to the future of lithium-based clean energies. Extraction of salts from water is generally carried out using an organic phase with some extractant molecule, though in the case presented in this research the solvent, octanol, can act as an extractant.

The purpose of this project is to determine the transfer rate of lithium from an aqueous phase to an organic phase based upon multiple criteria, namely the interfacial area, mixing, initial concentration of lithium, and octanol to heptane ratios. Only octanol facilitates the transfer of lithium, however computational chemistry conducted by Dr. Aurora Clark indicates two transfer mechanisms that are dependent on the concentration of octanol. A Lewis Cell and UV Spectroscopy was used to characterize the transfer chemistry and test which transfer mechanism dominated lithium extraction.

33 O Urinary Biomarkers as Personalized Feedback: A More Successful Approach to Weight Loss

Author: Marisa Sandoval, Senior, Chemistry
Mentor: Dr. Judith Klein-Seetharaman, Chemistry

Current methods for losing weight do not consider human metabolism for quantitatively tracking dieting. To enable personalized feedback for weight loss, we investigated the correlation of urine metabolites, that change within a 24-hour period, with weight loss. These novel findings will help develop improved strategies for weight loss that are personalized to the individuals' metabolism. Adult participants (n=52) skipped one meal from their three-meal routine while their daily calorie restriction was ~1450KCal. An in-house app was developed and used to track food intake, weight, and time of urine collections. 1D-NMR was conducted on 154 urine samples to identify metabolites that change with dieting. Thirty-seven metabolites showed promising data as biomarkers of weight loss. Among these metabolites are beta-hydroxyisovaleric acid, hippuric acid, and alanine – some of which are involved in central metabolic pathways such as glycolysis and citric acid cycle. Twenty-three of the 37 metabolites appeared in lower concentrations for those who were dieting, and the remaining metabolites appeared in higher concentrations for individuals dieting. These metabolites are probable short-term urine biomarkers for assisting with personalized weight loss. By further developing an understanding of these biomarkers, we can begin to discover more precise relationships between metabolite concentrations and weight loss.

34 P Reactive Ion Etching of Silicon Clathrate Materials for PV Applications

Author: Michael Dawson, Junior, Chemistry
Mentor: Dr. Carolyn Koh, Chemical and Biological Engineering
Mentor: Dr. Reuben Collins, Physics

Silicon clathrate is an improved silicon structure for applications in photovoltaics and batteries. However, during synthesis, an amorphous layer forms which must be removed to access the clathrate. To do so, a reactive ion etching system removes the top layer of material by physical and plasma etching. This project focuses on optimizing the parameters of this system, such as power and pressure, to obtain a set that provides a reliable etch rate. This was achieved by applying a black wax that resists etching to a clathrate film, etching, removing the wax, and analyzing the difference between the regions with a profilometer. This process was repeated for many different powers and pressures to compare the effect that these parameters had on etch rate and profile consistency. In general, only pressures below 0.5 torr produce a meaningful etch depth which suggests physical etching has more impact than plasma. Increasing power causes the etch rate to increase and can be used to control the depth. However, the clathrate profiles are very rough and have high elevation variation which may cause the amorphous layer to be incompletely removed. Overall, etching at pressures below 0.5 torr and high powers show promise for amorphous removal.

35 P Tracking Extracellular Reactive Oxygen Species with Oxidatively Activated Hydrogels

Author: Lauren Kelly, Junior, Quantitative Biosciences and Engineering
Author: Kevin Huang, Senior, Chemical and Biological Engineering
Mentor: Dr. Dylan Domaille, Chemistry

Reactive oxygen species (ROS) play important roles in inflammatory diseases and in healthy processes, such as cellular signaling. While several methods exist to monitor ROS inside cells, no current techniques enable tracking extracellular ROS with high spatial resolution. The goal of this project is to develop a new biomaterial-based technique to track extracellular ROS with high spatial resolution. To accomplish this, we synthesized a fluorescent probe that increases its fluorescence in response to ROS. Next, the probe was covalently linked to polyacrylamide hydrogels. The resulting probe-modified hydrogels (ROSMap hydrogels) were assayed for their ROS selectivity with a fluorescence plate reader. Our results show that the ROSMap hydrogels are selective for hydrogen peroxide and peroxynitrite, two biologically relevant ROS in human health and disease. Current efforts are focused on culturing immune cells (macrophages) on the ROSMap hydrogels to determine if our new material can track cellularly produced ROS. If successful, this new technique will enable new insight into cellular ROS signaling pathways.

36 P Production of Plastic Scintillators for the Efficient Detection of Nuclear Radiation

Author: Luis Borrego-Castaneda, Senior, Chemistry
Mentor: Daniel Astridge, Chemistry
Mentor: Dr. Alan Sellinger, Chemistry

Accurate detection of harmful nuclear materials requires the differentiation of neutrons and gamma radiation due to the potential of false positive measurements from benign sources of radiation, for example, kitty litter and piles of bananas. Inorganic crystals and liquid scintillators have been used in the past to accurately separate neutrons and gamma radiation, but their high cost and lack of scalability prevents them from limits their feasibility for widespread use. Plastic scintillators have recently gained more attention to due to their relatively low cost and scalability, however they lack the ability to efficiently differentiate neutrons from gamma radiation. This work highlights the synthesis of Methacrylate-Functionalized 2,5-Diphenyloxazole fluorescent dopants that will be cross-linked to plastic scintillators. These dopants are capable of providing plastic scintillators with the ability to efficiently segregate neutrons from gamma radiation via pulse shape discrimination.

37 P Digestive Enzyme-Mediated Controlled Release of Bioactive Agents from Delivery Nanovehicles

Author: Annabel Weizenbeck, Junior, Chemistry
Mentor: Dr. Brian Trewyn, Chemistry

This conceptually innovative project focuses on the development of a novel drug delivery system for oral

delivery of medications using natural polymers for sustained release of drug molecules for the treatment of pancreatitis. This project will clearly test the hypothesis that the kinetics and capacity of drug release from starch coated mesoporous silica nanoparticles can be tuned and controlled through careful synthesis of hybrid organic and inorganic delivery vehicle nanomaterials along with tuning the adhesion to Caco-2 human colon cells. This investigation should provide direct evidence of the clear potential of the multifunctionality of this nanomaterial for oral drug delivery.

38 P Computational Protocol to Predict NMR Parameters of Perfluoroalkyl Substances

Author: Jessica Pauling, Senior, Chemistry
Mentor: Maleigh Mifkovic, Chemistry
Mentor: Dr. Shubham Vyas, Chemistry

Per- and Polyfluoroalkyl Substances (PFAS) are chemicals that have been widely used for a wide range of applications since the 1950s, despite their toxicity. These chemicals do not degrade naturally, leading them to become widespread environmental contaminants. Current characterization of these compounds often involves mass spectrometry, which requires expensive standards that are not available for many PFAS currently in circulation. 19-Fluorine NMR can be used to identify the structures of PFAS and their degradation products, thus giving us a better understanding of degradation pathways in places where mass spectrometry does not have chemical standards. In this work, a protocol was developed for computationally predicting chemical shifts of C3 to C6 and C9 perfluoroalkanes and comparing them to experimental shifts using root mean squared error (RMSE). Results indicated that the ωB97XD level of theory and the 6-31+G(d,p) basis set in the gas phase provided the most accurate chemical shifts. In addition, multiple solvents (DMSO, water, and chloroform) were assessed using implicit solvation and NMR shifts had only a little difference between the solvents. Overall, however, the addition of implicit solvation was found to decrease the accuracy of the calculated NMR shifts. The most accurate method was applied to cationic and anionic PFAS which may be present in the environment. The protocol yielded reasonable performance (4-6 ppm), indicating robustness with respect to different chain lengths and functional groups. The ongoing work on the project involves testing the method against polyfluorinated alkyl substances and predicting degradation pathways of PFAS.

39 O Electron Microscopy Analysis of Fuel Cell and Battery Electrodes

Author: Sara Kim, Sophomore, Computer Science
Mentor: Dr. Svitlana Pylypenko, Chemistry

Polymer Electrolyte Membrane Fuel Cells (PEMFCs) are a promising clean technology, but a major barrier is cost of device stacks, which can be improved by optimizing individual components and interactions between those components. This project develops tools for common characterization of catalysts, inks, and electrodes towards development of a large matrix of structure-property-process-performance correlations for catalysts and electrodes. This project provides extensive characterization to correlate composition, morphology, and structure of PEMFC catalyst layer constituents with processing and fabrication parameters and their impact on overall structure and performance. The main focuses of this presentation are the following: (i) Analyzing a wide range of electrodes using Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) to gather data (including images and element quantization); (ii) Applying image processing on Image J to extract quantifiable parameters from SEM images; (iii) Correlating parameters extracted from electron microscopy to each other and processing variables as well as performance results in order to draw conclusions between specific characteristics and PEMFC device fabrication and performance.

40 P X-ray Photoelectron Spectroscopy on Polymer Electrolyte Membrane Fuel Cell Components

Author: Maxim Shepherd, Freshman, Chemical and Biological Engineering
Mentor: Jayson Foster, Chemistry
Mentor: Dr. Svitlana Pylypenko, Chemistry

Sustainable technology is a way to reduce environmental impact of proton exchange membrane fuel cells (PEMFCs) and provide clean energy using hydrogen, a fuel with water as the only byproduct. The cathode catalyst layer is a major influence on the overall cost of a PEMFC as it requires a significant loading of platinum to achieve reasonable power density. One of the current challenges within the cathode catalyst layer is that many catalysts active sites may have too much or too little ionomer coating which directly impacts mass transport and device efficiency. Additionally, there is a general lack of understanding about how the catalyst support, catalyst, and ionomer interact with one another at the molecular scale. X-ray Photoelectron Spectroscopy (XPS) is a highly surface sensitive technique that is commonly used to characterize elemental and chemical speciation within the first 10 nm of the surface, however it has not been widely applied to studies of catalyst layers. This poster will provide general background on XPS and how this characterization technique can be used to characterize the catalyst layer with a focus on catalyst-support-ionomer interface.

41 P Resolution of Poorly Retained Polymers in Thermal Field-Flow Fractionation

Author: Alexandra Ezell, Freshman, Metallurgical and Materials Engineering
Mentor: Michael Toney, Chemistry
Mentor: Dr. Kim Williams, Chemistry

Thermal Field Flow Fractionation (ThFFF) is a separation technique that utilizes a temperature gradient to move polymers and nanoparticles across a fluid flow. This fluid flow has a parabolic shape that results in a distribution of different flow velocities across the ThFFF channel at different positions, which pushes the analytes out of the channel at different times. This combination of thermal field and fluid flow separates polymers/particles by size, molar mass, or composition. These characteristics affect the observed properties and behavior. One of the key features of ThFFF results is the presence of a void peak, which occurs when non-retained materials come out of the channel first. Historically, this void peak was thought to have no useful information. Our hypothesis is that while the analytes eluting with the void peak are poorly retained, there may still be separation occurring and hence, important information may be gleaned. To test this, we ran triplicates of polystyrene standards with molar masses of 30, 200, 400, and 612 kDa in toluene, whose behavior is well predicted. This provided a baseline to compare to when running mixtures of polystyrene. From these results, we concluded that separation was occurring within the void peak.

CIVIL AND ENVIRONMENTAL ENGINEERING

42 P Engineering Design Outcomes of Constructed Wetland Biomat

Author: Blake Knipple, Junior, Civil and Environmental Engineering
Mentor: Lily Bosworth, Civil and Environmental Engineering
Mentor: Dr. Jonathan Sharp, Civil and Environmental Engineering

Due to population growth and resulting production of wastewater, current wastewater treatment methods often require additional support, such as constructed wetlands. In open water constructed wetlands, contaminant removal is performed by a benthic microbial mat that naturally accumulates in the wetland, accreting by ~1 cm per year. Open water wetlands are known to remove nitrate, which can cause eutrophication. Wetland biomat reduces nitrate to nitrite, then ammonia, then nitrogen gas. Therefore, nitrite production is a way to indirectly measure biotic nitrate removal, and we wanted to understand if nitrite production changes with increasing biomat depth. Previous experiments attempted to quantify nitrate removal and nitrite production with variable biomat depth, but didn't yield significant results, so we adapted experimental features to clarify results. We hypothesized nitrite production would increase as biomat depth increased up to 2 cm, then would plateau, and sampled nitrite, nitrate, and ammonia from 4 pilot scale constructed wetland flumes over 4 days to test this hypothesis. Alongside understanding long term wetland optimization, we hope to determine if dried biomat can be sent to partners in Peru to start their own wetlands. We analyzed the effect of different biomat drying methods (room temperature, 50C, 70C) on wetland establishment.

