12th ANNUAL STUDENT RESEARCH SYMPOSIUM

April 5, 2022

Abstract Book

SOUTH DAKOTA MINES
An engineering, science and technology university

The South Dakota Mines Annual Student Research Symposium showcases research from graduate and undergraduate students across multiple disciplines on campus.

Schedule

Event Held in Surbeck Center:

Bump Lounge:

8:00 AM - 10:00 AM - Graduate Oral Sessions
10:00 AM - 12:00 PM - Graduate Oral Sessions

Dorr Room:

8:00 AM - 9:40 AM - Graduate Oral Sessions
10:00 AM - 12:00 PM - Graduate Oral Sessions
12:15 PM - 3:00 PM - Undergraduate Oral Sessions

McKeel Room:

8:00 AM - 10:20 AM - Graduate Oral Sessions
11:00 AM - 1:40 PM - Graduate Oral Sessions

Ballroom:

9:00 AM - 11:30 AM - Graduate Poster Session
12:01 PM - 2:30 PM - Undergraduate Poster Session

5:30 PM - 6:30 PM - Awards Ceremony

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Undergraduate Students

Graduate Students

Examining the Effects of Wildfire Smoke on Ozone Content Near-Surface and Above in the Colorado Front Range

Lexy Elizalde, Atmospheric and Environmental Sciences
Dr. Adam French, Atmospheric and Environmental Sciences

Abstract. Wildfires have greatly contributed to worsening air quality across the US within the last several years. As the climate warms, drought conditions continue to worsen and create a plethora of fuels allowing for increased fire severity. It is largely misunderstood how wildfire smoke may influence near-surface and tropospheric ozone in conjunction with volatile organic compounds (VOCs) via anthropogenic sources in urban areas. Anthropogenic sources, especially nitrous oxides, pose the greatest threat to stratospheric ozone depletion, therefore resulting in higher UV radiation negatively affecting the population. Ozone can also be extremely hazardous for human health near-surface, which is typically enhanced during the summer. The Colorado Front Range will be the most ideal location for this research due to its topography, urban emissions, commonality to wildfires, air trapping against the Rockies and availability of data. Ozonesondes will be examined for the years 2020 and 2021 during the summer months (May-September) while noting where the wildfire smoke is coming from by using archived vertically integrated smoke data. The main goal of this research will be to identify how wildfire smoke affects ozone content throughout the atmosphere on proximal vs. distal smoke days while comparing it to a control of a no-smoke day which still features urban pollution. Not only can identifying the correlation be beneficial for forecasting and the local communities, but also future research in health assessments, climate resilience and better air quality standards.

Optimizing Transductions for Advanced Imaging
Jillian Linder
Dr. Brandon Scott

Expressing fluorescent proteins in live cells is essential for advanced imaging experiments. However, delivering nucleic acids into immune cells using cationic polymers remains challenging. Viral transductions result in a permanent fluorescence that can then be passed on through cell division, but it requires optimizing the transfections to gain a good amount and quality of virus to proceed with transduction. The first step is to have effective nanoparticles for transfection of the packaging cells, which will produce our virus. This process is affected by many factors, including, plasmid ratios, mixing methods, incubation time, cell passage, and confluency. I optimized these variables one at a time and measured the transfection efficiency after 24 hours. The biggest factors were the DNA to reagent ratio and the mixing method. The final formulation ended up with a 90 percent transfection efficiency, which then allows us to optimize the transduction efficiency. Transduction efficiency is affected by cell confluency, virus concentration in the media, and using antiviral response inhibitors. After optimizing all of these, transduction ends up being around 80 to 90 percent. Future research will use these findings to expedite the process of preparing cells for advanced imaging.

Small bugs for big problems: Enriching microbes to degrade plastics

Brianna Hoff, Department of Materials and Metallurgical Engineering & Department of Chemical and Biological Engineering
Dr. Rajesh Sani, Department of Chemical and Biological Engineering

Plastics have revolutionized many industries, but their desirable properties also bring disposal challenges. Importantly, plastics are recalcitrant to biological degradation and have negative impacts on the ecosystems in which they accumulate. This research seeks to develop a methodology to depolymerize and convert plastic waste into a commodity. Currently, plastic-rich samples have been collected from the Rapid City Water Reclamation Facility and Rapid City Landfill and are being enriched to isolate microbes in purity and consortia with the ability to degrade various plastics. Additionally, degradation testing protocols are being refined, and once the microbes are isolated, metatranscriptomic analysis will begin in order to understand what genes are responsible for degradation and how they might be engineered to improve efficiency. In the future, we will create a ‘consortium’ of engineered microbes to valorize plastic waste, and model microbial isolates will be used to transform degradation products into valuable bioproducts and green chemicals.

Bioleaching of Manganese from Sea Nodules

Helen Babits, Department of Chemical and Biological Engineering (CBE)
Dr. Brett Carlson, Department of Materials and Metallurgical Engineering (MET)
Dr. Scott Beeler, Engineering and Mining Experiment Station (EMES)

Bioleaching is a promising alternative method to hydrometallurgical and pyrometallurgical techniques to leach manganese ores. This experiment investigated bioleaching of ferromanganese sea nodules from the Pierre Shale Formation utilizing their indigenous microbial communities. Bioleaching experiments were prepared to test the capacity of microorganisms to leach unroasted nodules, oxidatively roasted nodules, and pure MnO_2 as ore material. Experiments were performed with microcosms by combining ground ore material with mineral salts media (MSM) and 1 mM sodium acetate as a carbon source. The effect of pH on leaching efficiency was tested by adjusting initial pH to 4.01 or 7.15, and either allowing pH to vary during the experiment or adjusting pH weekly to 4.01. Two sets of controls were prepared by either adding propylene oxide (PO) for sterilization to jars with media or adding nodules to distilled water to assess the effects of abiotic processes on manganese leaching in the microcosms. Manganese concentrations were analyzed weekly via ICP-MS to determine the amount of leaching in each microcosm. The greatest amount of Mn leaching was observed in the microcosm with MnO_2, MSM, an initial pH of 4.01, and no weekly pH adjustments. The microcosms with unroasted nodules as their ore material had the least amount of leaching. The microcosms with weekly pH adjustments showed an increase in leaching compared to their unadjusted counterpart when oxidatively roasted nodules were used, however, an opposite trend was observed for microcosms with unroasted nodule or MnO_2. The microcosms that were sterilized with PO showed less leached manganese compared to unsterilized microcosms suggesting that biotic processes are increasing manganese extraction rates. Some of the unsterilized microcosms showed fungus-like growth providing visual evidence of fungal or other microbial activity. Future work may include determining the microbial community structure in the microcosms or altering additional variables to increase leaching rates.

Optimization of the Synthesis of PLA Nanoparticles through Flash-Precipitation

Henry, Brouwer Chemical and Biological Engineering
Timothy Brenza Chemical and Biological Engineering

For the synthesis of Poly-Lactic Acid(PLA) nanoparticles, a method of nano-emulsion is used. This has often raised issue by taking a long time to create as well as inconsistent particle size and quality. In addition to the time limit, the emulsion method uses water which can cause swelling of the particles. By using a method of nanoprecipitation, these issues are removed. Organic solvent and anti-solvent systems are applied instead which reduce the likelihood of the swelling of the particles. By using solvents known to dissolve PLA, the anti-solvent can then be interchanged until the most optimal nanoparticle is achieved. This method has higher reproducibility as well as the potential for scale up for larger batch sizes. The significance of these particles comes from their wide range of uses, but most notably as a drug-delivery method that can help deliver pharmaceuticals that can aid in the fight of various kinds of cancers. The current primary purpose of these particles is to have them fight lung cancers by being delivered via inhaler straight to the lung rather than through injection. This will then avoid the negative side affects often experienced by the solvent that is often used for these therapeutics during treatment.

Effects of surfactants on corn stover biomass under hydrothermal liquefaction

Paiton Mueller*, Karen M. Swindler Department of Chemical and Biological Engineering
Mentor/Advisor: Professor (Dr.) Rajesh Shende, Karen M. Swindler Department of Chemical and Biological Engineering

On an average United States produce ~9.6 billion bushels of corn stover per year. It is imperative to make use of the agriculture residue for bioenergy and bioproducts. Among several conversion technologies, thermochemical conversion technology platform offers several advantages. Hydrothermal liquefaction (HTL) is one such thermochemical technology, which utilizes hot and pressurized water environment to convert an agricultural residue into value added products. Water acts as both solvent and reactant, which helps in breaking down solid biopolymeric structure of a biomass residue. In this study, we investigated HTL of corn stover at 250°C and 800-1000 psi (system autogenous pressure) in presence and absence of the surfactants. Presence of a surfactant is known to change the wettability, reduce the hydrophilicity of particles and increase interfacial surface area, which can influence production of hydrochar as well as liquified products, mainly the carboxylic acids. HTL process resulted in product gas, aqueous biocrude, heavy bio-oil (HBO) and solid char. The biocrude was characterized by TOC analyzer and gas-chromatography mass spectrometry (GC-MS) to understand extent of liquefied carbon and oxygenated hydrocarbons, respectively. Both solid char and HBO were analyzed by the elemental analyzer and HHVs were estimated based on C, H, N and O content. Yield and quality of the products will be presented to understand the effect of surfactants during HTL processing.

Keywords: Biomass, corn stover, hydrothermal liquefaction (HTL), surfactant.

Trihalomethanes in tap water

Author: Rylie N. Andrews, Karen M. Swindler Department of Chemical and Biological Engineering
Contributor: Rabbi Sikder, Department of Mechanical and Civil Engineering
Mentor: Dr. Tao Ye, Department of Civil Engineering

Fresh water and water quality play crucial roles in the maintenance of human health and welfare, and despite it being a renewable resource, there is still limitation and scarcity of true clean drinking water. Despite the installation of modern technology and worldwide efforts for improvement, there is still a lingering concern regarding the transmission of waterborne diseases and other detrimental health effects via drinking water.

Disinfection is a vital step in the insurance of clean and safe drinking water, where chlorination processes are highly favored worldwide. Chlorine disinfection processes assist in the removal of a wide variety of microbial waterborne pathogens, but also simultaneously leads to the formation of other harmful disinfection byproducts (DBPs) such as trihalomethanes, which are genotoxic, carcinogenic, and mutagenic, due to the reaction between chlorine and natural organic matter present in water. Trihalomethanes (THMs) include chloroform, bromodichloromethane, dibromochloromethane, and bromoform, which are currently regulated by EPA. THMs can cause many adverse health effects and enter the human body through inhalation, ingestion, and dermal contact. Inhalation and dermal contact account for 25-60% of total exposure to harmful THMs, since the same water is being processed through both shower heads and faucets within homes.

Measuring the active THMs in tap water samples is the first step into understanding and improving water quality. Methyl tert-butyl ether (MTBE) is used in conjunction with pure water and known concentrations of THMs to create a calibration curve to later test varying samples of unknown THM concentrations in tap water specimens. This is possible by using the practice of liquid-liquid extraction (LLE) to isolate the immiscible phases of water and organic solvent.