43 P Exploring the Influence of Biomat Depth on Nitrate Removal in a Lab-Scale Flume

Author: Kayla Benson, Junior, Civil and Environmental Engineering
Mentor: Lily Bosworth, Hydrologic Science and Engineering
Mentor: Dr. Jonathan Sharp, Civil and Environmental Engineering

Engineered wetlands, such as the Prado Wetlands in California, passively treat water in an open water, geotextile lined, shallow water column system. A benthic microbial mat ("biomat") colonizes the wetland, breaking down contaminants in the water. Biomat deepens with time, changing the volume of water, hydraulic residence time, and associated contaminant treatment. Lab-scale flumes were constructed to simulate the Prado wetlands and help us optimize nitrate removal efficiency with respect to biomat depth. Recent modeling and field data suggest nitrogen species removal will not change with a deepening biomat. Therefore, we hypothesized biomat depth will not influence nitrogen species removal efficiency. To test this hypothesis, we sampled nitrate, nitrite, ammonium, and the conservative tracer fluorescein in the flume effluent over 12 days. Results from this experiment, the first in an anticipated series that explore biomat depth and its impacts on constituents of concern, provided insight on experimental design over conclusions about nitrate removal. We confirmed diel cycling, a 24-hour HRT, and anecdotal nitrate reduction early in the experiment. Nitrogen species were likely removed in the influent tubing lines, so many of the expected trends weren't there to observe and draw conclusions from, instead suggesting we need to improve experimental methods.

44 P Dissolved Oxygen Diel Cycling and Its Environmental Implication on Mining Water

Author: Pablo Chang Huang, Sophomore, Geophysics
Mentor: Zhaoxun Yang, Civil and Environmental Engineering
Mentor: Dr. Jonathan Sharp, Civil and Environmental Engineering

Engineered wetlands are used broadly to treat wastewater for residential areas. An example of this technology in use is in Corona, California at the Prado open water wetlands. Our current research is focused on treatment of mining-impacted water, particularly in the mining areas of Southern Peru as part of a Pan-American collaboration. To study the photosynthetic microbial biomat in Prado wetlands, we constructed lab-scale flow-through systems seeded with fresh biomat and recorded the pH and dissolved oxygen (DO). The diel cycling of these basic water quality parameters and of other elements were observed. To further understand the variabilities of the reactions in the biomat across different times and at different depths, a new non-invasive DO measurement technique was utilized with a fluorometer probe. With this probe, the fluctuation of DO production can be measured at different depths during the diel cycles. This will serve as a starting point for future experimentation and exploration of the processes in the most dynamic zones within the first millimeters of the biomat. This is relevant as the DO and pH cycling has implications in the metal's solubility and precipitation. Understanding in depth the biomat is important to find a sustainable biologically supported water treatment option.

45 P Low Energy? This ABR is the Wastewater Treatment for You!

Author: Jade Glaister, Sophomore, Mechanical Engineering
Author: Allison Bean, Sophomore, Civil Engineering
Mentor: Carolyn Coffey, Civil and Environmental Engineering
Mentor: Dr. Junko Munkata-Marr, Civil and Environmental Engineering

This project analyzes the effectiveness of an anaerobic baffled reactor (ABR) to remove carbon and suspended solids from wastewater that would otherwise cause environmental problems such as eutrophication. Since the only aspect of the system that requires energy input is the water pump and it does not require aeration, ABRs are novel low-energy wastewater removal systems. To measure the ABR's effectiveness at removing solids and organics from wastewater, we performed frequent tests for biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), and volatile suspended solids (VSS). The results from these tests can be compared to the U.S. Environmental Protection Agency secondary treatment standards for TSS and BOD. The standard for TSS has been met, but the standard for BOD has not, which is the currechnt objective of this project.

COMPUTER SCIENCE

46 P Proof of Concept Implementation of the Haystack API Over a Brick-Haystack Translation Layer

Author: Benjamin Costa, Senior, Chemical and Biological Engineering
Mentor: Dr. Gabriel Fierro, Computer Science

One challenge associated with the analysis of building data is creating models that demonstrate the connections and relationships between the data to derive further insights. Current building data representation models include the Haystack model, a semantic data model for representing IoT (Internet of Things) data. One issue with Haystack is that it uses unstructured "tags" to describe entities rather than standardized definitions, which makes it easy to use, but difficult to interpret the associated data. The Brick model is an open-source effort to standardize the descriptions of physical assets and represent the relationships between the data. The goal of this project was to explore how the usability of the Haystack model can be combined with the interpretability of the Brick model. This was accomplished by implementing the Haystack API over the Brick model, allowing users to interact with the Brick model as if they were interacting with Haystack. This allows for low-cost integration of the Brick model into existing IoT systems. This involved analyzing existing Haystack implementations, designing a data storage system, and developing a query interpreter based on the Haystack filter language. The performance of the system will be analyzed by timing queries against sample datasets.

47 P Protecting your Car from Relay Theft

Author: Dhruva Sogal, Sophomore, Computer Science
Author: Wilhelm Northrop, Junior, Computer Science
Mentor: Dr. Dejun Yang, Computer Science

Phone-as-key technologies give consumers the ability to use their mobile devices to access their homes and cars. This project investigates the vulnerability of bluetooth low energy (BLE) enabled phone-as-key products to signal relay theft, an attack in which wireless signals are amplified to fake the proximity of a key. This project attempts to use BLE packet sniffing technology to reverse engineer the communication flow between a phone and smartlock in order to design and implement a signal-relay attack.

48 P Exploring the Privacy Concerns of Bystanders in Smart Homes from the Perspectives of both Owners and Bystanders

Author: Amiya Prasad, Senior, Computer Science
Author: Joseph Spielman, Junior, Computer Science
Mentor: Ahmed Alshehri, Computer Science
Mentor: Dr. Chuan Yue, Computer Science

Smart home IoT devices collect data not only from owners of the devices, but also from bystanders in a smart home (e.g., visiting family members, friends, or domestic workers). Existing research mainly considered the privacy concerns of bystanders from their own perspectives. In this paper, we design and conduct a survey study to explore the privacy concerns of bystanders more comprehensively from the perspectives of both owners and bystanders. For owners, we investigate their understanding of their own data practices, their views on bystanders' privacy, and their willingness to negotiate data practices with bystanders. For bystanders, we investigate their privacy concerns, their expectations of disclosures by owners, and their willingness to share their data with owners. We found that many owners and bystanders have different preferences regarding negotiating data practices. Based on our findings, we provide recommendations for enhancing privacy protection in smart homes.

49 O Proteome-Wide Association Study: Enhanced Linking of Genes and Phenotypes with Machine Learning

Author: Akshati Vaishnav, Junior, Computer Science
Mentor: Stephen Thoemmes, Computer Science
Mentor: Dr. Hua Wang, Computer Science

A genome-wide association study (GWAS) is a standard method used to determine which genetic variants are associated with a certain disease, trait, or behavior. This is done through connecting the genotypes of a population with their corresponding phenotypes. Although GWAS is a widely used method for genetic studies, it has multiple significant drawbacks. For example, if a variant is rare and appears a few times in a cohort, GWAS does not have the statistical power to detect it, which is important since those rare variants might amount to a lot of the heritability in complex traits. A novel method known as the Proteome-Wide Association Study (PWAS) works towards the same purpose of GWAS while reducing the drawbacks associated with it. By linking genotypes to phenotypes through machine learning and statistical analysis, PWAS can identify variant-genotype relationships outside of the constraints and assumptions of traditional GWAS. Since PWAS is a relatively new approach, it does not have as much documentation and support as GWAS. Using genomic data from the UK Biobank and public proteomic data, we aimed to extend the performance of PWAS while making it more streamlined and accessible for use.

50 O Unveiling Hidden Viral-Host Protein Interactions in COVID-19 for Drug Repurposing

Author: Armand Ovanessians, Sophomore, Computer Science
Mentor: Dr. Hua Wang, Computer Science

The ongoing COVID-19 pandemic has resulted in over 6.1 million deaths worldwide and is caused by a beta coronavirus termed SARS-CoV-2. In the absence of effective antiviral drugs for the treatment of COVID-19, we designed a novel k-partite graph learning method for data matrix completion to uncover hidden viral-host interactions and drug-target interactions. Our framework produces a holistic map of the pathogenesis of COVID-19 and unveils novel FDA approved drug candidates for COVID-19.

ECONOMICS AND BUSINESS

51 P Sports Analytics for Team-Building Decisions for an NBA Team

Author: Elijah Knodel, Sophomore, Applied Mathematics and Statistics
Mentor: Megan Muniz, Economics and Business
Mentor: Dr. Tulay Flamand, Economics and Business

Sports analytics is a growing field as teams across all major sports are looking to gain an edge. Our research has a focus on NBA team building, with a goal of making a model that determines the management decisions to be made to put together the best team possible, given constraints. This research, specifically, focuses on the consideration of the economic value that a player brings to their team. This is an important aspect to examine because while teams have a goal of winning, professional sports are also a business, and teams are hoping to maximize their profit. The goal of our research was to determine which metrics are the strongest predictors of an NBA player's economic value. We began with an exploratory data analysis involving plot relationships and correlations between various metrics. Through linear regression, we have found the metric "WS/48" to be the best predictor of an NBA player's economic value.

ELECTRICAL ENGINEERING

52 P PeCS Multi-UAV Testbed

Author: Kristen Ung, Senior, Electrical Engineering
Author: Peter Hall, Senior, Electrical Engineering
Author: Corey Schanker, Freshman, Computer Science
Mentor: Jonathan Diller, Computer Science
Mentor: Dr. Qi Han, Computer Science

The objective of this project was to create a physical testbed of multiple unmanned aerial vehicles (UAVs). This testbed has been used to evaluate and validate the concepts of using mobile ad-hoc networks of UAVs for more effective collection of application data. The testbed consists of three UAVs which communicate with a base station to send data. The UAVs follow predetermined flight paths to emulate an orbit around an asteroid. The testbed uses Raspberry Pi 3B+'s with an Emlid NAVIO hat to control the path and functionality of the UAV, which also facilitates the communication between the UAVs and the base station. Tests were conducted on both single-hop and multi-hop approaches. In the multi-hop approach, the UAVs form a multi-hop ad-hoc network. We measured the amount of data collected using both approaches and then compared to simulation results. The results show that the multi-hop approach is more effective than the single-hop approach since it reduces the packet loss.

53 P Design and Optimization of Sparse Antenna Arrays

Author: Clayton Daly, Senior, Electrical Engineering
Mentor: Dr. Payam Nayeri, Electrical Engineering

Grating lobes in sparse arrays can be removed by using aperiodic element spacing; however, traditional random sampling methods cluster some elements too close together, making fabrication impractical. In this research, a new constraint based design approach using guided random search algorithms is presented. Numerical results are given for the proposed design, and it is shown that this approach is capable of removing grating lobes and reducing the sidelobe level, while also keeping the elements sufficiently spread apart with an organized distribution within the aperture.

54 P Assessment of IOT Processor Security by Measuring Radiated Side-Channels

Author: Jackson Willner, Junior, Electrical Engineering
Mentor: Dr. Peter Aaen, Electrical Engineering

As the internet of things (IoT) becomes a reality, ensuring the security of devices in both industrial and commercial applications is paramount. It is the focus of this research to investigate non-invasive technologies to determine if a device has been compromised by malicious software. By measuring the electromagnetic side channel emissions of a device, the leaked emissions may be directly mapped to actions on the CPU. A measurement system composed of a magnetic field loop detector and real time spectrum analyzer was developed and used to measure the emissions above an ATmega2560 processor running at 16 MHz. A simple program which sent messages through the USART was observed and the corresponding emissions were recorded. Distinct spikes in the spectrum were observed when the processor was actively communicating on the USART. Future work should be done to observe the emissions from a programable logic controller for a dynamic, non-linear quadrature tank process.

55 O Multiphysics Optimization of GaN-Based Power Transistors for 5G mm-Wave Operation

Author: Jessica Kennedy, Junior, Electrical Engineering
Mentor: Dr. Peter Aaen, Electrical Engineering

As communication systems evolve, higher frequencies emerge as the most effective frequencies to transmit data. This poses a significant challenge to the design of power transistors that are used to amplify signals for transmission. Gallium nitride transistors are emerging to be the semiconductor of choice due to their capability of supporting high power densities. The design challenge is that to reach the power levels required, many small transistors have to be placed in parallel, and the electromagnetic propagation of the waves within the semiconductor at mm-wave frequencies (~30GHz) introduces nonlinearities and discrepancies of phase as the signal propagates, leading to signal distortion. This poses a significant design constraint that must be incorporated into the layout of semiconductor circuits.

In this project, we are working to develop computationally efficient electromagnetic modeling techniques so that we can optimize the design of transistors. We present how a GaN power transistor can be partitioned in an electromagnetic simulator (Sonnet) and effectively reconnected using circuit theory. By building a library of GaN power transistor components, we decreased the total simulation time by multiple orders of magnitude. This results in an extremely efficient simulation technique that will permit design optimization of the transistor.

56 P Design and Fabrication of a Printed Patch Antenna for 10GHz Operation

Author: Kenneth Hora, Freshman, Electrical Engineering
Mentor: Dr. Atef Elsherbeni, Electrical Engineering

A microstrip patch antenna is widely used in many commercial and medical applications. This work is focused on the design and fabrication of 10GHz microstrip antenna. The fabrication was performed using milling and silver ink printing. The design was simulated using the finite-difference time-domain method as implemented in the CEMS software package. The milled antenna was created on 1.6mm thick FR4 printed circuit board. The printed antenna was created on 125 μm thick Kapton in silver nanoparticle ink and attached to a 1.6mm thick, single-sided piece of FR4 as a substrate and ground plane. The antenna reflection coefficient S11 was measured for the milled and printed antennas and compared with the simulation results. The milled antenna resonates at 10.3 GHz. While attaching a connector to the printed antenna, the heat from the soldering gun affected the printed feed line and a good connection to the SMA connector could not be made. The printed antenna had lower performance as the measured S11 was -8.9 dB at 10GHz. Future work will include methods to better attach connectors to printed antennas and learning how to simulate and measure the radiation pattern of the antenna.

57 P Fabrication of Printed Microstrip Patch Antennas

Author: Silje Ostrem, Freshman, Electrical Engineering
Mentor: Robert Jones, Electrical Engineering
Mentor: Dr. Atef Elsherbeni, Electrical Engineering

Microstrip patch antennas are small antennas printed directly on circuit solid or flexible boards. They are simple and quick to produce. However, despite the relatively easy production, it is exceptionally important to conform with the design dimensions during fabrication for accurate and precise prediction of the operating frequency. The radiation efficiency of the antenna is largely determined by the dimensions and the used board properties, and any error could lead to inaccurate frequency response and lower antenna gain. To maintain precision, we use a LPKF milling machine for antennas operating with millimeter dimensions resolution. This allows us to make extremely precise circuit boards using CNC technology with CAD models of antennas operating at frequencies as high as 40 GHz. However as pointed out in a recent publication, a blade type antenna was first created using copper tape on top of an FR4 substrate material to prove the concept and then fabricated professionally and tested. We simulated this blade antenna and then investigated other modifications to the blade with several slot design to see if efficacy could be improved. The simulation of this antenna was based on our finite-difference time-domain (FDTD) method.

ENGINEERING, DESIGN, AND SOCIETY

58 O Understanding Engineering Students' Experiences with Perceiving and Rationalizing Meritocracy in the Development of Professional Identity

Author: Kylee Shiekh, Senior, Applied Mathematics and Statistics
Mentor: Dr. Dean Nieusma, Engineering, Design, and Society
Mentor: Dr. Qin Zhu, Humanities and Social Sciences
Mentor: Dr. Stephen Rea, Humanities and Social Sciences

Meritocracy is a system of social organization in which individual advancement is based on one's abilities and expertise rather than family, wealth, or social class. Engineers, including engineering faculty and students within educational environments, typically hold closely to a meritocratic ideal, where hard work and technical excellence gain deserved rewards. According to this ideal, merit can be measured by effort and technical skill, which in turn explains individual successes and failures. Previous studies mainly examined meritocracy as an ideological context of engineering education while not paying sufficient attention to how students perceived and engaged meritocracy in their educational experiences. Based on empirical data drawn from semi-structured interviews conducted with 18 engineering students, this paper examines their understandings of meritocracy in two dimensions: academic integrity and institutional evaluation tools such as exams. This paper will further discuss how engineering students perceive and rationalize meritocracy, how their beliefs in meritocracy contradict students' actual educational experiences, and how they respond to these contradictions. Since merit is meant to overwrite any alternative systems of privilege, including structures of class, gender, and race-based privilege, this gives the impression that low-status groups can and should leverage meritocracy to improve their place in society. However, consistently lower rates of participation among female, black, and Hispanic engineering students, compared to their white and male counterparts, raises compelling questions about the limitations of meritocracy as a foundational assumption in actual engineering environments. Why, then, do engineering students continue to hold fast to the meritocratic ideal as an accurate descriptor of their environments? This paper provides some tentative answers and may be of particular interest to scholars and educators who advocate a critical and cultural approach to students' experience with their development of engineering identity.

59 P Humanitarian Engineering, Global Sociotechnical Competency, and Student Confidence: A Comparison of In-Person, Virtual, and Hybrid Learning Environments

Author: Angelina Rivera, Senior, Civil and Environmental Engineering
Mentor: Dr. Juan Lucena, Engineering, Design, and Society
Mentor: Dr. Jessica Smith, Humanitarian Engineering

The PIRE Responsible Mining, Resilient Communities (RMRC) project is an international, interinstitutional, and interdisciplinary research collaboration whose goal is to co-design socially-responsible and sustainable gold mining practices with communities, engineers, and social scientists. The RMRC project was analyzed to consider how participating in the summer session influences students' global sociotechnical competency and how the changes in sociotechnical competency impact the students' confidence in their engineering ability. The project hosted three intensive summer field sessions, each enrolling a different group of students. The students conducted research in the field in Colombia in 2019, in a virtual format in 2020, and in a hybrid format in 2021 due to the ongoing pandemic. To assess changes in students' learning and attitudes, data was collected from the students before and after the summer sessions in the form of interviews, surveys, and essays. The data was analyzed to investigate whether the format of the summer session differently influenced students' global sociotechnical competency and their confidence as engineers. This project shed light on broader concerns in engineering education about if and how specific kinds of service learning can enhance students' global sociotechnical competency and their confidence as engineers.

60 P Mineral Dissolution Rates Measured Through Microfluidics at Variable pH and Fluid Velocity

Author: Rachel Fontan, Junior, Chemistry
Mentor: Dr. Elanor Heil, Geochemistry
Mentor: Dr. Alexis Sitchler, Geology and Geological Engineering

Mineral weathering reactions are involved in many natural and engineered systems. Quantifying how fast minerals weather allows for the prediction of water chemistry and changing rock properties that result from water-rock interactions. To do so, mineral dissolution rates were measured using microfluidic techniques on an anorthite rock chip. This chip was laser engraved in order to simulate the porous pathways in natural rock. A polydimethylsiloxane (PDMS) gel was then plasma bonded onto the surface of the engraved anorthite with holes for tubing on both ends of the gel at reservoirs in the anorthite. Fluid at varying pH levels was pumped through this makeshift water shed with speeds that were controlled from trial to trial. Ca+2 levels were measured from the outflow and this measurement could be used to calculate the dissolution rate for each speed and pH combination. Through these calculations, it was determined that lower pH values and faster flow rates result in faster dissolution of the anorthite chip. This is consistent with recent experiments performed in this manner.

61 P How Does Global Warming Affect Rivers?

Author: Savannah Dilley, Senior, Civil and Environmental Engineering
Mentor: Jacob Slawson, Geology and Geological Engineering
Mentor: Dr. Piret Plink-Bjorklund, Geology and Geological Engineering

Climate models based on greenhouse gas emissions show that temperatures similar to those of the Early Eocene Epoch are expected by the year 2150 CE. In order to assess the effects of these climatic changes on surface hydrology, this study examines how shifts in precipitation variability and intensity, chosen based on expected latitudinal shifts in climatic zones, affect hydrologic variables such as discharge, floodplain width, and sediment transport. The hydrologic model SWAT+ was used to insert, analyze, and visualize current climate precipitation and temperature data for the watershed and how it affects watershed characteristics with high temporal resolution. SWAT+ was also used to insert and visualize the effects of hypothetical climate data that are expected based on current models. The hypothetical climate data was taken from areas classified as a Desert, Monsoonal, and Tropical Wet-Dry by the Koppen-Geiger climate classification system. This study will examine and compare watershed variables in each of the four climate scenarios, such as flow rates, vegetation, and sediment transport. We aim to determine initial correlations between watershed characteristics and climate as a way of predicting and understanding what may occur in other watersheds around the world in response to rising greenhouse gas concentrations. Two billion people rely on nearby rivers for drinking water alone, and a disturbance that a watershed endures from climate change can drastically impact the availability of water. This can also negatively affect irrigation, recreation, and the nature and wildlife around the area, even to a point of no return.

62 P Insights on Bioturbation-Driven, Post-Fire Soil Mixing and Sediment Transport Mechanics from Short-Lived Radionuclides

Author: Natalie Lasater, Junior, Geology and Geological Engineering
Mentor: Dr. Danica Roth, Geology and Geological Engineering

Current hillslope sediment flux models are unable to account for dynamic, high magnitude erosion and deposition due to disturbances like wildfire. They also cannot account for sediment fluxes over short timescales in landscapes where transport is dominated by patchy and stochastic processes such as bioturbation. At our field site on the Blue Oak Ranch Reserve near San Jose, CA, sediment transport occurs primarily in the form of dry ravel initiated by burrowing mammals. Here, we use a novel application of short-lived radionuclides to examine enhanced rates of ravel transport following the SCU Lightning Complex Fire in August, 2020. We use gamma spectroscopy to determine concentrations of fallout 137Cs and meteoric 210Pb and 7Be in soil cores, freshly exhumed material collected from squirrel burrows, and mobile ravel material collected along a

hillslope transect from channel to ridge. We examine radionuclide concentrations in freshly exhumed material and soil depth profiles in order to assess bioturbation-driven soil mixing, postfire sediment transport patterns, and an approximate source depth for bioturbation-generated ravel material. We estimate travel times for ravel moving along the hillslope surface by comparing radionuclide concentrations in fresh and mobile ravel material, and hypothesize that mean travel times will decrease after wildfire. Our analysis will provide new insights and tools for better understanding the mechanics of dry ravel, bioturbation and post-fire sediment transport in steeplands.

63 P Quantifying Channel Networks Indicates that the Jezero System is a Fluvial Fan Rather Than Delta

Author: Jack Henry, Senior, Geology and Geological Engineering
Mentor: Luke Gezovich, Geology and Geological Engineering
Mentor: Dr. Piret Plink-Bjorklund, Geology and Geological Engineering

On Earth, deltas and fluvial fans are fan-shaped landforms created by fluvial activity. Deltas and fluvial fans have been differentiated as only deltas require a standing body of water to deposit their sediment while fluvial fans can form either along a body of water or on land. A flowing river channel entering a standing body of water causes sediment deposition and resultant channel bifurcations in deltas. Fluvial fans generate new channels through avulsions. To differentiate channel geometries, we examined the angle at which channels split, and lengths and widths for the channels as they trend down-fan. Since the landform geometries are preserved even when the standing body of water is absent, this project has applications to extraterrestrial environments on Mars. Here, we apply methods to quantify channel geometrics on Earth and Martian systems to determine what the landforms in the Jezero and Eberswalde Craters resemble. Our results agree with literature that channel bifurcations occur in deltas with an average angle of 72 degrees, while fluvial fans have a comparably lower channel avulsion angle of 65 degrees. Our results indicate that the channel geometries of the Eberswalde system resembles a delta while the Jezero system is comparable to a fluvial fan.