Effects of Mixing on Hydrolysis in Anaerobic Digestion

Michael Hickey, Chemical Engineering
Dr. Patrick Gilcrease, Chemical and Biological Engineering

Anaerobic digestion (AD) is a method of generating renewable energy (e.g., methane, hydrogen gas) from organic waste. While most research focuses on maximizing methane gas production, other value-added products may be derived from AD, including volatile fatty acids (VFAs), which can be used as chemical feedstocks or converted to biofuels. This investigation focused on determining the effects of fermenter agitation on VFA production in AD. Results from experiments with four different agitation rates suggested that moderate agitation levels promoted higher VFA production. After 1 day, the highest rate (800 RPM) gave a VFA production rate 67% lower than the moderate rate (70 RPM), suggesting that the hydrolysis step in AD was limited at higher agitation. After 2 days, the lowest agitation level (50 RPM) produced lower VFA levels compared to 70 RPM, with 29% lower VFA production. It is speculated that the formation of solid layers on the tank bottom limit solid surface area available for hydrolysis. Conversely, too high of an agitation rate may inhibit microbes and enzymes from interacting with food waste solids, also limiting hydrolysis. Future research will investigate hydrolysis factors such as enzyme to solid interaction, microbial attachment to solids, and microbial abundance.

Effects of Electroporation and Cold Atmospheric Plasma on FD4 Uptake and Viability in Human Lung Cells

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Mentor: Dr. Prasoon Diwakar, Department of Mechanical Engineering
Mentor: Dr. Timothy Brenza, Karen M. Swindler Department of Chemical and Biological Engineering, Program of Biomedical Engineering

Lung cancer is the leading cause of all cancer deaths, with estimates of 236,740 new cases and 130,180 deaths in the United States for 2022. Available treatments for non-small-cell lung cancer include chemo- and immunotherapies which have undesirable side effects such as pain, flu-like symptoms, fatigue, hair loss, anemia, lymphedema, and appetite loss. Current treatments are also limited by toxicity to non-cancerous cells, drug resistance causing immunity to anti-cancer drugs, and length of treatment time. A goal of developing modern lung cancer treatments is to improve the quality and reduce current side effects. In this study, a novel approach to cancer treatment utilizing membrane electroporation (EP) and administration of cold atmospheric plasma (CAP) is explored. EP delivers electrical pulses to cells which open pores in the cell membrane while CAP generates reactive oxygen and nitrogen species. The goal of this combination treatment is to take advantage of the disrupted oxidant-antioxidant balance of cancerous cells and deliver reactive oxygen species to an apoptotic-inducing state, while causing relatively small damage to healthy cells. Previous studies from Mazandaran University of Medicinal Science observed that CAP administration to B16 melanoma and L929 normal breast tissue cell lines increased cell death in B16 cells and had no significant toxicity in L929 cells.

Human epithelial lung cancer cell line, A549, was used in this study. FITC-dextran 4 (FD4) was delivered to cells at varying time intervals with electroporation at various voltages and pulse durations to investigate A549 pore formation and optimal EP parameters. Cellular uptake of FD4 was quantified by fluorescence intensity. Next, cell viability by mitochondrial activity was evaluated following EP treatment and CAP delivery using MTT assay. Future work includes reactive oxygen species quantification, evaluation of cellular progression to apoptosis by caspase 3 activation, and inflammatory cytokine secretion.

Non-noble cocatalyzed photocatalytic materials for hydrogen generation

Zoe Fickbohm*, Karen M. Swindler Department of Chemical and Biological Engineering

Mentor/Advisor: Professor (Dr.) Rajesh Shende, Karen M. Swindler Department of Chemical and Biological Engineering

Typically, a photocatalyst is sensitized with a noble metal cocatalyst to achieve higher efficiency of hydrogen generation from a water-splitting reaction. As noble metals are expensive and somewhat scarce, research efforts are being made to replace noble metals with non-noble metals while maintaining the photocatalytic efficiency, which is very challenging. This study reviews the use of non-noble metal catalysts for photocatalytic applications. In addition, this study investigates heterojunction semiconductor nanocomposites for photocatalytic hydrogen generation from aqueous solutions containing sacrificial agents (e.g., alcohols, sugars). In particular, ZnO/TiO_2 heterojunction nanocomposite was evaluated for the photocatalytic hydrogen generation from an aqueous solution containing ethanol as a sacrificial agent. The ZnO/TiO_2 nanocomposite was co-catalyzed with non-noble metals and their efficiency towards photocatalytic hydrogen generation was evaluated. The surface area and other characteristics of the nanocomposites were analyzed by using BET surface area analysis, x-ray diffraction, and zeta potential. A review summary of non-noble cocatalysts for photocatalytic applications and few experimental findings on hydrogen generation will be presented.

Keywords: photocatalysis, hydrogen, sacrificial agents, noble/non-noble, heterojunction nanocomposites

Flexible Pressure Sensors using Piezoresistive Sponges

Author: Phillip Hauck
Mentor: Dr. Zhengato Zhu

Within the past decade the use of wearable electronics has exploded. This has led to an increase demand of soft, flexible electronics. One major issue with this is that currently, most wearable technology uses hard rigid structures or have wires that are not flexible. One solution to this is to use a material that can be both flexible and conductive. Using a commercially available polymer, carbon, and organic solvents we were able to make a dispersion that dried into a polymer that could be bent, stretched, and compressed while still being able to conduct electricity. The conductive polymer has been paired with a treated sponge that has piezoresistive properties to create a pressure sensor. The goal of this research is to embed these sensors within fabrics to create a real time motion tracking suit.

Victoria Tucker
Dr. Kelsey Gilcrease

Soil Productivity and Phospholipid Fatty Acid (PLFA) Microbial Community Analysis Performed on Different South Dakota Ecoregions

South Dakota terrain provides a unique approach to understanding different characteristics of soil. The areas of study for this research have been, Skyline Wilderness Area and Rocky Point Recreational Area in Belle Fourche. Both locations are ecologically diverse in terms of vegetation composition, land use, and inhabiting wildlife. When considering soil for agricultural use, soil productivity is one of the main contributing factors. Soil productivity is the capacity of the soil in its baseline environment, favorable for plant growth. Five different experiments have been conducted to observe and measure soil properties of the different soil samples obtained such as water-holding capacity, ion-exchange capacity, macronutrient content, particle distribution, and permeability. The nitrogen, phosphorus, potassium, and pH levels were tested for each soil sample during the seasons showing staggering differences between seasons for the Belle Fourche location. Although, Skyline Wilderness area samples have similar results showing adequate levels of potassium in the Spring and Fall, as well as a deficiency in the nitrogen. In addition, a Phospholipid Fatty Acid (PLFA) microbial community analysis was completed to determine the different functional group biomass and diversity in the soil. The PLFA analysis determined there to be a high number of total bacteria and phospholipid fatty acids in the soil collected at both Skyline Drive and Belle Fourche. In comparison, the Skyline Wilderness area had a variety of fungi including *Arbuscular Mycorrhizal, Saprophytes,* and *Protozoa,* whereas the Belle Fourche sample did not have any fungi. These differences can explain key concepts to understanding vital growing mechanisms such as determining the need for fertilizer or irrigation. Furthermore, expanding these comparisons throughout the different seasons allow for a better understanding how the soil response to varying growing conditions.

Microplastics in Waterways

Brandon Thomas CEE

Dr. Lingwall CEE

There is a lot of microplastics in our water sources that are consumed by humans. On average, a human will consume four credit cards worth of microplastics a year. The research being performed is to locate and prevent the sources of the plastics from reaching the water sources. There were eight different locations in South Dakota used to gather the water samples. Each location had an upstream and a downstream sample. The samples were taken using a net that dragged against the bottom of the waterway. The samples were first analyzed to find the number of plastics in the water source. The samples were prepared by filtering the large particles out of the water and then using hydrogen peroxide to eliminate the organic material. Samples were dyed with Nile Red and then imaged under a fluorescence microscope. A picture of each sample under the fluorescence was collected to find how many microplastics exist at each location. Another analysis was done to determine what kind of plastic is present in the water. This analysis was done using a Fourier Transform spectrometer. The samples of plastic spectra can then be compared to a library of plastic spectra to get an idea of where the plastic is coming from.

Life Cycle Environmental Assessment of Metal Extraction from Perovskite Photovoltaics

Emma, McCalmont Civil and Environmental Engineering
Ilke, Celik Civil and Environmental Engineering

Perovskite photovoltaic cells (PVs) have created a significant interest in the way we are able to create renewable energy over the last few years due to their low-cost and high-power conversion efficiencies. However, the impact due to the materials selected, could be more environmentally friendly if these materials could be reused. To protect the environment, we must learn how to reuse our resources more sustainably. In this study, we focused on the environmental life cycle assessment (LCA) of recovering metals such as lead, copper, gold, nickel, and silver from the end-of-life perovskite PVs. We assessed the recovered metal efficiencies in the reusing process, determining if recovering and recycling the metals is more sustainable than extracting raw materials, and finding ways we can optimize the recovery of these materials. The recovery process will include separating the solar cell in layers to extract the metals from absorber, hole transport, and back contact layers.

Use of Activated Carbon for Adsorption of Iodinated X-Ray Contrast Media

Author: Katie Magni

Mentor: Dr. Tao Ye

Abstract

Iodinated X-ray Contrast Media (ICM) is an intravenous radiocontrast agent containing iodine, which is widely used for radiological visualization of human tissues and cardiovascular system in hospitals. These chemicals biodegrade poorly and therefore cannot be effectively removed in conventional wastewater treatment plants, resulting in their presence in drinking water. In this study, we aim to develop advanced adsorbents and focus on the adsorption of diatrizoate because diatrizoate (1) is a representative ionic ICM and has been frequently detected in wastewater treatment plant effluent-receiving water bodies and in drinking water sources, (2) is one of the recalcitrant ICM whose removal in wastewater treatment and drinking water is limited, and (3) can act as an iodine source in drinking water disinfection and lead to the formation of toxic iodinated disinfection byproducts.

Adsorption by activated carbon presents an effective option to remove certain organics from our drinking water and wastewater treatment plants.

Activated carbon can remove toxic pollutants during water treatment by adsorption. This study focuses on activated carbon because it is environmentally friendly and easy to produce. Activated carbon adsorbents have shown adsorption capacity for agrichemicals, pharmaceuticals and personal care products, and endocrine disrupting compounds.

Performance of Fiber-Reinforced Syntactic Foams

Liam Slavin, Civil and Environmental Engineering
Dr. Marc Robinson, Civil and Environmental Engineering

Syntactic foams consisting of hollow glass spheres in an epoxy matrix are ideal for many structural and/or thermal applications in the marine, aerospace, and automotive industries. Previous researchers have shown that small amounts of additives, such as carbon nano-tubes or short fibers, can enhance the mechanical properties of syntactic foams. The objective of this research is to investigate the effects of adding small amounts of short carbon fibers to syntactic foams which are highly loaded with hollow glass spheres. The research seeks to determine the ratio of hollow glass spheres, epoxy matrix, and carbon fibers to optimize the mechanical properties of the foam. Furthermore, the study investigates manual methods of steering the fibers to enhance mechanical properties in a preferred direction. Three different syntactic foam types are considered in this study; specimens without fibers, specimens with randomly oriented fibers, and specimens with fiber alignment. Compressions testing and three-point bending tests are conducted to quantify the mechanical properties of each specimen type. Specimens were tested under a load cell. Research is still ongoing into short fiber-reinforced syntactic fibers.