GEOPHYSICS

64 P Slipping and Sliding: Hydrologic Impacts of the Slumgullion Landslide on Lake Delta Formation

Author: Morgan Tuminello, Junior, Geology and Geological Engineering
Mentor: Dr. Brandon Dugan, Geophysics

The Slumgullion landslide, located in southwestern Colorado near Lake City, has been an area of interest for many scientists for 300 years. Data on the movement of the slide indicates that the younger, active part of the landslide moves over the older, inactive part of the landslide. To further our understanding of the landslide dynamics, we integrated data previously collected from easy-to-access outcrops with our analyses of satellite imagery and hydrologic data. We see that on average the shallow landslide moves 0.755 m/yr (+/- 0.078 m/yr) with faster movement to the south. Aerial data combined with precipitation and lake level data was used to determine if the amount of rainfall and the lake level have any effect on the average rate of movement determined. Based on our analyses of the annual precipitation data, we interpret that precipitation does impact the migration rate. This work demonstrates the necessity for more process-based linkages between surface and subsurface hydrology and mobility of the Slumgullion slide. We recommend future, priority measurements to further our understanding of the slide dynamics include water table levels along the slide, strength of materials in the slide, and higher resolution characterization of the hydrology and deformation.

65 P **Mapping Ice Shelf Calving Fronts at Thwaites Glacier using Deep Learning and Satellite Imagery in a Cloud-Based Workflow**

Author: Michael Field, Senior, Geophysics
Mentor: Tasha Snow, Geophysics
Mentor: Dr. Matthew Siegfried, Geophysics

Thwaites Glacier (TG) is one of the primary sources of ice mass loss from the West Antarctic Ice Sheet, making it a critical site for monitoring changes in the calving front location. The long duration of the Landsat mission provides a valuable opportunity to analyze over 50 years of historical imagery and produce near-real-time calving front monitoring solutions for the future. Here, we have developed a tool that allows users to produce calving front maps from cloud-hosted Landsat imagery using a U-Net, a deep learning architecture commonly used for semantic segmentation. The tool utilizes open-source Python packages for rapid querying of the Landsat catalog stored in a the Spatio-Temporal Asset Catalog (STAC) standardized metadata format, and for scalable and distributed cloud processing. This cloud-based workflow will provide researchers with access to pre-trained calving front segmentation models and decades of Landsat imagery from Thwaites Glacier. This workflow may be expanded in the future to provide historical analysis and near-real-time monitoring of other important ice shelves and glaciers in Antarctica.

66 P **Exploring the Use of Radar Polarimetry to Derive Physical Properties of Asteroids**

Author: Amanda Camarata, Senior, Mechanical Engineering
Mentor: Dr. Dylan Hickson, Geophysics

Asteroids hold the evidence necessary for understanding the formation of our solar system but are potentially hazardous if not monitored, as some asteroids have orbital paths that come near Earth. Radar observations of asteroids contain information regarding the polarization of the reflected light, which tells us how the waves were scattered on the surface of the asteroid. These data are key to understanding the composition and surface properties of asteroids and can be linked to asteroid taxonomies. Today, the connection between radar data and optical observations is not well understood. The circular polarization ratio has been most widely used as a method for analyzing the surface properties of asteroids from polarimetric radar data. My work aims to expand on previous methods by including randomly and linearly polarized components of the radar echo as an additional metric to analyze the surface properties of asteroids. This process involves implementing algorithms to calculate polarimetry from continuous wave data and subsequent statistical analysis. These data will continue to be studied to show how effectively this method predicts asteroid surface properties and what restrictions should be considered when applying this method to additional targets.

MECHANICAL ENGINEERING

67 P **Exploring the Impact of Wildfires on Photovoltaic Power Generation**

Author: Erick Garcia, Senior, Electrical Engineering
Mentor: Dr. Paulo Tabares-Velasco, Mechanical Engineering

Over the past few decades, the intensity and frequency of wildfires has grown. During any type of fire particulate matter is ejected into the air and depending on the weather and the intensity of the blaze that particulate matter may travel far from the original location of the fire. Studies that analyzed the relationship between particulate matter in the atmosphere and drops in photovoltaic power generation have found that concentrations of around 75 ug/m3 of PM2.5 caused drops in production of around 20%. We seek to explore and verify the effect that particulate matter has on the efficiency of solar panels. Corroborating the established link that other studies have found will help solidify our understanding of how a changing climate will affect future power production. This understanding will help us adapt our power generation systems for the trend in increasing wildfire intensity.

68 P Limb Dominance and Unilateral Dynamic Balance Performance in Older and Younger Adults

Author: Cameron Shelley, Sophomore, Engineering, Design, and Society
Mentor: Ava Segal, Mechanical Engineering
Mentor: Dr. Anne Silverman, Mechanical Engineering

Limb dominance has little effect on balance performance in younger adults, but how this relationship changes with age remains unclear. This study examined the relationship between limb dominance and dynamic balance performance in older and younger adults to provide insight into dynamic balance ability and limb preference across the lifespan. Balance performance was measured using the modified Star Excursion Balance Test (SEBT), which incorporates strength, mobility, and proprioception to assess dynamic balance. Twelve healthy older adults and twenty healthy younger adults reported their limb dominance. Participants performed three trials of the modified SEBT in three reach directions in random order, alternating between stance legs for 18 total trials. Separate linear mixed-effects models by age group tested for metric differences ($p<0.05$) between maximum reach distances measured with optical motion capture and normalized by body height for each limb. There were no significant main effects between limbs for normalized maximum reach distances in either age group (older: 0.12±0.4%, younger: 0.44±0.3%, mean differences ± standard error, $p>0.05$). Thus, limb asymmetry in unilateral dynamic balance performance did not increase with healthy aging. Consequently, research protocols may not require balance testing on both limbs. Clinically, unilateral rehabilitation may target the performance of the contralateral leg.

69 P Ocular Trauma Due to Blast Wave Impact

Author: Jonah Olivas, Junior, Mechanical Engineering
Mentor: Dr. Veronica Eliasson, Mechanical Engineering

There are multiple situations in which groups of people may be subject to blast wave exposure within their day to day lives such as military combat, mining, and construction. While it is known that close proximity to a blast wave can be hazardous to the eye, the mechanical response of a human eye to blast wave exposure is not fully understood. This research project seeks to develop an understanding of the mechanical response of an eye to blast wave loading. The long term intention is to use the acquired data to prevent future ocular trauma due to blast wave exposure. Experimentation involved creating gelatin eye model samples that roughly modeled the consistency of a human eye. These samples were then subjected to controlled shock wave impact while being photographed using a high-speed camera. Digital Image Correlation (DIC) techniques were implemented to measure surface displacements of the eye model samples resulting from the imposed shock wave. Current research progress has yielded promising results for determining surface behavior of the gelatin eye model. Further refinement of methodology is required, however, to ensure that experimentation is controllable and repeatable before more data can be collected.

70 P Decarbonization of Residential Buildings in Golden,CO

Author: Andrew Balmaseda, Junior, Mechanical Engineering
Author: Andy Vanyo, Junior, Mechanical Engineering
Mentor: Dr. Paulo Tabares-Velasco, Mechanical Engineering

Increasing interest to reduce carbon emissions has driven interest in electrification and on-site energy generation. The residential sector, accounting for 20% of CO_2 emissions within the US, would target the replacement of large appliances fueled by petroleum, natural gas, and heating oil. These changes can incur a significant financial burden on residents and may be limited by the power limitations of the existing electrical infrastructure. This research utilizes BEopt to model several typological housing models for Jefferson County, Colorado, and compare them to four retrofit improvement cases. The data extracted from BEopt is then used to show the changes in peak loads, particularly for the summer and winter. This data is then imported into System Advisory Model (SAM) to investigate the optimal usage of solar panels and storage batteries to limit the load on the electrical grid and reduce utility costs. The results show a 77.5% increase in the electrical load with full electrification with a reduction to 45.7% when insulation, infiltration, and lighting are made more efficient. Similarly, the utility cost of electricity increased by 86% following electrification and 44.9% after efficiency improvements were made.

71 P Fracture Behavior of Traditional and Additively Manufactured Thermosets

Author: Kathleen Sullivan, Senior, Mechanical Engineering
Mentor: Megan Shepherd, Mechanical Engineering
Mentor: Dr. Leslie Lamberson, Mechanical Engineering

Thermoset materials have distinct advantages over thermoplastics, including improved chemical resistance, heat resistance and structural integrity due to enhanced cross-linking of the polymer bonds. However, these advantages also come with the caveat that thermosets are typically more brittle than thermoplastics. More recently, thermosets are being fabricated through additive manufacturing (AM) techniques, which allows for improved prototype complexity and reduced logistics burden and has specific advantages for modern military and defense applications. As such, this study focuses on understanding the fracture and failure behavior of both traditionally fabricated and additively manufactured thermosets. In particular, a unique AM technique leveraging ultra-violet light known as digital light processing (DLP) is used to created thermosets with improved mechanical properties. These AM thermosets are also further toughened by the addition of micro-rubber particles in the matrix. Specifically, single-edge notch tension (SENT) experiments are performed on a 50 kN load frame for both a model material of polymethyl methacrylate (PMMA) and for rubber toughened DA-5-20 DLP samples. Orientation of the layers with respect to the crack tip is considered and further explored with the crack perpendicular to the layers, in the through-thickness direction of the sample. The average PMMA quasi-static fracture toughness is 1.41 MPa√m (SD +/- 0.15) and falls within reported values from literature. The average DA-5-20 quasi-static fracture toughness is 1.73 MPa√m. (SD +/- 0.29). The AM thermoset average is relatively low compared to fracture toughness values of other crack-to-print orientations with observed trends seen in previously analyzed DLP printed thermosets; however, when compared to neat resins without a second phase rubber additive, the fracture toughness values are approximately doubled.

72 P A Preliminary Investigation of Continuous Fiber-Reinforced Aluminum Composites Produced Through Cold Spray Additive Manufacturing

Author: Tyler Burt, Freshman, Mechanical Engineering
Mentor: Dr. Craig Brice, Mechanical Engineering

Cold spray additive manufacturing (CSAM) is a process in which metal powder is accelerated in a heated carrier gas leading to its mechanical deposition on a substrate. CSAM can be used to join dissimilar materials and its relatively low temperature preserves the original properties of many feedstocks. Its common uses are applying coatings and repairing damaged components. This research investigates the use of cold spray to create aluminum composites reinforced with continuous fiber, which could offer higher strength or impact resistance in a variety of applications. Continuous basalt fiber, selected for its high tensile strength, compatibility with aluminum, and relative cost effectiveness, was held in tension across an aluminum substrate and commercially pure aluminum was sprayed over the top of it. Cold spray led to the destruction of the fibers and their crystallization, even at low spray pressures not sufficient for aluminum adhesion. However, this research leads to numerous new opportunities for the application of CSAM. One such possibility is the use of CSAM to encase wire or fine-gauge metal tubing for potential high strength or high surface area (heat exchanger) applications. A preliminary investigation into this identifies numerous challenges, which may be investigated with further research.

73 P Aging Reduces Dynamic Balance Control as Measured by the Star Excursion Balance Test

Author: Brooklyn Vargas, Junior, Mechanical Engineering
Mentor: Ava Segal, Mechanical Engineering
Mentor: Dr. Anne Silverman, Mechanical Engineering

Identifying balance decline in healthy older adults is needed because early targeted interventions can mitigate balance losses. The Star Excursion Balance Test (SEBT) is one method of assessing dynamic balance with a high test-retest reliability in young adults. However, the ability to detect balance decline in older adults with the SEBT is unclear. The purpose of this study was to compare older and younger adult dynamic balance, quantified by the SEBT. Twenty healthy younger and twelve healthy older adults performed three trials per foot in the anterior, posterolateral, and posteromedial directions. Maximum reach distance was calculated for each trial using optical motion capture and normalized by height (%H). A significant main effect was found between age groups for the normalized maximum reach distances (mean ± standard deviation, older: 33.1±7.3 (%H), younger: 40.2±4.4 (%H), $p<0.05$). Pairwise comparisons revealed younger adults reached 7.4 ±

1.6% and 11.2 ± 1.6% farther (mean ± standard error) than the older adults in the posterolateral and posteromedial directions, respectively ($p<0.001$). These findings indicate the SEBT can detect balance decline in healthy older adults. This decreased balance control could be addressed through training programs that target strength, mobility, and proprioception to minimize balance losses.

74 O Applying Optical Diagnostics and Laser Flash Diffusivity to Characterize Electrolytes

Author: Sean Skweres, Senior, Mechanical Engineering
Mentor: Lydia Meyer, Mechanical Engineering
Mentor: Dr. Jason Porter, Mechanical Engineering

The rising popularity of electric vehicles has increased demand for extreme fast charging batteries. Lithium-ion batteries are one of the most promising technologies for this application, but they are limited by electrolyte diffusion capabilities. This project proposes a new technique for characterizing electrolyte properties by applying Laser Flash Diffusivity (LFD) methods to a symmetric lithium-lithium cell. This will enable researchers to quickly and cheaply measure properties such as the diffusion coefficient and transference number. The ultimate goal is to use a Fourier Transform Infrared spectrometer to measure lithium-ion concentration decay at the electrode surface after applying a short current pulse to the symmetric cell. Current investigations are focused on comparing two analytical models to a numerical model that simulates experimental results. The first analytical model utilizes 1D Fickian diffusion to predict the lithium-ion concentration profile's transient response during the current pulse. The second model leverages electrolyte properties and LFD methods to predict lithium-ion concentration decay at the electrode's surface following the pulse. Preliminary analysis reveals a low percent error between the LFD analytical model and numerical model. This suggests that LFD methods can be applied to future experimental results to ascertain electrolyte diffusion properties.

75 P Performance Degradation in Proton-Conducting Ceramic Fuel Cell and Electrolyzer Stacks

Author: John Shepherd, Freshman, Mechanical Engineering
Mentor: Dr. Neal Sullivan, Mechanical Engineering

Proton Conducting Ceramics are enabling materials for efficient electrochemical electricity generation, energy storage, and fuel synthesis. The research focuses on proton conducting ceramic fuel cells and electrolyzer stacks based on a $BaCe_{0.4}Zr_{0.4}Y_{0.1}Yb_{0.1}O_{3-\delta}$ (BCZYYb). Proton conducting ceramics have shown robust performance at 500 °C. This is nearly 200-300 °C below the more well established ceramic oxide ion conductors. Despite the high performance at these lower temperatures rapid performance degradation is observed. Degradation has been traced to a deficiency in adhesion between the BCZYYb electrolyte and air steam electrode. However, with the insertion of an “interlayer” lower degradation rates are observed. In this project, we seek to quantify the adherence between the BCZYYb electrolyte and air steam electrode. Following adherence quantification of the as-fabricated cells, the impacts of operating conditions, interlayer material, and interlayer morphology on adherence will be explored.

METALLURGICAL AND MATERIALS ENGINEERING

76 P Development of Additively Manufactured Nuclear Reactor Fuel

Author: Hanna Bakula, Junior, Chemical and Biological Engineering
Mentor: Dr. Jeffrey King, Metallurgical and Materials Engineering

Additive manufacturing provides a potential new way to create fuel pellets for nuclear reactors. This method could reduce radioactive waste, limit radiation exposure, and create innovative fuel shapes. Waste management, build plate adhesion, and the type of resin used are significant factors to take into consideration when designing a new print. An AnyCubic Photon Mono 3D printer created trial fuel pellets for this research project. The optimal print settings for black AnyCubic 3D printing UV sensitive resin consistently produced plastic pellets with no warping in a waste-efficient manner. Prints using Alphasense’s ceramic resin were more difficult, as there were problems with adhesion to the build plate and severe deformation of the print. Modification of the printer settings and the use of an Alphasense adhesive increased the success in printing green ceramic parts. In the future, the project will demonstrate the printing of uranium oxide-based ceramic resin using the technology initially demonstrated with the surrogate ceramic materials. Future work will also include evaluating the impact of cure time on part strength and the possible development of a customized resin base for nuclear fuel ceramics.

77 O Analysis of Electroplating Bath Composition for III-V Substrate Reuse

Author: Kayla Andis, Junior, Chemical and Biological Engineering
Mentor: Anna Braun, Metallurgical and Materials Engineering
Mentor: Dr. Corinne Packard, Metallurgical and Materials Engineering

III-V solar cells are highly efficient but also very expensive. Being able to reuse the growth substrate can significantly reduce overall production costs. Controlled spalling is a technique for separating semiconductors from their host substrates and is a promising method to allow substrate reuse. Controlled spalling uses an electroplated stressor layer that puts the top surface of the substrate under strain. That strain allows for the initiation of a crack that runs parallel to the surface and allows a device to be removed. The electroplating bath used in this work contains nickel (II) chloride hexahydrate and phosphorous acid, but the bath chemical composition changes with each wafer, which affects the stress imparted by the stressor layer and makes the process unstable. In this work, we studied bath stability as wafers were electroplated. We found the bath became unstable after approximately 3.5-amp hours of current was provided to the bath and we investigated methods of regaining stability with additives to the bath.

78 O Influence of Titanium on Pitting Corrosion of 304 Stainless Steel

Author: Ashley Galligan, Junior, Chemistry
Mentor: Dr. Terry Lowe, Metallurgical and Materials Engineering

Despite 304 stainless steels (SS) being designed to resist corrosion, cannula made from this type of SS can undergo the phenomenon of pitting corrosion. The purpose of this study was to determine the origin of pitting corrosion by recreating this process through an accelerated corrosion study. Field Emission Scanning Electron Microscopy (FESEM) and Energy-dispersive X-ray Spectroscopy (EDS) were applied to study the evolution of pit morphology and composition of the corrosion products. The accelerated corrosion experiment focused on how three factors, saline concentration, titanium concentration, and time, impacted the corrosion process of SS. The main conclusions drawn from the accelerated corrosion study were 1) various types of corrosion products form (both in structure and composition) with time, 2) corrosion products often occur at or near a surface feature (grain boundary, scratch, surface imperfection), 3) titanium concentrations are higher at pitting corrosion sites, and 4) the density of corrosion sites increases with increasing saline concentration, greater titanium concentration, and longer exposure times. The findings from this study have important implications in the medical field when deciding the composition to use in cannula that contain saline/salt solutions, especially concerning the concentration of titanium.

79 P Mag-O-Vision: Enhancing Residual Magnetism in Nexiva™ 18 Gauge 1.75 Inch Stainless Steel Needle Assemblies

Author: Erin Cooper, Freshman, Chemistry
Mentor: Dr. Terry Lowe, Metallurgical and Materials Engineering

In previous studies conducted by the Transdisciplinary Nanostructured Materials Research Team (TNMRT), it was discovered that Nexiva™ 18 Gauge 1.75 Inch Stainless Steel Needle Assemblies experienced induced magnetism after treatment with the Nexiva™ Handheld Magnetism Device. Over the course of a year, the residual magnetic fields produced by these needles were monitored, and it was found that the magnetic fields produced remained stable over time. For this experiment, the goal was to determine if TNMRT magnetization methods and devices produced larger residual magnetic fields in the needles as compared to previous methods and devices. During this experiment, 80 needles in total were separated into 2 groups, Group A and Group B. Each group had 40 randomly selected needles from the 4 boxes received. Group A was then demagnetized, and magnetized using the Nexiva™ Handheld Magnetizer, and Group B was then demagnetized, and magnetized using the TNMRT Custom Handheld Magnetizer. It was found that TNMRT methods and devices induced stronger overall residual magnetic fields into the needles, which could then better aid doctors in monitoring the position of needles within the body during surgery.

80 P Refrigeration Without Refrigerants: Discovery of New Low-Temperature Thermoelectric Material

Author: Adam Carranco, Sophomore, Mechanical Engineering
Mentor: Dr. Prashun Gorai, Metallurgical and Materials Engineering
Mentor: Dr. Michael Toriyama, Northwestern University

Solid-state thermoelectric (TE) devices convert thermal to electrical energy and vice versa. TE devices can be used for cooling and offers an environmentally-friendly and reliable alternative to conventional cooling technologies that employ harmful refrigerants. The low efficiency of currently used TE materials remains a challenge, which can be addressed by discovering new high-performing TE materials. Inspired by the recent success of semi-metallic Mg3Bi2-based TE devices for Peltier cooling, we performed a computationally guided search for new semi-metallic compounds with good TE performance. Semi-metals are suited for low-temperature TE because of their inherently high electrical conductivity and thermopower that is better than metals. Semi-metals are characterized by zero or negative band gaps. We used first-principles density functional theory (DFT) calculations to obtain the electronic structure of 666 Zintl phases from the ICSD database. Within this dataset, we identified 51 phases that exhibit the desired semi-metallic behavior in their electronic structures. We then estimated the TE performance of these 51 phases using DFT calculations and models to compute electronic transport properties. We identified several Zintl phases, such as Ba5In2Sb6, that are promising candidates for low-temperature thermoelectrics. The general computational framework can be extended to search for semi-metals beyond Zintl phases.

81 P Additive Manufacturing of High Temperature Materials For Power Generation Applications

Author: Bryan Dickson, Junior, Mechanical Engineering
Mentor: Dr. Jonah Klemm-Toole, Metallurgical and Materials Engineering

Oftentimes it is difficult to print models of complex 3D structures using the Wire Arc Additive Manufacturing (WAAM). WAAM is a Directed Energy Deposition (DED) printing process which uses a welding arm to arc metal onto a substrate to develop a 3D structure. DED is often a desirable process because it has high deposition rates and can create larger structures than many AM techniques and WAAM has the advantage of being much cheaper than other metal printing techniques because it does not require a controlled atmosphere to print. Certain 3D models are capable of being printed using this technique using Cura, an open-source slicer software capable of turning STL files into a G-code path which the Wire Arc Robot can use to build the full 3D structure. DED also often has an issue with thermal gradients within a build which often can lead to one part of the structure being hotter than another which can cause an imbalanced build, this can be alleviated some by randomizing the start and stop locations at each layer allowing for a shift which helps limit the thermal imbalance.

82 P 3-D Printing Fracture Networks with Synthetic Geology for Modeling Rock Dissolution Rates

Author: Alexander Hopkins, Junior, Metallurgical and Materials Engineering
Author: Aileen Le, Sophomore, Quantitative Biosciences and Engineering
Mentor: Dr. Geoff Brennecka, Metallurgical and Materials Engineering
Mentor: Dr. Alexis Sitchler, Geochemistry

Rock weathering plays a vital part in the uptake of CO2 from the atmosphere. Modeling the movement of fluids through rock fractures allows for a more comprehensive understanding of the way reactive material dissolves out of a fracture matrix. Due to the variability composition and fracture geometry of rocks in nature, controlled experimentation is very difficult. This project aims to develop methods to create synthetic “rocks” to enable repeatable flow experiments in the lab. To make these simulated rocks, we used 3d printing to create resin models of real fracture networks based on x-ray computer tomography images of natural rock samples. These networks were then cast in cement and burned out. This method provides a proof of concept of a technique to control chemical composition and fracture geometry in realistic matrix.

83 P Advanced Manufacturing of Gen3 CSP and its Components

Author: Aric Adamson, Junior, Metallurgical and Materials Engineering
Mentor: Dr. Zhenzhen Yu, Metallurgical and Materials Engineering

The Generation Three Concentrating Solar Power System (Gen3 CSP) requires high corrosion resistance

cladded piping. As a possible material candidate, a wrought 304H stainless steel backer pipe was cladded using powders of Ni-based alloy C276 through the combustion synthesis/centrifugal rotation (CS/CR) method. Microstructural evaluation of the synthesized C276 cladder indicated solidification cracking of 0.5 mm length on the inner diameter of the pipe. Further evaluation using backscatter scanning electron microscopy (SEM) showed a secondary phase, sigma, within the interdendritic regions of the C276 γ-austenitic matrix, with increasing secondary phase concentrations near the inner diameter of the cladder. Energy dispersive spectroscopy (EDS) coupled with spark optical emission spectroscopy (OES) determined that the synthesized matrix contains threefold the maximum nominal iron content acceptable in wrought C276 alloys, while the secondary phase was enriched in molybdenum compared to the matrix. Thermodynamic calculations, using Thermo-Calc© simulations with the OES composition, determined the sigma phase could be dissolved with heat treatment at 1260℃ for 30 minutes followed by a water quench. The experimental heat treatment successfully reduced sigma phase concentrations, but the corrosion rate, using molten chloride salts, was not reduced with heat treatment.