Samantha Overend

Mengistu Geza Nisrani

Research Symposium Abstract

3/4/2022

Quantifying Biofilm Growth Impacts on Wastewater Infiltration Systems, Modified with 2D Materials

In the United States, about 21 million households use septic systems for wastewater treatment opposed to the modern sewer systems. These septic systems are prone to bio-clogging caused by microbial biomasses, reducing the hydraulic conductivity and porosity in the system, leading to failure. Using two-dimensional modified soil media, the conducted experiment aims to change the soil infiltration rate and observe the biofilm growth. High, medium, and low BOD levels are input into the soil to then measure the hydraulic conductivity of the soil. Nitrate concentrations are also measured to actively observe the biofilm growth. The tested soil media is local soil, biochar, a biochar control, and a mix of soil and biochar. In previous research, similar soil medias were used to evaluate the transport and retention of graphene oxide. It was found that sand retained the least amount of graphene oxide while biochar and a biochar-nZVI mix had higher retention. Throughout the duration of this experiment, it was observed that biochar performed the best with high BOD levels, biochar and the mix performed the best with medium BOD levels, and all soil medias had similar results with low BOD levels. More specifically, the results of the experiment showed that the biochar control media with high BOD had the highest drainage on average, and the biochar media with medium and low BOD had the lowest drainage on average. The biochar control with medium BOD had the highest nitrate concentration on average while the biochar media with low BOD had the lowest nitrate concentrations on average.

Title: Distinguishing geometric changes due to bed and bank processes in a 3-mile reach of Rapid Creek

Researcher Name: Coleton Deitz

Advisor Name: Dr. David Waterman

Rapid Creek has undergone many changes during Rapid City's history, both in sediment and flow regime. These adjustments have continued to modify the channel and its configuration significantly over the past 21 years. Therefore, the purpose of this research is to analyze the changes that have occurred in the Rapid Creek channel. In a study completed last year, a 3-mile reach of Rapid Creek, originally surveyed in 2000, was repeat surveyed in 2020/2021 at approximately 150 stations. Using these cross sections, the team looked to evaluate the repeat surveys and the significance of the vertical bed aggradation and degradation versus lateral bank erosion and accretion. The bed and bank areas were evaluated separately at each station and were distinguished using a unique method based on the hydraulic depth relative to the top of bank of the 2000 cross sections. After identifying the elevation at which the flow exceeds the top of bank, the resulting hydraulic depth was calculated. The hydraulic depth was subtracted from the bankfull to obtain the elevation in which the bed and bank are differentiated. Changes below this elevation were attributed to bed processes, whereas changes above this elevation were ascribed to bank erosion and accretion. Specific attention in this study was given to determine if the bank accretion and erosion were acting in equilibrium. The preliminary results of this research suggests the vertical component of the Rapid Creek channel has remained approximately in balance while the bank erosion has exceeded the bank accretion. These results are significant in beginning to understand how physically constrained urban streams, such as Rapid Creek, adjust their geometry to changing sediment and flow regimes. In the end, this research seeks to provide information in predicting changes to urban channel geometry with varying input parameters.

DJ Gonzalez
March 4, 2022
Advisor: Dr. Celik

Techno-Economic Assessment of Metal Extraction from Perovskite Photovoltaics

Abstract

The solar energy sector has experienced recent growth in using perovskite photovoltaic solar cells (PVSCs) due to the increased power conversion and reduced costs associated with the cells. We conducted a techno-economic assessment on PVSCs which compared the economic valuation of virgin material extraction to produce a new cell, and the recycling of metals from expired PVSCs for reuse. The research is aimed to determine the minimum sustainable price (MSP) for a PVSCs needed to allow its reuse in place of extracting more virgin materials to produce new cells. Levelized cost of energy metrics were used for a standard perovskite module produced in the United States to develop the MSP for the reuse process. The back-contact, electron transport layer/ hole-transport layer, and absorber layer contain metals such as lead, aluminum, gold, and silver that can be reclaimed. Recycling processes and virgin extraction for these specified metals were analyzed using GaBi modeling software for assessing the environmental performance of these processes.

Sulfate Attack Resistance Capability of Marginal and Unconventional Source Fly Ashes

Duncan Pilling, Civil and Environmental Engineering

Jetsun Thinley, Prannoy Suraneni, Douglas Hooton, Christopher Shearer, Civil and Environmental Engineering

Sulfate attack is a deleterious chemical reaction that induces concrete deterioration. Sulfate attack occurs when sulfates react with compounds in the cement paste (i.e., monosulfate, portlandite, and C-S-H gel) to form expansive products (i.e., gypsum, thaumasite, and delayed ettringite formation) causing cracking, strength loss, and disintegration of the concrete. Mortar bar test MBT (ASTM C1012) is used to assess the sulfate attack resistance capability of marginal and unconventional source fly ashes. For this test, mortar prism bars are made and submerged in sodium sulfate (Na_2SO_4) solution over a temporal range of 18 months. Length change or expansion measurements of the bars are made periodically at 1-,2-,3-,4-,8-,13-,15-,16-,24-,36-,48-,60-, and 72-week ages. Differential thermogravimetric analysis (DTG) for portlandite (CH) consumption is also conducted at 48- and 72-weeks on representative samples to track ingress of sulfate into the specimens and to quantify reactivity. Results show that mortar bars with high calcium oxide (CaO > 18%) contents exhibit the highest expansions or most susceptibility to sulfate attack out of any marginal and unconventional fly ashes used. Additionally, results also show reactivity and sulfate attack resistance capability of these emerging fly ash sources comparable to standard fly ashes depending on their chemical compositions.

Biodegradation of Per- and polyfluoroalkyl substances (PFAS) by Microbiome Enriched from International Space Station

Josie Tornberg[1], Obulisamy Parthiba Karthikeyan[1], Md Mahmudul Hasan[1] , Anna Simpson[2], Nitin Singh[2], Venkateswaran Kasthuri[2], Gadhamshetty Venkataramana[1,3]

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Abstract: Per- and polyfluoroalkyl substances (PFAS) are synthetic fluorinated compounds that are widely used in firefighting foams, cook wares, cosmetics and other packaging industries since 1940. These compounds are resistant to degradation, and accumulate in the food chain, causing serious threats to public health and the environment. Recently, physiochemical methods have been developed to treat PFAS contaminations; however, these methods leave residual wastes to handle and/or are very expensive. Therefore, developing an alternative, cost-effective and eco-friendly technology to remove PFAS is important. Here, we attempt to screen and characterize the microbial community (i.e., microbiome) from the International Space Station (ISS) for their ability to degrade PFAS, since they were shown promising results with the dehalogenation of compound such as di-chloromethane under lab conditions and more resilient towards environmental stress (e.g., UV exposure, low-gravity, temperature, etc.). In this research, the ISS-microbiome was enriched using methanol as a carbon source in ammonium mineral salt medium under 150 rpm at 30ºC. At the exponential growth phase, the cultures were spiked with two PFAS chemicals for a final concentration of 1 mg/L, as follows: (i) test 1 – perfluorooctanoic acid (PFOA) only; (ii) test 2 – perfluorooctane sulfonic acid (PFOS) only; (iii) test 3- mixture of PFOA and PFOS. The microbial interactions with the two different PFA S compounds and their assimilation rates were measured and compared between the test conditions. The results were found to be promising, while we study the bio-electrochemical process to further improve the process efficiency and degradation kinetics. Using TiO2 (anode) and Stainless steel (cathode) as an electrode, the bio-electrochemical degradation of PFAS was found to be multi-fold higher than conventional biodegradation systems. The study outcome will pave the way to develop a new bio-remediation technology for removing PFAS contamination from the environment.

Generative Data Obfuscation!

Peyton, Krahulik Computer Science and Mathematics
Kyle Caudle Mathematics

Real data often contains proprietary information, or in the case of military applications, the data may actually, be classified. The goal of this research is to investigate generative models and maps that will create a distribution that resembles the population with sensitive information that has been masked. In this research, a generative adversarial network (GAN) is used to generate data from the masked distribution that is similar to the population distribution while obscuring sensitive information. Through computer experiments, we show that if we have a large sample from the population and a relatively small sample of data with masked information, we can create fake instances from the masked distribution. We measure success by comparing the distance between the masked distribution and the population distribution.

SD MINES 2022 Research Symposium – Jackson Cates

Dr. Hoover and Dr. Caudle

Forecasting Dynamic Graphs via Transform-Based Tensor Autoregression

In the era of big data, there is an increasing demand for new methods for analyzing and forecasting dynamic graphs, a graph that changes over time. This presents many applications for forecasting such as IT networks, social networks, and criminal networks. The current research aims to accomplish these goals through the combination of time-series modeling and multilinear algebraic systems. We expand previous autoregressive techniques to forecast 2-dimensional data, aptly named the L-Transform Tensor autoregressive (L-TAR for short). We achieve statistical independence between the columns of the observations through invertible discrete linear transforms, enabling a divide and conquer approach. We present an experimental validation of the proposed methods with a focus on dynamic graphs, where we show improvement in forecasting and computational speed.

Inferred growth patterns from textural and petrographic analysis of Rushmore Cave speleothems

Sawyer Hagen, Geology and Geological Engineering

Dr. Sarah Keenan, Geology and Geological Engineering

Abstract:

Cave formations, known as speleothems, develop as secondary mineral precipitates in karst environments. Though internal cave conditions remain fairly constant, seasonal climate conditions can cause alterations in average development found in speleothems. To understand the development of speleothems from Rushmore Cave, South Dakota, four stalactites were thin sectioned to petrographically analyze the minerals and fabrics present in this system. Initial observations indicate the crystal habit of these stalactites are columnar with inclusions and fracture-filling calcite. These fabrics not only indicate the speleothems had a constant water source aiding in their development, even during seasonal fluctuations to climate, but likely underwent secondary development and dissolution, resulting in different fabrics in each speleothem. Secondary development is further inferred from potential growth breaks where siliciclastic clays are included within large crystals in the speleothems. Though some growth conditions can be inferred from these samples, further research into the hydrogeology associated with their consistent water source and absolute dating of the speleothems could be used to better understand cave formations and their growth.