84 P Enabling Next Generation Magnets Free of Rare Earth Elements

Author: Emmelia Ashton, Sophomore, Metallurgical and Materials Engineering
Mentor: Dr. Terry Lowe, Metallurgical and Materials Engineering

The FeN Super Magnet project is part of a multi-institution effort to build stronger, lighter, and more efficient magnets from abundantly available materials. When compacted, Iron (Fe) and Nitrogen (N) nanoparticles create an extremely powerful magnetic material which is relatively inexpensive due to the natural abundance of the constituent elements. The potential uses are incredibly compelling and extremely versatile. If implemented, they could reduce some of the environmental strain caused by human applications of magnets in technology and create much more sustainable and affordable interactions between humanity and current technology. Developing a consistent method of manufacturing FeN magnets would allow the replacement of rare earth metal and bonded magnets currently used in electronic products with lighter, more powerful, and environmentally sustainable products allowing for the next generation of efficient technologies. This work focuses on developing a consistent method of manufacturing by inducing shear during compaction to make prototype FeN magnets and characterizing the increased density and magnetic coercivity.

85 O Robotic Blacksmithing

Author: Mason Weems, Junior, Metallurgical and Materials Engineering
Author: Natalie Compton, Junior, Metallurgical and Materials Engineering
Author: William Stodgehill, Sophomore, Electrical Engineering
Mentor: Dr. Kester Clarke, Metallurgical and Materials Engineering

Metamorphic Manufacturing is a novel way to produce parts by simply changing the shape of the part without changing the volume. This is a process analogous to historical blacksmithing. In this project, group members were educated about blacksmithing procedures and applied those procedures to building and programming a robot capable of similar methods. This robot was used alongside a manually-operated hydraulic press to deform annealed 6061 aluminum to a certain shape along different deformation pathways. The microstructure of the material was analyzed afterwards to determine optimal deformation pathways.

86 O Development of Consumables for Deposition Rate Additive Manufacturing

Author: William Lansing, Junior, Metallurgical and Materials Engineering
Mentor: Dr. Jonah Klemm-Toole, Metallurgical & Materials Engineering

As manufacturing technologies advance, parallel innovations in material design must be accomplished to produce more advanced structural components. To fully realize the benefits of additive manufacturing (AM), new feedstocks that are conducive to AM must be developed. Twinning induced plasticity (TWIP) steel alloys are attractive for structural applications due to exceptionally high work hardening rates and high toughness, but these alloys have largely been investigated in wrought form. There is a need to develop wire feedstocks to enable high deposition rate wire arc additive manufacturing of TWIP steels. In this presentation, we describe the development and manufacturing of a high manganese TWIP wire feedstock.

87 P State-of-the-Art Multiphysics Simulations to Better Understand Additive Manufacturing

Author: Beau Nannie, Junior, Metallurgical and Materials Engineering
Mentor: Dr. Jonah Klemm-Toole, Metallurgical and Materials Engineering

Physical processes such as solidification in additive manufacturing (AM) occur too quickly and are too localized to directly measure cooling rates or temperature gradients. However, cooling rates and temperature gradients significantly affect how materials evolve in AM. Accordingly, sophisticated modeling and simulations must be used to estimate heat transfer conditions during the process. In order to do this, the program SysWeld will be utilized in order to complete these simulations.

88 P Understanding Influence of Heat-Treatment on Serrated Yielding in a Ni Superalloy

Author: Nathan Brown, Senior, Metallurgical and Materials Engineering
Mentor: Dr. Kester Clarke, Metallurgical and Materials Engineering

Nickel-based superalloys have been reported to experience serrated yielding at certain temperature regimes which overlap with their working temperatures. This phenomenon results in increasing strain with a nominal change in stress, leading to undesirable operating conditions. Understanding the origins of localized deformation that accompanies serrated yielding would improve mechanical properties, leading to better performing and more efficient turbine engines. Methods to determine the activation energy for serrated yielding have been determined which gives insight into the mechanisms responsible for this phenomenon.

89 P Optimization of Space Nuclear Reactor Shielding Compositions through Computational Analysis

Author: Madeline Hoffmann, Freshman, Physics
Mentor: Dr. Jeffrey King, Metallurgical and Materials Engineering

Nuclear reactors emit ionizing radiation that can be harmful to people and electronic equipment. Shielding materials that attenuate this radiation can significantly increase the size and mass of nuclear-powered spacecraft. Creating shielding materials that are viable for additive manufacturing processes may allow the production of customizable shield geometries that can reduce the size and mass of shielding materials needed to meet the spacecraft dose requirements. This project generated a Python 3.10 script that allows the user to test arbitrary compositions of different materials using OpenMC to optimize these materials for additive manufacturing. OpenMC is an open-source Monte Carlo-based neutron transport code that probabilistically models the movement of neutrons and photons as they interact with a user-specified environment. The program analyzed combinations of plastic matrices (polylactic acid, acrylonitrile butadiene styrene, and low-density polyethylene) and neutron/gamma ray absorbers (boron, lithium oxide, and iron oxide) based on their ability to attenuate neutrons from a monodirectional, monoenergetic source. A mixture of 20 wt% boron in low-density polyethylene is the most effective absorber for 1 MeV neutrons, with a tenth-layer thickness of 10.7 cm. Future investigations will expand the model to include gamma ray tracking, additional materials, and more realistic radiation sources.

90 P Additive Manufacturing Radiation Shielding

Author: Keenan Edward Myers, Senior, Physics
Mentor: Dr. Jeffrey King, Metallurgical & Materials Engineering

Additive manufacturing of space radiation shielding may allow for in situation manufacturing of customized shield geometries, which may decrease shield size and mass. Plastics used in fused filament fabrication provide poor radiation shielding; however, doping these plastics with radiation absorbing materials can improve their shielding properties. Acrylonitrile butadiene styrene (ABS) filament doped with iron (III) oxide using a commercially available filament extruder serves as a conceptual demonstration of the process needed to produce 3D printed radiation shielding. Extruding and shredding the plastic five times to mix it before the final extrusion process makes the doped plastic more flexible and easier to 3D print consistently. A commercially available fused filament 3D printer produced small test disks from the doped plastic. Measuring the mass and volume of the disks based on water displacement provides an estimate of the density of the printed disks. The measured density of the printed disks provides input data to a computational model that estimates the effectiveness of the shielding material. The high porosity of the filament and printed plastic introduces a large systematic error to these density measurements. More tests are required to determine the final composition and density of the printed disks.

MINING ENGINEERING

91 O Traceability of Colorado's Frac Sand Supply Chain and Related Emissions

Author: Erik Villar, Junior, Petroleum Engineering
Author: Jonathan Juaneza, Junior, Petroleum Engineering
Mentor: Cansu Perdeli Demirkan, Earth Resources Development Engineering
Mentor: Dr. Nicole Smith, Mining Engineering
Mentor: Dr. Sebnem Duzgun, Mining Engineering

Monocrystalline, spherical, silica sand is a critical proppant that is used to maintain the integrity of fractures caused by hydraulic fracturing. Considerable amounts are consumed in this process – industry experts estimate the average unconventional well in the DJ-Basin will use 10-30 million pounds of silica sand. From 2012 – 2017, Colorado performed approximately 17,000 frac jobs consuming a total of 1.004E+11 pounds of natural silica sand. This particular type of sand is sourced from a few locations within the contiguous United States. Therefore, this team sought to identify the sources of proppant used in unconventional wells nationwide through multimodal data analysis. Nineteen states contribute to gross proppant production but the largest producers by average contribution are: Wisconsin (41%), Illinois (20%), and Missouri (8%). The silica sand is transported by railway and roads from these states to Colorado. Emissions caused by the transportation of this proppant can fall into a range between 10,500 – 2,785,000 pounds of CO2 one-way for a single well, depending on factors such as distance traveled, tonnage, etc. Ultimately, we suggest that one way to lower CO2 emissions from oil and gas production would be to identify alternative sources of sand closer to the operations.

PHYSICS

92 P Electrochemical Growth of Superconductors

Author: Brandon Di Genova, Sophomore, Chemical and Biological Engineering
Mentor: Dr. Serena Eley, Physics

This project is focused on increasing the Tc of electrochemically grown rhenium. Rhenium is grown by inducing an overpotential using an ammonium perrhenate solution creating a superconducting layer over a gold silicone substrate. Optimal solution conditions consisted of .01M H2SO4, .025M NH4ReO4 and 5M LiCl. This grown rhenium has a Tc of abot 1.8 K, research has shown it can increase by creating multilayers of grown rhenium and copper. Copper was deposited over the rhenium samples through thermal evaporation or electrochemical growth in a copper sulfate solute with an adjusted pH of 4.32. More acidic copper sulfate solutions were found to inhibit copper deposition. In addition, research was done into growing a superconducting rhenium-cobalt alloy. The Tc would be very sensitive to any shifts in composition of this alloy and composition was very sensitive to any changes in solution composition and applied voltage. Without conducting X-ray diffraction to test the actual composition of the grown samples it is impossible to know if non superconducting samples were due to inadequate compositions or a failure in theory.

93 P Activity of SARS-CoV-2 Protease 3CLpro on Collagen Fibrils

Author: Ashley Turnage, Freshman, Chemical and Biological Engineering
Author: Katherine Newburry, Freshman, Chemical and Biological Engineering
Mentor: Dr. Susanta Sarkar, Physics

COVID-19, caused by SARS-CoV-2, often manifests multi-organ disease pathology: (1) increased MMPs, (2) increased fibrosis post-recovery (more deposition of collagen), and (3) increased blood clots. The current pandemic-causing virus SARS-CoV-2 produces 3CLpro in infected human cells. The broad-spectrum protease

activity of 3CLpro is essential to produce functional proteins necessary for coronavirus propagation. Preliminary results suggest that 3CLpro also has significant collagenolytic activity. 3CLpro as a viral collagenase will initiate a wide range of applications. Collagen is highly resistant to degradation by proteases, and only a few MMPs can degrade collagen. 3CLpro is the smallest (~34 kDa) in comparison to human matrix metalloprotease-1 MMP1 (~43 kDa in the activated form) and bacterial collagenase (~130 kDa). 3CLpro is already a drug target, and as such, MMP inhibitors may work against 3CLpro. The goal is to define how 3CLpro (PDB ID 6YB7), the main protease produced by SARS-CoV-2, interacts with collagen (PDB ID 4AUO). The premise is that our preliminary results suggest that 3CLpro has a collagenolytic activity. We propose quantifying the collagen degradation activity of 3CLpro and establishing 3CLpro as a viral collagenase (i.e., it degrades collagen, the most abundant structural protein in humans). We have performed molecular docking of 3CLpro (PDB ID 6YB7) with collagen (PDB ID 4AUO) using ClusPro and molecular dynamics simulations using GROMACS. We defined changes at the catalytic site upon collagen binding and identified allosteric sites with strong correlations with the catalytic dyad. We performed virtual screening against these allosteric sites for eventual experimental validation of the top ten lead molecules.

94 P Machine Learning Software Development for X-ray Photoelectron Spectroscopy

Author: Leon Wan, Junior, Computer Science
Mentor: Dr. Kenneth (Xerxes) Steirer, Physics

X-ray Photoelectron Spectroscopy (XPS) is a valuable technique, not only for identifying a material's surface chemistry, but also for revealing the bonding structures of the observed elements. It has numerous applications in the development of solar energy, batteries and mining ore. However, the scope of XPS is still hindered by certain aspects, such as variability between sample measurements and limited accuracy. Employing machine learning algorithms could facilitate applied XPS analyses. To accomplish this, a spectral fit routine is essential. Both real and simulated data are then subjected to the peak fitting model as a way to supply inputs for machine learning. Algorithms including k-means and DBSCAN are explored to better understand the clustering behavior of spectra components. In the future, we will investigate L1 minimization and implement software that incorporates our chosen machine learning model.

95 P Super Resolution Metrology for Advanced Manufacturing

Author: Morgan Trexler, Senior, Mechanical Engineering
Mentor: Dr. Jeff Squier, Physics

Various feedback techniques have been developed for additive manufacturing (AM) to provide details about the chaotic fusing process in laser powder bed fusion (LPBF). Rapid thermal differentials cause many effects, including warping of the part, thermally induced stress, and ejection of material from the melt site. Therefore, understanding the thermal structure of the part throughout the manufacturing process is critical for building more complete models and providing in-situ feedback. Researchers have developed ultrafast 2D camera-based thermal imaging to create the required thermal feedback, but these approaches lack a validation strategy. Additionally, almost all papers quote a magnification of their detector's resolution as their feedback capabilities. However, optical effects such as aberrations can drastically reduce the actual resolution of the feedback system. We have developed a methodology for evaluating the actual resolution of a thermal imaging system using LEDs to mimic the blackbody radiation from an additive manufacturing process. Using the LEDs, a standardized resolution target can be illuminated without the need for the 200+ watt lasers used in metal AM. By creating this validation methodology, we can ensure that the data provided by novel feedback systems accurately represent reality.

96 P Rapid Thermal Annealing Investigations of Silicon Clathrates

Author: Jessica Richman, Junior, Metallurgical & Materials Engineering
Mentor: Dr. Reuben Collins, Physics
Mentor: Dr. Carolyn Koh, Chemical and Biological Engineering

Silicon clathrate is an allotrope of silicon consisting of a cage-like structure and is of interest due to its direct band-gap and high absorption with possible applications in photovoltaics. The dopant atoms required to make electronic devices are often inserted into semiconductors via ion implantation. This process is often followed by an anneal to repair lattice damage. This process may not work, however, since silicon clathrate converts to diamond silicon at higher temperatures. In this study, a rapid thermal annealer was used to heat the clathrate sample to higher temperatures in a shorter amount of time to prevent the change to diamond silicon. The results are shown using X-ray diffraction spectra for annealing at temperatures ranging from 450°C to 550°C. Silicon clathrate was shown to convert to diamond silicon at a temperature of 550°C during rapid thermal annealing. This work was partially supported by the National Science Foundation.

97 P Vortex Dynamics in Superconductors

Author: Connor Hewson, Junior, Physics
Author: Aliyah Matthews, Junior, Physics
Mentor: Dr. Serena Eley, Physics

Distinguished for their ability to carry high zero-resistance currents when cooled below a critical temperature Tc, superconductors are used in motors, generators, and gamma ray detectors. However, the performance of these devices is often impaired by the motion of vortices, discrete, nanoscale regions of quantized magnetic flux that penetrate type-II superconductors. For example, thermally induced vortex motion, known as vortex creep, reduces the materials’ current carrying capacity □□ and introduces energy loss and noise in superconducting circuits. For applications, we must choose materials with low creep rates and often tune the material microstructure to reduce the creep rate. Unfortunately, the electromagnetic properties of superconducting materials cannot yet be reliably predicted due to large gaps in our knowledge of vortex dynamics. In this study, we report on our measurements of the vortex creep rate S in different superconductors. Specifically, we study how creep depends on temperature and an applied magnetic field. It has been predicted that S positively correlates with a material-dependent parameter called the Ginzburg number Gi, which tends to be orders of magnitude higher for high-Tc superconductors than low- Tc materials. We test this prediction by comparing our creep measurements in these different superconductors with different Gi.

98 P Skyrmions in 2D Materials

Author: Paul Slayback, Junior, Physics
Mentor: Dr. Serena Eley, Physics

Skyrmions are nanoscale magnetic whirlpools that arise in certain magnetic materials due to interactions between neighboring atomic spins, in which spin is an intrinsic quantity that results in magnetism. Behaving as particles that can be controllably manipulated, skyrmions are potentially useful as information carriers in next-generation low-energy spintronic devices and topological qubits. Notably, they were recently observed in Fe3GeTe2 (FGT), a 2D van der Waals (vdW) ferromagnet. A vdW material can be separated into crystalline, atomically thin layers, referred to as a 2D material. The vdW materials are of interest for devices due to their readily tunable electronic properties and for fundamental studies of low dimensional long-range magnetic order. To enable studies of skyrmion dynamics in FGT heterostructures, we first built a system that allows us to deterministically place air sensitive 2D vdW materials onto substrates. We are now fabricating Hall bar patterns of FGT, which consist of FGT flakes connected to six micropatterned Ti/Au leads, enabling electrical transport measurements. Next, we will measure these devices at the low temperatures and applied magnetic fields to look for signatures of skyrmion formation and dynamics. The end goal is to fabricate FGT-superconductor heterostructures in which superconducting vortices and skyrmions co-exist and may host modes that are of interest for fault tolerant quantum computing.

99 P Energy Loss in Superconducting Resonators

Author: Nathan Taylor, Junior, Physics
Mentor: Dr. Serena Eley, Physics

The performance of superconducting quantum circuits is limited by energy losses from parasitic two-level systems (TLSs), quasiparticle poisoning, and dissipative vortex motion. Despite numerous studies that have tuned the effects of these decoherence mechanisms, the microscopic origin of TLSs and source of quasiparticles is usually unknown and no methods exist to fully eliminate these mechanisms. Here, we study energy loss in superconducting Nb microwave resonators, which are integral components in certain platforms for quantum sensors and qubits. To this end, first we used Sonnet simulations to design a device containing multiple co-planar waveguide resonators (with resonant frequencies from 2 to 5GHz) coupled to a common feedline. Second, we fabricated these devices using DC magnetron sputtering followed by standard photolithographic and etching techniques. The next steps involve measuring the frequency response and the power dependence of the quality factor, a metric for energy loss, to extract the density of TLSs. Lastly, we will study energy loss in epitaxially grown NbN resonators to compare the density of parasitic TLSs in granular versus epitaxial materials. This work will help to determine whether epitaxial materials are superior to non-epitaxial ones for quantum circuits and to identify the microscopic origin of TLSs.

100 P Determining Electron-Phonon Thermalization Using FIB C-Pt Thermometers

Author: William Brackney, Junior, Physics
Mentor: Dr. Meenakshi Singh, Physics

Thermal relaxation is one of the many variables that is detrimental to the development and management of quantum technology. Thus, much time and effort has been put into examining how to minimize the effects of thermalization on quantum information. This project examines the effects of substrate morphology on electron-phonon thermalization times. Specifically, nanoscale modifications of the substrate surface are coupled with thermalization measurements to enable extraction of electron-phonon thermalization parameters. This poster focuses on the fabrication of these samples.

101 O Systematic Analysis of Low-Energy 7Be Decay Spectra in Superconducting Quantum Sensors for the BeEST Sterile Neutrino Search Experiment

Author: Sergio Oscar Nuñez Silva, Senior, Physics
Mentor: Dr. Kyle Leach, Physics
Mentor: Dr. Geon-bo Kim, Lawrence Livermore National Laboratory

The BeEST experiment uses a novel approach with superconducting tunnel junctions (STJ) quantum sensors to make precision measurements of the 7Be electron capture decay (EC) for keV sterile neutrino search. This concept is among the most sensitive methods to probe beyond Standard Model (BSM) physics in the neutrino sector. In the present work, we report the first systematic analysis of experimental 7Be EC spectra measured by four pixels in the BeEST Phase-II operation. The analysis was performed by constraining the fraction of the high-energy tail in the 7Be L-capture peak due to this tail is physically originated from atomic shaking effects and thus its fraction should be the same for all four pixels. Our results show a high-energy tail fraction with a minimum chi-square value in the 20% - 30% range, being consistent with current theoretical calculations. This result would significantly reduce systematic uncertainties in sterile neutrino analysis and is already being used to improve the sensitivity of the experiment for the Phase-III measurement campaign using arrays of sensors which is currently underway.

102 P Developing a Piezoelectric Stage for Measuring Spin Qubit Dynamics

Author: Joshua Barbell, Junior, Physics
Author: Declan Knies, Freshman, Physics
Mentor: Dr. Meenakshi Singh, Physics

Spin-orbit coupling plays a key role in spin qubit dynamics. Efforts to modify spin-orbit coupling, and thereby spin qubit dynamics, using electromagnetic fields abound. Our research group aims to study the impact of strain on this important parameter. Our goal in this project was to setup a piezo actuator-strain gauge system with fully computerized control to enable this study. Our current work has resulted in calibration of the strain gauge that will be attached to the silicon chip. By the end of the semester, we expect to calibrate the actuator as well as setup the piezo stage with a silicon chip.

103 P Thermal Conductivity at Ultralow Temperatures

Author: Portia Allen, Junior, Physics
Mentor: Dr. Meenakshi Singh, Physics

Thermal conductivity measurement techniques are well-established at room temperature, but become more challenging at cryogenic temperatures. The development of a dedicated thin film measurement platform for sub-Kelvin temperatures allows for the measurement of thermal conductivity of a range of materials at cryogenic temperatures. Here, we have developed and characterized an experimental platform for the measurement of thermal conductivity below 1 K. The use of suspended Si-N platforms ensures thermal isolation of the sample. Local joule heaters provide a controllable temperature gradient across the platforms. Carbon-platinum (C-Pt) composite, fabricated using focused ion beam (FIB) assisted deposition, acts as a highly sensitive, local, resistive thermometer. The calibration of these thermometers at low temperatures is critical to ensuring their functionality for thermal conductivity measurements. The initial data follows expected trends for resistance vs temperature, especially at low temperatures. Efforts to mitigate high noise are underway.

104 ○ A Triple-Pinhole Apparatus For the Exploration of Vortex Dynamics

Author: Finnegan Rush, Freshman, Physics
Mentor: Dr. Mark Lusk, Physics

This project seeks to move beyond a one-dimensional setting of the Young Double-Slit Experiment by replacing the two slits with three pinholes located on the vertices of a triangle. This produces a more complex pattern of constructive and destructive interference, now two-dimensional, in which dark bands are replaced by dark spots. Interestingly, these spots are places where the phase of the light is not defined. I have created a simulation in which both the intensity and phase of light is generated at a movable measurement screen, and this shows that the dark spots are actually optical vortices. The construction of optical vortices is not new, but the connection to a simple extension of the Young Double-Slit Experiment is novel and may offer new insights. My research will explore the relationship between the pinhole geometry and the structure of the optical vortices produced, both their position on the screen and the internal structure of the vortices themselves. Intriguingly, the vortex patterns should not be limited to light so this must have a quantum mechanical manifestation as well. Electron beams, buckyballs, and even organic molecules should all exhibit a "vortex nature" if properly probed.

NOTES

ABOUT MURF

MINES UNDERGRADUATE RESEARCH FELLOWSHIP

The objective of Mines Undergraduate Research Fellowship (MURF) is to enhance the education of undergraduate students with opportunities to work as research assistants on faculty-led research projects. This program broadens and deepens 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 that is funded by MURF cannot be taken for research credit or for senior design credit. Participating faculty members are encouraged to increase the research participation of qualified female identifying students and students from under-represented ethnic backgrounds.

Terms of Employment and Eligibility

All full-time undergraduate students currently enrolled at Mines are eligible to apply.

- Fellowship stipend for MURF is a total of $1500.
- Renewals for a second period are allowable upon demonstration of adequate progress and have to be applied for through the next solicitation.
- Students who are available to conduct research during both fall and spring semesters will be given preference.
- First-year/sophomore/junior students are all encouraged to apply.

Requirements

Students who receive the fellowship must fulfill the following requirements:

- Complete several Canvas Assignments, including a Mentor & Mentee Contract, two Student Participant Agreements and Payment Requests, and Responsible Conduct in Research Training.
- Provide a 1-2 page summary of the research work at the end of fall semester.
- Present a poster or give a talk at the annual Undergraduate Research Symposium held in the Spring semester (April).

The student application for MURF 2022-2023 is open from April 1st, 2022, through May 20th, 2022.

You can learn more about MURF, search available research projects, and submit a student application at the following URL:

THANK YOU TO OUR MENTORS

AND, THANK YOU TO ALL MENTORS NOT LISTED HERE!