Probabilistic Sensitivity Analysis in Cost-Effectiveness Models to Identify Cost Variation in Product Manufacturing

Presenter: Jamie Pazour, Industrial Engineering and Engineering Management
Advisor/Mentor: Hyeong Suk Na, Industrial Engineering and Engineering Management

The growing interest and recent breakthroughs in the manufacturing standard such as AS6500A, developed by the SAE G-23 Manufacturing Management Committee, and the requirements in the U.S. Department of Defense have actively contributed to an increase in research and development of new methods to investigate the manufacturing and production management system. Accordingly, in this study, a statistical analysis tool is developed to identify the cost variation in product manufacturing based on the cost-effectiveness analysis (CEA) and the cost sensitivity analysis (CSA). CEA is the method to compare the costs and their effectiveness of various alternatives while CSA allows to identify the underlying variation of costs caused by different mature levels of products. In this study, three cost categories are addressed: labor, material, and others. Labor costs are compiled from the time put into the production of goods then assigned a price per labor hour. Material costs are the raw material costs from vendors. Other costs are reserved for all costs that do not fall within labor or material. The result of the proposed analysis model can display the production area where there is the largest variation in cost. Compared to the current cost variations, our strategy suggested by the proposed analysis model has lower variation and higher effects in reducing the uncertainty of cost variations. We believe that this cost analysis study can serve as a useful tool for projecting profit more accurately and estimating the costs of the final product, resulting in minimized financial risk and increased operating profit.

Mechanochemistry for Creation of Functional Surface Treatments

Jennifer Johnson & Material and Metallurgical Engineering Department
Dr. Jon Kellar, Material and Metallurgical Engineering Department
Dr. William Cross, Material and Metallurgical Engineering Department
Dr. Albert Romkes, Mechanical Engineering Department

This research explores mechanochemistry to create functional surface treatments. A planetary centrifugal mixer was used to modify fluorite (CaF2) and BAM particles (Aluminum Magnesium Boride, Al3Mg3B56) surfaces. BAM and fluorite particles were treated with oleic acid to increase hydrophobicity. The particles were evaluated using Fourier transform infrared spectroscopy (FTIR) and contact angle goniometry to determine the effectiveness of mixing and possible reactivity. Contact angle measurements revealed that the fluorite particles turned from hydrophilic to hydrophobic with a contact angle of 150° when treated with low amounts of oleic acid. FTIR spectroscopy revealed a chemisorbed calcium oleate on fluorite while oleic acid with boric acid was present for BAM. The mechanochemical process is successful in transforming surface properties without the use of water or heat and holds promise for surface engineering in areas of mineral processing, and additive manufacturing.

Method Optimization for Accurate and Precise Values of Nucleation and Plating Potentials in Metal Electrodeposition.

Trystan L. Duck – Department of Materials and Metallurgical Engineering

Peter A. Adcock – Department of Chemistry, Biology, and Health Sciences

Prior attempts to measure both nucleation and plating potential for industry technology from an electrochemical scan with controlled current identified IR compensation as crucial to obtaining robust data. The experimental procedure relies on knowledge of the uncompensated resistance (R_u) between the reference and working electrodes. The main types of IR compensation are post-scan processing, positive feedback, and current interrupt methods. Adcock typically used the post-scan processing method of IR compensation but believes that current interrupt may be the key to solving the issue of minimizing the uncertainty in measured plating potential values. A current interrupt method of IR compensation may offer the possibility of dynamic measurement of R_u during a scan. When this resistance has been compensated correctly, nucleation and plating potential data sets will be more valuable for prediction of deposit morphology and possibly control. Aside from primary production of metals like zinc, nickel, and copper, these methods may also be useful for control of electroplating processes and secondary metal recycling and recovery.

Exploring Covariance within Third Order Tensors

Jordan Baumeister, Applied and Computational Mathematics
Dr. Kyle Caudle (MATH), Dr. Randy Hoover (CSE), Dr. Karen Braman (MATH)

With a massive influx of new methods for analyzing, modeling, and forecasting 2-dimensional observational data, methods for indicating relationships between observations need to be developed. This research aims to accomplish this by finding a way to compute the covariance for third order tensors. Transforming the multilinear data through invertible discrete linear transformations enables statistical independence between observations. Thus, we explore computing the covariance for each frontal slice using traditional matrix methods. Once a tensor-tensor covariance is computed, then exploration into algorithms such as partial autocorrelation, expectation maximization, and maximum likelihood estimators can be applied to forecasting problems. Experimental evaluation is presented using statistically independent tensors, highly correlated tensors, and random tensors.

Solving Composition Differential Equations Using Taylor Series

Raiza Soares, Department of Mathematics
Dr. Travis Kowalski, Department of Mathematics

General ordinary differential equations (ODE) of the form

$$\begin{cases} y^{(n)} = f(x, y,\ y', y''..) \\ \qquad y(0) = a \end{cases}$$

are the backbone of several engineering applications, including Newtonian mechanics, simple harmonic oscillating systems, and complex electronic circuits. There is a significant body of theory on ODEs, and several techniques have been identified for solving them, such as separation of variables, variation of parameters, eigenfunction expansion, and so on.

A generalization of differential equations are composition differential equations (CDE), which have the form

$$\begin{cases} y^{(n)}(g(x)) = f(x,\ y,\ y',\ y''..) \\ \qquad y(0) = a \end{cases}.$$

CDEs often arise in complex analysis and have applications in several complex variables and complex number theory. Unlike ODEs, there remains a significant lack of literature on the solutions of CDEs.

This research aims to analyze formal power series solutions to a general class of first-order CDEs using Taylor series, and to provide insight into the structure of these solutions. The solutions obtained by the Taylor series technique are shown to be unique using an inductive approach. We also address the convergence of CDE solutions, given examples of divergent solutions and disproving the analog of the Cauchy-Kovalevskaya Theorem, showing convergence is a much more subtle feature for CDE than it is for ODE.

Future work will involve collecting more data on the bounds of these solutions and putting together a complete proof showing convergence or divergence of solutions.

Advanced Soft Magnetic Materials for Electrified Propulsion Systems

Elijah Meakins, Mechanical Engineering
Dr. Nickolaus Bruno, Mechanical Engineering

The scientific community is currently seeking to design efficient, high power filter inductors for circuitry in electrified propulsion systems. Advanced soft magnetic materials, like FINEMET alloys, can provide the necessary power transfer solutions. These alloys are produced as long ribbons using a planar casting system and wound into toroids for filter cores. At South Dakota Mines, these FINEMT alloys are currently studied in collaboration with NASA Glenn Research Center in a project entitled "Advanced Soft Magnetic Materials for Electrified Propulsion Systems". Various compositions of as-cast amorphous FINEMET ribbon are stress-annealed by pulling the ribbon in tension while heating the ribbon above its recrystallization temperature for several seconds to improve the magnetic properties of the core. Parameters such as the amount of tension, temperature, and length of heating during stress-annealing are varied as well to study the resulting magnetic and mechanical properties as well. A custom stress-annealing machine was built at South Dakota Mines. The machine uses a drive motor attached to a large aluminum wheel to continuously spool stress-annealed ribbon onto the wheel. The ribbon is held in tension using a magnetic brake and is heated while being spooled using an electric furnace. The magnetic properties of the stress-annealed ribbons can then be studied using a magnetic loop measurement system. The magnetic loop measurement system employs a small circuit, function generator, and power supply to produce an applied field, H, in an inductor core through copper windings, and another set of copper windings as a pickup coil to measure the resulting induction, B, in stress-annealed ribbon. A custom LabView VI (virtual instrument) is used to automate the measurement process and post-process raw data resulting in BH loops. These loops can be studied to determine the magnetic core losses and the relative magnetic permeability of the processed FINEMET alloys.

Producibility and Future Artifacts: Students Considering Manufacturing Lightsabers and Magic Wands

By: Dr. Micah Lande and Jarod White

The activity of designing for the future provides interesting challenges and raises considerations for what might be feasible, desirable, or viable as a design. It may be that one imagines a fantastical world 50 years from now of prosperity or a dystopian setting with environmental or societal worries.

Undergraduate engineering students in a design for manufacturing course applied learned design methods in a final project. The project goal was to design or redesign amorphous concepts, prototypes, or future products. Artifacts from the future were of students' own imagination or borrowed from pop culture references. One example artifact is the lightsaber of Star Wars canon; this rendered a useful discussion among the project about tradeoffs of resources or labor. Additional examples include yet-to-be realized future products like personal droids, space elevators, etc. Such fictional scenarios gave some levity, intrinsic motivation, and engagement for the students.

The design world focuses on feasibility, viability, and desirability. In a manufacturing context, there is focus on the concepts of time, scope, and cost, and being able to optimize one, constrain the other, and leave the third to be.

The goal of this paper is to explore the design task within this course. And to use the future-orientation of the design project to make insights about the tradeoffs between the designs imagined and the manufacturing and producibility of the future artifacts.

Initial categorization and qualitative pattern finding has led to attempting to find pattern(s) between the results of a future based product design project and the viability, feasibility, and desirability of the design. This has implications for how we might 1) understand how students design the future, and 2) how we might bring this forward in a design for manufacturing context.

Custom designed compression platens for cold-temperature thermomechanical testing of shape memory alloys

Armand Lannerd, Mechanical Engineering
Dr. Nickolaus Bruno, Mechanical Engineering

Preferred presentation type: Oral

Today, many active materials that have unique mechanical, magnetic, or electric responses to a variety of stimuli are currently being studied. One class of materials that has attracted particular interest are shape memory alloys (SMAs). Within the realm of SMAs, some of their most notable behaviors include the shape memory effect and superelasticity. The shape memory effect is defined by the ability of the SMA to regain its initial shape following apparent plastic deformation by increasing its temperature above a critical threshold. Likewise, the superelastic effect is the ability of the SMA to exhibit multiple regions of (recoverable) elasticity during uniaxial mechanical testing, with a remarkable ability to exhibit up to around 6% reversible strain response. These remarkable properties are largely due to a solid-solid phase transition from a high temperature austenite phase to a low temperature martensite phase as conditions like temperature and uniaxial stress are varied. Thus, the ability to conduct constant pressure (isobaric) or constant temperature (isothermal) testing is crucial for the investigation of SMA materials. In this work, custom compression platens and their associated setup were designed and made for this purpose. Their key features and major design points will be described, in addition to some initial data demonstrating superelasticity in a couple of already tested SMA samples. Lastly, the future tests and goals for the use of this setup to investigate superelasticity in FeMnGa SMAs will be presented.

Earlier Experiences in Creativity and Design as
Antecedents to Success in and Comfort with Design in College

Madison Goldsmith - Dr. Lande

Design learning experiences often revolve around delivering technical solutions in engineering coursework or co-curricular activities. Balancing technical proficiencies within a team-based, open-ended design challenge makes it harder to realize creative solutions that may not fit within the resources given. This can be ironic given engineering presented as areas of study and majors for creative problem solvers. In many ways students may view their coursework, as being without appreciation for creativity. Students may have an accumulation of prior creative experiences in K-12 yet see that dwindle in their college studies.

This project examines engineering curricula, to identify opportunities for creativity present in and out of the classroom. Abductive thinking and reasoning lessen as technical know-how is emphasized. We characterize this assumption with analysis of student learning goals across coursework in undergraduate engineering majors.

We use qualitative semi-structured, critical incident interviews of undergraduate engineering students. Students are asked to reflect on previous educational experiences, past opportunities for creative work, and perceptions of the role of creativity in their preparation before college and role within their majors. They are asked about the utility and purpose of creativity in future endeavors to allow the research team to explore opportunities or gaps of our curriculum. Insight into undergraduates previous schooling, their ability to perform using creative thought processes now, and the use of creative examples from previous years of education will provide a basis. This information will help to determine what is an advantage and a detriment towards creative thinking and design education.

The objectives are to better understand student prior and ongoing experiences with creative thinking, self-efficacy with creativity in relation to design work, how systems of education have helped support or avoid creativity, and how design might be highlighted as an opportunity to express creativity within the constraints of engineering education.

Using ultra-clean conditions of the MAJORANA DEMONSTRATOR to measure unobserved ^{180m}Ta decay

Samuel Schleich, Physics

Cabot-Ann Christofferson, Chemistry

The nuclear isomer ^{180m}Ta has yet to have an observed decay as it has an expected half-life of over 10^{15} years—which is much longer than the current age of the Universe. The conditions necessary to detect such a rare event exist only in ultra-clean, radio-silent detectors, such as the MAJORANA DEMONSTRATOR. The uniqueness of this isomer arises from the nature of its stability: the isomeric state of ^{180m}Ta is more stable than its ground state. By recording the decay of ^{180m}Ta, more accurate nuclear models can be created. Furthermore, if recorded, constraints can be applied to certain dark matter candidates, as some are expected to couple to the nucleus of atoms. This coupling would cause a forced deexcitation from the isomer to the ground state. If this deexcitation were not to be observed, better constraints could be applied to current dark matter models.

In the current attempt to detect the ^{180m}Ta decay, 15 kg of high-purity Ta disks will be placed within the germanium array at the core of the MAJORANA DEMONSTRATOR. They will remain there for one year while data is collected; the decay of ^{180m}Ta can be identified by the energy of the gamma rays emitted. The Ta disks will be arranged within seven different strings, five of them containing 34 disks and the other two containing 12 disks. The former arrangement will be divided into four stacks of disks, each separated by a germanium detector, while the latter will be divided into three stacks of disks also each separated by a germanium detector. Ultra-pure electroformed copper plating will act as the support structure of these strings.

Time Stability Study and Derived Precision Correction for the "Rabbit" Germanium Detector

Serenity Engel, Department of Physics

Dr. Juergen Reichenbacher, Department of Physics

The Deep Underground Neutrino Experiment (DUNE) is the largest particle physics experiment in the country, taking place between the Sanford Underground Research Facility and the Fermi National Accelerator Lab. Excavation is currently underway 4850 feet underground for this highly sensitive experiment, which includes a detector buried in two extensive caverns which contribute gamma and neutron radiation. This background radiation can hinder the measurement of rare neutrino interactions, making it essential to assay the rock, shotcrete, and materials used to create the detector to understand its interference and make strategic decisions about which materials should be used for DUNE.

The radioactive assays of these materials are performed by gamma-ray spectroscopy employing a broad energy germanium detector dubbed "Rabbit" located at the SD Mines campus. The excavation for DUNE is set to take until 2024, allowing time for a detailed examination of the germanium detector's precision and gain change over time to ensure the best data is being used and the detector has the most efficient turnaround time of assays to cycle through hundreds of samples in the future.

Compiling data from the past two years, assessment of the peak of electron-positron annihilation and the tracer K-40 peak further proved that there is a need for a small signal correction for time-dependent electronic drift, avoiding the need for continuous adjustment in the analytic macros in the following years. Existing materials samples have been re-examined to create this correction function, which will be implemented into a "master macro" to simplify the uninterrupted operation that will come with the completion of DUNE's excavation and detector installation process. The time stability study and derived precision correction will be vital to understanding and controlling radioactive backgrounds for the success of DUNE.

Radon Emanation Analysis

Seth Bendigo, Physics
Dr. Richard Schnee, Physics

Highly sensitive experiments, such as the LZ dark matter experiment, have backgrounds due to radon emanating out of materials. The radon emanation system at SD Mines is used to reduce radon background by measuring the emanation rate of radon out of these materials. If the emanation rate is too high, those objects can be replaced. Analysis of the emanation rate requires corrections when the detector's gain shifts, a log-likelihood analysis, and an understanding of background rates. Due to statistical uncertainty, the background for the system and its time dependence cannot be determined accurately from a single background run. However, co-adding multiple background runs together provides sufficient statistics. I will summarize my contributions to the Python code that performs this analysis, show how the co-added data constrains the background of the radon emanation system, and discuss the implications.

Development and Use of a System to Improve Radon-Reduction Methods

Name: Marcus Heintz, Department of Physics
Mentor: Dr. Richard Schnee and Joseph Street, Department of Physics

Experiments such as the Super Cryogenic Dark Matter Search (SuperCDMS) have seen a significant background caused by radon daughter decays which look like dark matter interactions. Radon present during the assembly process eventually creates this background and must therefore be reduced. Here at Mines, we have a system designed to replicate radon-reduction methods through carbon adsorption and allows us to isolate and manipulate variables. Through our work the system measures pressure, temperature, relative humidity, flow, and radon concentration to allow us to test our current model. I will describe tests of our model including temperature dependence and the dependence of radon diffusion on flow. Validation of our model will enable us to better understand and improve this radon-reduction method.

Feasibility Study For Neutrino-Argon Interaction Measurement In ANNIE

Noah Everett, Physics and Mathematics
Dr. Jingbo Wang, Physics

The Deep Underground Neutrino Experiment (DUNE) aims to measure the neutrino CP-violating phase and determine the mass ordering, using the Liquid Argon Time Projection Chamber (LArTPC) technology. These measurements rely on the precise reconstruction of the incoming neutrino energy. However, the nuclear effects on neutrino-nucleus interactions are not well understood in argon, which could affect the precision of the experiment. Of particular interest, the measurement of the number of final-state neutrons from neutrino interactions can help constrain the theoretical neutrino-nucleus interaction models. Unfortunately, neutrons are quite elusive in most current large neutrinos detectors as both their interaction cross section and signature are faint. Hence a small-scale experiment capable of measuring the final-state neutrons in a well-known neutrino beam is needed. To study neutrino-argon interactions, we propose to use the currently existing Accelerator Neutrino Neutron Interaction Experiment (ANNIE) at the Booster Neutrino Beam (BNB) at Fermilab. ANNIE is currently a water-based neutrino detector but can be modified to study neutrino-argon interactions such as those in DUNE. A feasible experimental strategy is to deploy a liquid argon target at ANNIE's fiducial volume location. This idea was never investigated before, and I am currently working on a feasibility study using the neutrino interaction generator called GENIE. In this talk, I will report on the preliminary results and overlook the future of work.

Assessing nitrate uptake in the large, transboundary Kootenai River

Mori Staar, Program of Atmospheric and Environmental Science

Lisa Kunza, Department of Chemistry and Applied Biological Sciences and Program of Atmospheric and Environmental Sciences

The Kootenai River flows from southeastern British Columbia into Montana through eastern Idaho and back into northern British Columbia. Mining activity in the river basin has increased nitrogen concentration in the water. In recent years, the river has had excessive nitrogen loading, but phosphorous availability remains low which may lead to negative effects on biota. The nitrogen in the river is primarily in the form of nitrate, and the biota utilize nitrate via assimilation and denitrification. Nitrate uptake is an ecosystem function that is beneficial and helps minimize nitrate transport downstream. Unlike most nitrate uptake studies via nutrient addition to small streams; this project focuses on the nitrate depletion in a large river ecosystem. The change in nitrate uptake may also vary during the day as compared to the night due to changes in rates nitrate uptake rates and denitrification. Our objectives include: 1) observe different river reaches for nitrate uptake and examine uptake changes compared to locations with different river management practices, 2) how nitrate uptake varies in a continuous cycle throughout day and night and 3) speculate how excessive nitrate loading will affect the lower trophic levels in the food web. SUNA nitrate loggers will be placed in 2-3 locations in the river. These probes will read nitrate concentration in 10-min intervals continuously throughout day and night. This data will be analyzed using R to look at the change of nitrate uptake over time. This project will evaluate the effects of excessive nitrate in rivers and how they affect the overall biota, including the important function of nitrate uptake.

Examining seasonal impoundment salinity and salt transport influences on water and rangeland health, Northwest South Dakota

Patrick Kozak, Program of Atmospheric and Environmental Sciences
Lisa Kunza, Department of Chemistry, Biology, and Health Sciences and Program of Atmospheric and Environmental Sciences

Salinization of soil and water resources is an emerging issue globally and in the western United States. Butte and Harding counties in northwestern South Dakota have over 10,000 identified impoundments as primary water sources that may be influenced by seasonal impoundment salinity and upgradient soil conductivity. Seasonal impoundment conductivity changes may also affect regional soil salinity transport and concentration, thereby endangering rangeland health, water quality, and riparian areas used by livestock and wildlife. To evaluate the spatial variability of impoundment and soil salinity in 2019, we selected 138 impoundments across 12 HUC-12 subwatersheds. We measured impoundment conductivity, soil conductivity, and characterized soil salt concentrations upgradient and downgradient of each impoundment. To assess upgradient soil salt transport and its influence on impoundment and downgradient soil, we derived physical data about impoundments and their drainage area (impoundment area, impoundment drainage area, percent bare ground of the impoundment drainage area). In 2021 we then selected a subset of 68 impoundments across 8 HUC-12 watersheds to assess seasonal variations in impoundment salinity by measuring impoundment conductivity. Our analysis shows a relationship between upgradient soil conductivity and impoundment conductivity, implying salt transport from upgradient soils to impoundments. Magnesium and sodium salts influenced soil conductivity in both upgradient and downgradient soils in all HUC12 subwatersheds. We also found a correlation between the 2020 impoundment conductivity and the 2021 seasonal conductivity increase. Through the 2021 sampling season, we saw a decrease in the impoundments retaining water across the study area as well. Increases in salinity and loss of surface water from impoundments reduce the quality and quantity of consumable water for livestock and wildlife across the study area. Understanding the seasonal variability in impoundment salinity and the mechanisms of salt transport that influence rangeland health and water quality degradation will promote improvements in water quality and rangeland practices throughout the region.

Joseph Kragness

Dr. French

A Climatology Study of Supercell Environments Near the Black Hills

Of the different types of severe storms, supercells are among the most dangerous. These large, rotating thunderstorms commonly leave damage paths caused by large hail, strong winds, and occasional tornadoes. With the goal of increasing the understanding of supercells and their environments near isolated terrain features, a climatology of supercell days around the Black Hills is being conducted. Potential supercell events were identified using archived National Weather Service hail and tornado reports that occurred between 2000 – 2018 and within 100 miles of Rapid City, South Dakota. The reports were separated into two categories: reports 100 miles to the East and 50 miles to the West of Rapid City. These two categories will allow for the separate analysis of cases that were and weren't directly affected by the Black Hills. For each case, radar data will be used to determine the presence or absence of a supercell. On days where there was a confirmed supercell, archived surface meteorological data and atmospheric soundings of wind, temperature and moisture will be collected to quantify environmental conditions. These environmental conditions will then be compared with those near supercells not influenced by terrain. It is anticipated that the Black Hills may locally alter the environment to create conditions favorable for supercells in otherwise less-favorable environments.