Applied Mathematics and Statistics
Diniz Behn, Cecilia [4 P]
Hammerling, Dorit [1 P]
Leiderman, Karin [2 P, 5 P]
Pankavich, Stephen [6 P]
Strong, Scott [3 P]

Chemical and Biological Engineering
Boyle, Nanette [8 P]
Carreon, Moises [17 P, 19 P]
Cash, Kevin [15 P, 16 P]
Farnsworth, Nikki [13 P]
Gómez-Gualdrón, Diego [7 P]
Herring, Andrew [12 P, 26 P]
Jechura, John [10 O]
Koh, Carolyn [24 P, 34 P, 96 P]
Krebs, Melissa [18 P, 23 P]
Kumar, Ramya [9 P]
Kwon, Stephanie [25 P]
Marr, David [11 P]
Pak, Alexander [14 P]
Shaffer , Justin [21 P]
Sum, Amadeu [22 P]
Way, Doug [20 P]
Wolden, Colin [10 O]
Wu, Nin [27 P]

Chemistry
Domaille, Dylan [30 P, 35 P]
Jensen, Mark [32 P]
Klein-Seetharaman, Judith [33 O]
Pylypenko, Svitlana [28 P, 39 O, 40 P]
Sellinger, Alan [29 P, 36 P]
Trewyn, Brian [37 P]
Vyas, Shubham [31 P, 38 P]
Williams, Kim [41 P]

Civil and Environmental Engineering
Munkata-Marr, Junko [45 P]
Sharp, Jonathan [42 P, 43 P, 44 P]

Computer Science
Fierro, Gabriel [46 P]
Han, Qi [52 P]
Wang, Hua [49 O, 50 O]
Yang, Dejun [47 P]
Yue, Chuan [48 P]

Economics and Business
Flamand, Tulay [51 P]

Electrical Engineering
Aaen, Peter [54 P, 55 O]
Elsherbeni, Atef [56 P, 57 P]
Nayeri, Payam [53 P]

Engineering, Design and Society
Lucena, Juan [59 P]
Nieusma, Dean [58 O]
Rea, Stephen [58 O]
Smith, Jessica [59 P]
Zhu, Qin [58 O]

Geology and Geological Engineering
Plink-Bjorklund, Piret [61 P, 63 P]
Roth, Danica [62 P]
Sitchler, Alexis [60 P, 82 P]

Geophysics
Dugan, Brandon [64 P]
Hickson, Dylan [66 P]
Siegfried, Matthew [65 P]

Mechanical Engineering
Brice, Craig [72 P]
Eliasson, Veronica [69 P]
Lamberson, Leslie [71 P]
Porter, Jason [74 O]
Silverman, Anne [68 P, 73 P]
Sullivan, Neal [75 P]
Tabares-Velasco, Paulo [67 P, 70 P]

Metallurgical and Materials Engineering
Brennecka, Geoff [82 P]
Clarke, Kester [85 O, 88 P]
Gorai, Prashun [80 P]
King, Jeffrey [76 P, 89 P, 90 P]
Klemm-Toole, Jonah [81 P, 86 O, 87 P]
Lowe, Terry [78 O, 79 P, 84 P]
Packard, Corinne [77 O]
Yu, Zhenzhen [83 P]

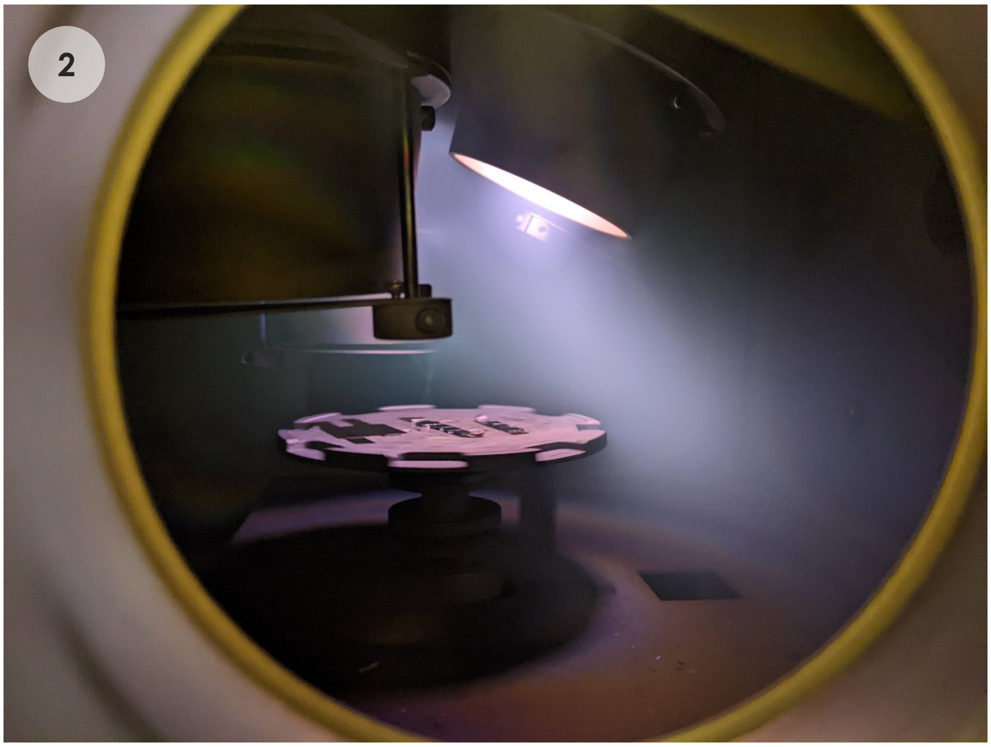
Mining Engineering
Duzgun, Sebnem [91 O]
Smith, Nicole [91 O]

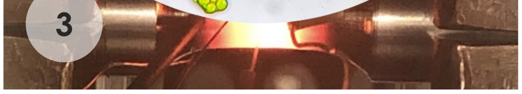
Physics
Collins, Reuben [96 P]
Eley, Serena [92 P, 97 P, 98 P, 99 P]
Leach, Kyle [101 O]
Lusk, Mark [104 O]
Sarkar, Susanta [93 P]
Singh, Meenakshi [100 P, 102 P, 103 P]
Squier, Jeff [95 P]
Steirer, Kenneth (Xerxes) [94 P]

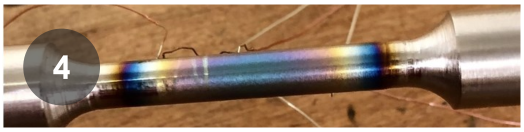
2022 STUDENT PRESENTERS

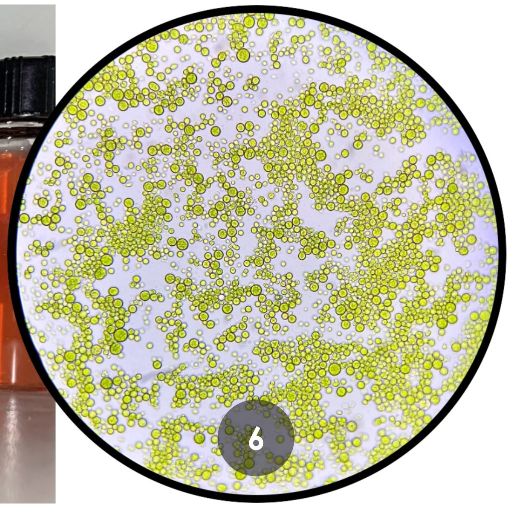
IN ALPHABETICAL ORDER WITH PROJECT NUMBER

Adamson, Aric [83 P]
Allen, Portia [103 P]
Andis, Kayla [77 O]
Ashton, Emmelia [84 P]
Bakula, Hanna [76 P]
Balmaseda, Andrew [70 P]
Barakoti, Prasanga [23 P]
Barbell, Joshua [102 P]
Bean, Allison [45 P]
Benson, Kayla [43 P]
Borrego-Castaneda, Luis [36 P]
Brackney, William [100 P]
Brown, Nathan [88 P]
Burt, Tyler [72 P]
Camarata, Amanda [66 P]
Carranco, Adam [80 P]
Cedillos, Joshua [12 P]
Chang Huang, Pablo [44 P]
Chase, Bella [24 P]
Clarke, Cameron [6 P]
Coatney, Caleb [20 P]
Compton, Natalie [85 O]
Cooper, Erin [79 P]
Costa, Benjamin [46 P]
D'Aquila, Alexandra [10 O]
Daly, Clayton [53 P]
Dawson, Michael [34 P]
Di Genova, Brandon [92 P]
Dickson, Bryan [81 P]
Dilley, Savannah [61 P]
Eiken, Julia [5 O]
Erdemir, Candan [7 P]
Ezell, Morgan [26 P]
Ezell, Alexandra [41 P]
Fein-Ashley, John [29 P]
Field, Michael [65 P]
Fink, Mara [16 P]
Fontan, Rachel [60 P]
Galligan, Ashley [78 O]
Garcia, Erick [67 P]
Glaister, Jade [45 P]
Hall, Peter [52 P]
Hampton, Drake [13 P]
Hampton, Griffin [4 P]
Hanson, Benjamin [27 P]
Henry, Jack [63 P]
Hewson, Connor, [97 P]
Hoffmann, Madeline, [89 P]
Hopkins, Alexander, [82 P]
Hora, Kenneth, [56 P]
Huang, Kevin, [21 P]
Huang, Kevin, [35 P]
Isbell, Sydney [15 P]
Junaeza, Jonathan [91 O]
Kelly, Lauren [35 P]
Kennedy, Jessica [55 O]
Kim, Kacey [25 P]
Kim, Sara [39 O]
Klein, Johnathan [32 P]
Knies, Declan [102 P]
Knipple, Blake [42 P]
Knodel, Elijah [51 P]
Lambardia, Isabella [28 P]
Lansing, William [86 O]
Lasater, Natalie [62 P]
Le, Aileen [82 P]
Li, Zi [1 P]
Matthews, Aliyah [97 P]
McLaughlin, Cosette [14 P]
Mehrabian, Ryan [22 P]
Myers, Keenan Edward [90 P]
Nannie, Beau [87 P]
Newburry, Katherine [93 P]
Nguyen, Sonny [21 P]
Nuñez Silva, Sergio Oscar [101 O]
Okolovitch, Evan [8 P]
Olivas, Jonah [69 P]
Ostrem, Silje [57 P]
Ovanessians, Armand [50 O]
Pauling, Jessica [38 P]
Pfeffer, Ryan [30 P]
Potter, Ashley [17 P]
Prasad, Amiya [48 P]
Raichart, Alexandra [18 P]
Richman, Jessica [96 P]
Rivera, Angelina [59 P]
Rudge, Kaleigh [3 P]
Rush, Finnegan [104 O]
Sandoval, Marisa [33 P]
Schanker, Corey [52 P]
Sela, Amit [19 P]
Shelley , Cameron [68 P]
Shepherd, Maxim [40 P]
Shepherd, John [75 P]
Shiekh, Kylee [58 O]
Skweres, Sean [74 O]
Slayback, Paul [98 P]
Sogal, Dhruva [47 P]
Spielman, Joseph [48 P]
Stodgehill, William [85 O]
Sullivan, Kathleen [71 P]
Taylor, Nathan [99 P]
Trexler, Morgan [95 P]
Tubbs, Azlan [2 P]
Tuminello, Morgan [64 P]
Turnage, Ashley [93 P]
Ung, Kristen [52 P]
Vaishnav, Akshati [49 O]
Vargas, Brooklyn [73 P]
Villar, Erik [91 O]
Wan, Leon [94 P]
Weems, Mason [85 O]
Weizenbeck, Annabel [37 P]
Wideman, Luke [31 P]
Willner, Jackson [54 P]
Wright, Aryelle [9 P]
Yeager, Logan [11 P]









1 | 6 Author: Emma Khorunzhy, CBEN | Mentor: Nanette Boyle, CBEN

Chromochloris zofingiensis in synthetic wastewater media.

Chromochloris zofingiensis in CORE media.

2 Author: Paul Slayback, Physics| Mentor: Serena Eley, Physics

Gold sputtering devices.

3 | 4 Author: Nathan Brown, MME | Mentor: Kester Clarke, MME

Elevated Temperature Tensile Testing of 304SS for the determination of thermal gradients in the Gleeble 3500.

Oxide Layer formation from elevated temperature Tensile Testing of 304SS for the determination of thermal gradients in the Gleeble 3500.

5 Author: Pilar Martin, CBEN| Mentor: Kevin Cash, CBEN

Sodium, nitrate, and oxygen nanosensors.

THANK YOU TO ALL OUR STUDENT RESEARCHERS AND THEIR DEDICATED MENTORS!

WITHOUT YOU, THIS SYMPOSIUM WOULD NOT BE POSSIBLE.