Development of a Physiologically-Relevant, Serum-Free In Vitro Angiogenesis Platform

Laura Brunmaier, Biomedical Engineering
Dr. Travis W. Walker, Chemical and Biological Engineering

The vascular system plays a significant role in homeostasis and disease. While adult vesels are generally quiescent, apart from wound healing and female reproduction, numerous pathological states rely on angiogenesis for the progression of disease. To investigate the molecular mechanisms and cellular response, various in vitro models have been developed to induce angiogenesis and study the mechanisms of vessel progression. Commercially available angiogenesis assays are not physiologically-relevant, being largely limited by their inability to introduce flow into the system. Additionally, angiogenesis is a complex pathway that is orchestrated by numerous signals and cells that are necessary for endothelial sprouting, migration, and anastomosis. The complex in vivo milieu is composed of both chemical signals and physical stimuli that impact the progression of angiogenesis, making physiological mimicry of angiogenesis in vitro challenging. However, in vitro models are critical in advancing our knowledge of the role of angiogenesis in homeostasis and pathology in a translatable fashion. The physiological environment of the vascular system involves a 3D extracellular matrix, flow induced shear stress, chemical factors, and both endothelial cells and mural cells or pericytes. Our goal is to develop a physiologically-relevant, serum-free in vitro angiogenesis model with quantifiable exposure of growth factors. The model will then be used to measure an inflammatory response of endothelial cells that are exposed to nanoparticles, as well as efficacy and mechanisms of nanoparticle drug delivery.

Electrical Conductivities and Melting Points of Binary and Ternary Deep Eutectic Solvents via Molecular Simulation

Gregory, Opdahl Chemical and Biochemical Engineering
Dr. Kenneth, Benjamin Chemical and Biochemical Engineering

Solvent properties, such as electrical conductivity, are crucial to the successful design and operation of batteries. In several instances, the types of conventional solvents used in batteries are both potentially toxic to an individual, as well as to the environment. As an alternative, deep eutectic solvents (DES) are biologically based ionic liquid eutectic mixtures which possess tunable properties according to the selected cation, anion, and hydrogen bond donating co-solvent partner. These tunable properties include density, dielectric constant, and solvating power. DES possess extremely low vapor pressures, and therefore do not volatilize as easily as conventional organic solvents used in the pharmaceutical industry. Moreover, because DES are comprised of biologically based ions (i.e. choline) rather than synthetic ions (i.e. 1-ethyl-3-methyl-imidazolium), they are less toxic to organisms and the environment, and less expensive.

This work seeks to characterize environmentally benign, non-toxic, tunable DES through molecular simulation. In particular, molecular dynamics (MD) simulations are used to compute electrical conductivities for various binary and ternary DES, comprised of mixtures of choline chloride, urea, and glycerol. Electrical conductivities are calculated via post-processing of mean-squared displacement data from conventional MD simulations. The mean-squared displacement data will also be used to determine melting point ranges via changes in Arrhenius behavior across a large temperature span (100 Kelvin).

MD determined melting point temperatures and ranges will also be compared to the experimentally determined melting points/ranges. Comparisons of computed electrical conductivities for NaCl/H_2O mixtures are presented for benchmarking against experimental data, along with new predictions for various binary and ternary DES. Comparison against electrical conductivities of conventional battery solvents are made as well to determine the feasibility of DES to become a more eco-friendly battery solvent alternative.

Molecular Modeling of Biomolecular Systems Using the MARTINI Force Field

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Molecular modeling can be used to predict physical and thermodynamic behavior of chemical systems. When modeling systems with macromolecules, such as proteins, a coarse-grained force field is required to reduce simulation time and allow exploration of longer length and time scales. In this study, to model biomolecules such as amino acids, peptides, and proteins in liquid water, the coarse-grained MARTINI force field was used to capture the structure and thermodynamic properties of a larger-scale system in a more efficient manner. The application of this research was to simulate the aqueous, liquid environment associated with biofilm formation.

We will show the structural and property comparisons of amino acids and peptides as computed with density functional theory quantum chemical calculations, all-atom molecular dynamics (AAMD) simulations, and MARTINI coarse-grained molecular dynamics (CGMD) simulations. After this benchmarking, we will present results from hybrid AAMD/CGMD simulations for aqueous amino acid systems (complete with ionization to zwitterions and hydronium ions, the later built from the all-atom SCP/E water force field).

Reported simulation properties include both solution volumetric and energetic properties (such as heat capacities) at different temperatures and amino acid concentrations and compared against experimental trends. Finally, we will discuss simulations with CG peptides using the MARTINI forcefield which will lead to building and simulating larger biomolecular systems (including proteins).

Investigating the novel ISS *Methylobacterium species* for PHA biosynthesis

Wageesha Sharma, Dr David Salem, Dr. Nitin Singh[1], Dr. Kasthuri Venkateswaran[1] and Dr Rajesh Sani

CNAM-Bio Center and Chemical and Biological Engineering Department

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Polyhydroxyalkanoates (PHAs) are gaining attention in the family of polyesters polymers due to their biodegradability and biocompatibility. The polymer molecular structure is generally directed by the biosynthetic pathways of microbes employed for PHA synthesis, influenced by the bacterial species, substrate utilized, and the culturing conditions provided. There are more than 100 PHA polymer monomeric units, and the composition of these sub-units in polymer structure determines their physical and thermo-mechanical features. This variability has produced PHAs with drastically different polymer properties. In this context, it is interesting to explore PHA producers with properties having desirable functionality. In this study, novel microbial species, namely *Mehylobacterium ajmalii* (JC-0089 and JC-0023) and *Methylorubrum rhodesium* (JC-1176) isolated from the International Space Station were investigated for the potential of PHA synthesis. Methane gas, Luria broth, and soyabean oil are the chosen substrates for this study. The research focuses on comprehensive *in-silico* analysis of the whole genome sequences and metabolic pathways entailed in the substrate to PHA production. This analysis showed a lack of methane monooxygenase, due to which methanol was used instead of methane gas as a C1 carbon source. In addition, nitrogen-limited growth conditions with 7:3 carbon source to minimal media ratio were provided for PHA accumulation, followed by molecular gene targeting, positive for PHA synthase gene (*phaC*). Further, the optimized solvent extraction method accomplishes the PHA extraction of 59.71% in JC-1176, 44.9% in JC-0089 and 48.7% in JC-0023 per gram of cell biomass. FTIR peak at 1723 confirmed the extracted product as PHA. Using biophysical techniques like XRD, NMR, AFM, DSC, TGA, etc., can report the physical and thermal properties of the extracted PHA polymers. The findings further elucidate the relationship between carbon substrate and the biochemical pathways resulting in polymer characteristics.

Integrated hydrothermal technologies for the conversion of agricultural residue into value-added bioproducts

Bharath kiran Maddipudi*, Karen M. Swindler Department of Chemical and Biological Engineering
Mentor/Advisor: Professor (Dr.) Rajesh Shende, Karen M. Swindler Department of Chemical and Biological Engineering

Bio-ethanol industries utilizing agricultural residue (e.g., corn residue) as a feedstock often generates lignin rich solid waste. The solid waste is generally referred as unhydrolyzed solids (UHS). Among several conversion technologies, thermochemical conversion technology platform can be implemented to convert UHS to value-added bioproducts. Hydrothermal Liquefaction (HTL) or catalytic HTL (CHTL) is known to effectively breakdown a complex macromolecule lignin or lignocellulosic biomass (LCB) into bioproducts such as char, bio-oil, liquid biocrude, and gasses. In this study, HTL of UHS was performed at different processing conditions of temperature, initial nitrogen pressure, biomass to water ratio, and the products generated were analyzed. Generated hydrochar can be used for energy storage application such as supercapacitors/batteries. Derived bio-oil or heavy bio-oil (HBO) can be made into blend fuels. This investigation focuses on identifying different compounds present in aqueous biocrude and identifying suitable pathways for selective enrichment or separation of value-added products such as lactic acid and phenols/substituted phenols. Solvent extraction methodology was developed to separate phenol/substituted phenols from aqueous biocrude. Lactic acid enrichment was accomplished by rotary evaporative separation, which could be polymerized into PLA. HTL processing, separation methodologies, process engineering aspects and scale-up strategies will be presented for the conversion of corn stover and UHS into value-added products.

Keywords: corn stover/ UHS, integrated biorefinery (IBR), HTL, value-added products

Simulation and Rheological Studies of Magnetorheological fluids

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Magnetorheological fluids are fluids that are composed of magnetic particles and a solvent. Upon the application of an external field such as a magnetic field, an induced dipole can be created within the suspended particles, causing movement of the particles. These movements, depending on the magnitude and direction of the external field, can result in the change of some rheological properties of the fluid, for example, viscosity. This property of magnetorheological fluids can be exploited for use in applications that requires materials with controllable mechanical strength, such as shock absorbers and liquid body armor. Studies of magnetorheological fluids have been conducted both theoretically and experimentally; however, most investigations uses a fixed-dipole model that considers the particles to be only induced by the external field, ignoring the inducing effect of neighboring particles.

In our work, we utilize a mutual-dipole model, which assumes that a particle is not only induced by an external field but also by its neighboring particles. Alongside the mutual-dipole model, accelerated Stokesian dynamics was used to accurately describe the dynamics of the suspension of magnetic particles in the presence of magnetic fluids and shear force. Furthermore, the changes in viscosity of the suspension as a result of the ratio of the applied magnetic force and the viscous force of the system was investigated.

HTL-derived hydrochar as electrode material for asymmetric supercapacitor

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Historically, energy storage is fulfilled by batteries/capacitors. Compared to capacitors, supercapacitors possess some advantages such as long charging-discharging characteristics, higher cyclic stability, etc. Recently, there is a great thrust in the scientific community to develop asymmetric supercapacitor (ASC), which is characterized by dissimilar electrode materials and possess a relatively high power and energy densities. Industrialized porous carbon (POC) materials (nanotubes, nanofibers, nanofibrous sponges) and activated carbon (AC) are currently being used in ASCs due to their high specific surface area (SSA), superior chemical/physical stability and low density. The primary precursor for AC or POC is coal, and its processing contributes to the greenhouse gas (GHG) emission. Lignocellulose biomass (LCB) is a renewable and sustainable resource that can be utilized for POC manufacturing. In this study, hydrothermal liquefaction (HTL)-derived biochar from LCB was activated with KOH and thermally treated to obtain POC with superior SSA, pore volume and pore size distribution for energy storage application. POC was characterized by Brunauer‐Emmett‐Teller (BET) surface area analyzer, Fourier transform infrared (FTIR) spectroscopy, Raman Spectroscopy, Scanning Electron Microscopy (SEM), and Transmission Electron Microscopy (TEM). Using POC and (Mn, Ti)-mixed oxide as electrode materials, ASCs were fabricated. The performance of ASC was measured by cyclic voltammetry (CV), galvanostatic charge-discharge (GCD) plots to determine the specific capacitance and cyclic stability. The results will be presented.

Electroactive characteristics in polymer-bound reactives

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Due to the demand for tailorable energetics, there has been an increased interest in developing smart reactive systems. Previous work explored the reactive systems Al/THV and Al/PVDF for their piezoelectricity and ability to be switched under a DC current. Early work indicates that non-piezoelectric composites could exhibit sensitization behavior, although the specific mechanism was not identified. A possible explanation could be the systems flexoelectric effect. Flexoelectricity is induced by an inhomogeneous strain gradient capable of switching, poling, and spontaneous polarization. This allows for the flexoelectric effect to influence a reactive system down to the interfacial contact between the fuel particles and polymer binder. In this effort we characterized the transverse flexoelectric coefficient for reactive systems in polymer binder.

Characterization of Polymeric Powders Through Capillary Flow for Additive-Manufacturing Techniques

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The wettability of powders plays a crucial role in many additive-manufacturing methods [e.g., drop on demand (DOD), selective laser sintering (SLS), electron beam melting (EBM)]. However, surface inhomogeneity of powder beds prevents easily measuring the wettability of powders through traditional measurements of contact angle like the sessile drop method. Traditional methods that are used to measure the surface wettability of the powder, including inverse gas chromatography (IGC), immersion calorimetry, capillary pressure, and Washburn rise, are not always available to researchers. Therefore, this study investigates fluid-powder interactions by using a non-invasive frugal technique for imaging (NIFTI) of the Washburn rise. This NIFTI Washburn rise approach records fluid flow in a packed powder bed, which can then be used to calculate the wettability and the surface energy of the powders. The NIFTI Washburn rise requires only a mobile phone and a cheap, commercial flow cell to analyze the fluid-powder interactions, making characterization of the properties of any polymer powder readily available to all industries. Given that the contact angle results that were collected from the NIFTI Washburn rise method and the traditional Washburn rise methods were comparable, this method is appropriate to collect measurements of surface energy of polystyrene powders. Further characterization techniques such as laser-diffraction particle size and sieve analysis were used for size and shape analyses, and scanning electron microscopy (SEM) was used to investigate the surface topography.

Characterizing the Effects of Food Waste Composition and Solids Retention Time (SRT) on Volatile Fatty Acid (VFA) Production and Profile During the Anaerobic Digestion of Food Waste

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A considerable amount of research has been devoted to optimizing methane gas production using anaerobic digestion. However, due to methane's environmental impact and current low economic value, attention has shifted towards the production of VFAs. VFAs are potential precursors in the production of biofuels and are commonly used as food and animal feed additives, antimicrobial agents, and chemical feedstocks. The focus of this study was to determine the effects of food waste (FW) composition and solids retention time (SRT) on VFA production and profiles. We hypothesize that high starch FW will yield higher VFA production when compared to less digestible substrates, and an increase in SRT will lead to higher concentrations of long chain VFAs. During experimentation, it was found that high starch FW promoted greater VFA production compared to standard cafeteria FW (2.7 gVFA/L/day vs 1.3 gVFA/L/day) and corresponded with higher hydrogen gas production (about 43% H2 in the digester headspace). Similarly, FW composition was shown to affect VFA profiles. The predominant VFAs generated by the high starch FW were acetic, butyric and caproic acid (2.29 g/L, 3.32 g/L and 1.09 g/L, respectively) compared to predominant VFAs consisting of acetic, butyric and caproic acid (1.36 g/L, 1.09 g/L and 1.11 g/L, respectively) generated by cafeteria FW. It was observed that increasing the SRT from 4 to 28 days with high starch FW led to dramatic shifts in VFA profile. Five days after increasing SRT there was a 17% decrease in acetic acid, 10% decrease in propionic acid, 35% increase in isobutyric acid and a 45% increase in caproic acid. These results show high starch FW favors higher VFA production, and an increase in SRT favors butyric and caproic acid production. Next steps will focus on analyzing the microbial community and testing more SRT values ranging from 4 to 28 days.

Mechanism of Biomolecular Adsorption on Graphene and Modified Graphene: Molecular Insights into Biofilm Formation and Adhesion

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Kenneth M. Benjamin, Karen M Swindler Dept. of Chemical & Biological Engineering

Graphene and graphene derivatives are potential candidates to be used as biofilm inhibiting coatings for metal surfaces due to their potential antibacterial properties. Chemical vapor deposition (CVD), an alternative to mechanical exfoliation of graphite, is a promising process for large scalable synthesis of graphene. However, CVD usually results in a number of structural defects and surface impurities. While defect-free graphene growth using CVD is still under investigation and these defects remain largely undesired, studies have shown defective graphene surfaces have distinct properties from the pristine layers. What remains to be known is what effect these surface defects have on biofilm adhesion and formation, since no foundational atomistic-level information is available on whether these defects produce positive or negative surface adsorption characteristics relevant to biofilm adhesion and formation.

Recent work has hypothesized that biofilm formation and adhesion may be related to the adsorption of key, early protein molecules including exopolysaccharides (EPS) to surfaces. Nevertheless, studies related to molecular mechanics of these early protein molecule-surface interaction and adsorptive performance of graphene and graphene derivative surfaces is rather scarce. As a first step towards exploring this hypothesis, we investigate the adsorption behaviors of 20 proteinogenic amino acids (as model compounds for microbes), the building blocks of proteins, on pristine and defect-induced graphene surfaces using molecular dynamics (MD) simulations. All the simulations were conducted in vacuum and in the presence of explicit water as solvent to deduce the effect of solvation on the adsorption behavior.

Specifically, the molecular dynamics simulations are conducted using the LAMMPS molecular dynamics simulation software package and the Adaptive Intermolecular Reactive Empirical Bond Order (AIREBO) and Assisted Model Building with Energy Refinement (AMBER) potentials. The adsorption energies and the binding free energies of the amino acids on graphene and graphene-modified surfaces are evaluated to assess the effect of surface defects on the adsorption phenomena. The binding free energies are computed using the umbrella sampling and the adaptive biasing force thermodynamic integration technique.

The results of this molecular-level study should aid in developing a larger, fundamental understanding of the interaction, adsorption, and adhesion of proteins and microbes to two-dimensional surfaces, such as found in biomedical device applications.

Composite Fuel/Oxidizer Crystals for Energetic Applications

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Mentor: Dr. Lori Groven, Department of Chemical and Biological Engineering

In the past decade, means to neutralize chemical weapons have been increasingly studied. Metal oxides, such as MgO and Al_2O_3 have been shown to be capable of neutralizing chemical warfare agents through catalysis; however, introducing the oxide particulate during a combustion (detonation) remains problematic. In this work, we consider a unique approach where the metal oxide is produced in-situ and is the product of combustion. Specifically, glycine and magnesium nitrate are studied to form a composite crystal in varying fuel to oxidizer ratios, with the goal of improved combustion characteristics and synthesis of a high surface area magnesium oxide. The method of forming the composite crystal along with the composite crystal's decomposition characteristics in comparison to a physical mixture of the reactive system that resulted from this study will be discussed. Combustion of the composite crystals results in magnesium oxide with specific surface areas from 7 to 52 m^2/g and is shown to be dependent on fuel to oxidizer ratio. These composite fuel/oxidizer crystals could be included in a variety of formulations and show promise for the formation of catalytically active nanoparticulate.

Synthesis Conditions and DAP-4 Crystal Growth and Sensitivity

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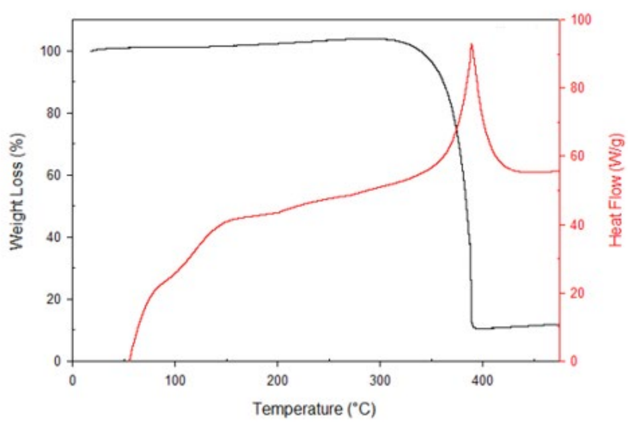
In the past few years there has been an increasing interest in the development of thermally stable propellants. For that application, this work explores the recently reported molecular perovskite, DAP-4. The perovskite compounds are synthesized through a straightforward process and have similar detonation performance to that of HMX and RDX (Zhang et al., 2020). However, these perovskites have improved thermal stability and are less expensive. In this work, DAP-4 is synthesized through bulk solution conditions and characterized via DSC/TGA, sensitivity testing and optical microscopy. Optical microscopy shows the crystals are cubic in structure. Thermal analysis shows that DAP-4 is thermally stable up to an onset temperature of 335°C. The ESD data (Method 1032) showed no reaction for 20 tests, DAP-4 passes the electrostatic test at the 0.25 joule level. Solution concentration and temperature are shown to influence the crystal size and the sensitivity will be reported as a function of synthesis conditions.

Zhang, W.-X., Chen, S.-L., Shang, Y., Yu, Z.-H., & Chen, X.-M. (2020). Molecular perovskites as a new platform for designing advanced multi-component energetic crystals. *Energetic Materials Frontiers*, *1*(3-4), 123–135. https://doi.org/10.1016/j.enmf.2020.12.003



Epigenetics of Sulfate Reducing Bacteria Under Copper Stress

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Epigenetics is a mechanism of gene regulation without changing the DNA sequence, which is heritable in nature. Epigenetic regulation is poorly studied in prokaryotes and is associated with DNA methylation that regulates the DNA-protein interaction in bacteria which often plays a role in phenotypic variations. Our study focuses on biofilm-forming *Desulfovibrio alaskensis* G20, which are sulfate-reducing bacteria (SRB), thereby producing hydrogen sulfide as an end product. Hydrogen sulfide is responsible for metal corrosion which is directly proportional to the biofilms formation by the SRB on metal surfaces. Preliminary experiments were performed on the planktonic SRB cells grown under variable bioavailable copper conditions (0, 5, 15, and 30µM) in anaerobic serum bottles. SRB cell density decreased with an increase in copper ion concentration. The DNA extraction was carried out, followed by the quality and quantity assessment. The samples were subjected to Whole-Genome Bisulfite Sequencing (WGBS) for epigenetic profiling. The sequencing data were processed in-house using the Galaxy platform, wherein Bismark workflow was set up to map the m^5C base modifications. The study reported more than a 20% change in the percentage methylation in the genes responsible for biofilm formation across CpG, CHG and CHH islands. The data is crucial to investigate the role of epigenetics in the biocorrosion of a metal surface by SRB biofilms.

Transcriptomics and functional analysis of copper stress response in the sulfate reducing bacteria *Desulfovibrio alaskensis* G20

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Copper (Cu) is an essential micronutrient required as a co-factor in the catalytic center of many enzymes in bacteria. However, excess Cu is hazardous and can generate pleiotropic effects. Cu has been the metal of choice for piping used in household water distribution systems. Due to its leaching from pipelines, Cu level is present at elevated concentration in ground water and in soils which is a matter of public health concern. Sulfate reducing bacteria (SRB) have been demonstrated to remove toxic levels of Cu. However, reports on toxicity of Cu towards SRB have primarily focused on degree of toxicity and subsequent elimination. In this study, we show in detail the Cu(II) stress-related effects on a model sulfate reducing bacteria, *Desulfovibrio alaskensis* G20. Cu(II) stress effects were measured at two different concentrations (5µM and 15µM) as changes in the transcriptome through RNA-Seq. In the pairwise comparison of 5µM vs control, 61.43% of genes were found downregulated and 38.57% genes were upregulated. In 15µM vs control, 49.51% genes were downregulated, and 50.5% genes were upregulated. The results indicated that the expression of inorganic ion transporters and translation machinery was massively modulated. Moreover, changes in important biological processes such as DNA transcription and signal transduction were observed at high Cu(II) concentration. In addition, the metabolomics analysis indicated the effect of certain organic acids and amino acids in cellular metal buffering system and reducing oxidative damage to cells. These results will help us better understand the mechanism of Cu(II) stress response and provide avenues for future research.

Sulfur-based Electrolytes for Solid-state Lithium-ion Batteries

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It is known that lithium-ion batteries with an organic liquid electrolyte are effective for small applications. However, in larger applications such as electric vehicles, they are unsafe and are difficult to safely dispose of. Because of this, there is much research into finding a suitable solid-state electrolyte. Using sulfur-based solid-state electrolytes can be an effective, sustainable, and green alternative. With their high ionic conductivity and more polarizable nature, sulfur-based solid-state electrolytes are ideal in lithium-ion batteries if not for the issues, one of which is the decreased ionic conductivity at room temperature. This research aims to investigate the molar concentrations of Li_2S and Li_2S_5 needed while finding different techniques to obtain the highest ionic conductivity at room temperature.

Analysis of Ruthenium-Doping on the Electrochemical Properties of $LiFePO_4$ Cathode Materials Prepared by Sol-Gel Synthesis for Use in Lithium-ion Batteries

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In recent years, the demand for high voltage and high-capacity energy systems has grown due to increased use of portable electronics, electric vehicles, and grid energy storage systems. $LiFePO_4$ (LFP) shows great promise as a cathode material due to its low cost, structural stability, safety characteristics, and low environmental impact. However, LFP cathodes possess a lower Li-ion diffusion coefficient and poor electrical conductivity compared to traditional lithium cobalt oxide (LCO) that are on the market. LFP cathodes have a theoretical specific capacity of 170 mAh g^{-1} while studies show specific capacities around 120 mAh g^{-1}. Doping of materials is a highly effective method of improving electrochemical characteristics in LFP cathodes. Ruthenium-doping of iron sites within LFP has shown positive effects in the promotion of Li-ion diffusion, reduction in band gap energies, and improved electrical conductivity. Previous studies have shown ruthenium-doping at 0.1 moles have an increased specific capacity of 162 mAh g^{-1}, with capacity reductions when ruthenium is higher than 0.1 moles. Here, samples of $LiFe_{1-x}Ru_xPO_4$ (x= 0.01, 0.0075, and 0.005) and undoped LFP were prepared via the sol-gel technique to explore the effects of lower levels of ruthenium-doping on LFP electrochemical characteristics. Furthermore, different chelating agents used in the sol-gel synthesis process were studied to determine the effects of using citric acid vs. glycine. Samples were characterized via scanning electron microscopy (SEM), X-ray diffraction (XRD), energy dispersive x-ray spectroscopy (EDX), C-rate testing, and impedance testing.

Comparison of Li- and Na-based antiperovskite solid-state electrolytes for use in Li- and Na-ion solid-state batteries

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Electrification of the automotive industry has increased demand for batteries that are safer, have high energy density, high capacity, and a long lifespan. Li-ion batteries have been the hero of this movement because they meet all these requirements. However, with an increased demand for lithium across multiple industries, coupled with limited recycling methods, it is likely that lithium reserves will become strained. Therefore, Na-ion batteries have garnered much interest to support and offer an alternative energy storage option to Li-ion batteries. This work will investigate and compare the electrical and ionic conductivities of both Li- and Na-based solid-state anti-perovskite electrolytes for use solid-state batteries. Lithium oxyhalide (Li_3OCl) was produced according to previous procedures but the synthesis of sodium oxyhalide (Na_3OCl) was investigated, and the final products were characterized by X-Ray Diffraction (XRD) spectroscopy. C-rate testing and impedance testing was carried out on Li-ion half cells with Li_3OCl as the electrolyte.

Effect of Curing Temperature on the Early-Age Properties of Metakaolin Alkali-Activated Geopolymers

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Abstract: Geopolymers an emerging construction material that can replace ordinary Portland cement (OPC) for construction purposes. To make structural-grade geopolymers, aluminosilicate powders blended with an alkaline solution. But due to the lack of understanding about their reaction mechanisms, the use of geoploymers as a construction material has been limited. In this research, metakaolin was used as a precursor for geopolymers. To activate the metakaolin, sodium hydroxide and sodium silicate solutions were used. For curing three different temperatures of 23˚C, 40˚C and 60˚C were selected. The reaction characteristics of the geopolymer pastes were analyzed for setting time, chemical shrinkage, free water loss and kinetics via calorimeter. Microwave characterization and resistivity analysis were also performed on the geopolymer pastes to find their dielectric properties in terms of permittivity and loss factor. This data is then correlated to begin to elucidate the role of water and rate of reaction of the geopolymers at early stages.

3D Electrochemical Mapping of Initial Biofilm Formation during Copper Pipeline Biocorrosion

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Corrosion of oil, gas, and water distribution pipelines costs an estimate $85 Billion per year in the United States and an estimated 20% of these damages are caused by microbial biofilms. The presence of sulfate in solution leads to many downstream environmental impacts from sulfate-reducing bacteria. Typically, sulfate reducing bacteria of the genus Desulfovibrio use H_2, organic acid substrates, formate, or short chain alcohols as electron donors for sulfate reduction to produce corrosive H_2S. To prevent the corrosion process from occurring understanding how the biofilm initially attaches and develops on the surface is crucial. The first stage of biofilm attachment occurs when planktonic microorganisms reversibly attach to a substrate. These initial interactions are crucial to produce a gooey substance called the EPS, where the attachment then becomes irreversible. To date there are few studies done on transient biofilm development of anaerobic bacteria experiencing shear stresses. No studies to our knowledge have been performed to investigate initial biofilm formation leading to corrosion in these environments. Commonly in corrosion research batch environments are used to observe corrosion of a material over time. Techniques such as open circuit voltage, electrochemical impedance spectroscopy, and linear polarization resistance are used to observe the impedances and corrosion rates over time. Only endpoint microscopic analysis and Raman spectroscopy are performed on the biofilm samples, leaving the initial biofilm formation understudied. Here we use an electrochemically modified Robbins device to investigate transient biofilm formation using scanning electrochemical microscopy and confocal Raman spectroscopy. Timepoint open circuit potential, electrochemical impedance spectroscopy, and linear polarization resistance are used to observe the corrosion rates of copper pipeline, while day 0-5 scanning electrochemical microscopy and confocal Raman 3D mappings observe how the biofilm growth. The results will bring researchers closer into understanding how sulfate reducing biofilms initial grow and their corresponding relationship to copper pipeline corrosion. Leading to advancements in material coatings that reduce initial biofilm proliferation, ultimately increasing the lifetime of many oil, gas, and water distribution systems.

Characterization of molecular mechanisms and genes involved in the nanowire development in Desulfovibrio alaskensis G20

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The molecular mechanisms and genes involved in the on-set of nanowires in sulfate-reducing bacteria *viz. Desulfovibrio alaskensis* G20 (DA-G20) were assessed through *in-silico* and biochemical approaches. We hypothesized that nutritional and oxidative stress conditions result in the upregulation of universal stress proteins in DA-G20, which controls the expression of type-IV pilin components. Sequence analysis of DA-G20 was carried out to identify 12 genes from *Flp-* subfamily. The structural and functional properties of the identified genes were cross-validated with phenotypic properties of electrically conductive filaments of reference strains (e.g., *Geobacter, Pseudomonas*). A significant similarity was observed between major nanowire protein (Flp protein) of DA-G20 and PilA protein of reference strains. Our superimposition studies validate the functional similarities between Flp and PilA proteins. Biochemical validations with reduced concentration of electron acceptor (sulfate) to induce nutritional stress for expression of type-IV pilin did not result in the formation of nanowires. Biochemical validation with reduced concentration of electron donor (lactate) is underway. The differential gene expression profiling of type-IV pilin encoding genes will provide more insight into the metabolic responsiveness of DA-G20 exposed to Fe coupon.

Life Cycle Assessment of Autonomous Vehicles

Author: Samantha Heiberg - Mentor: Dr. Ilke Celik

Autonomous vehicles have gained a lot of attention from the public in recent years. Many proponents of autonomous vehicles point to the reduced environmental impacts and increase societal and economic benefits. However, little is known about the true environmental impacts of autonomous vehicles. In this study, we aim to assess the environmental sustainability of autonomous vehicles. As a reference point, we compared autonomous vehicles to internal combustion engine vehicles and electric vehicles. We used two modeling tools to assess the environmental performance of the three vehicles: OpenLCA tool and GaBi. The environmental impacts of the three vehicle types are characterized using the Environmental Protection Agency's (EPA) tool for reduction and assessment of chemicals and other environmental impacts (TRACI). The environmental impacts found of the three vehicle types were then compared to each other.

Microbial Induced Corrosion Protection by Single-layer Graphene Coating on Single Crystal (111) Copper

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Abstract:

The cost of corrosion worldwide is increasing every year and microbially induced corrosion (MIC) contributes to this substantially. Here we have explored the effectiveness of graphene coating on {111} single crystal copper exposed to *Desulfovibrio alaskensis* G20 (DAG-20) sulfate-reducing bacterial atmosphere (10% DAG-20) because of the inherent barrier property of graphene. In this study, we carried out microbial corrosion test on bare {111} single crystal copper (SC-Cu) and single-layer graphene-coated single crystal copper (SLG/SC-Cu) and compared values such as open circuit potential, electrochemical impedance, and polarization resistance. The SLG/SC-Cu showed higher open circuit potential, higher impedance, and a lower corrosion rate compared to that of bare SC-Cu. The single-layer graphene coating acted as a barrier to corrosion and yielded lower corrosion than the bare SC-Cu. This outcome is contrasting while compared to that of the SLG/polycrystalline copper sample under similar circumstances. The underlying variation between the corrosion mechanism for {111} single crystal copper and polycrystalline copper due to their different crystalline structure would be the reason for these contrasting results. However, the widely acknowledged concept of graphene's barrier property is once again corroborated in this study.

Passivation of Microbiologically Influenced Corrosion by Bacterial Biofilm

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Microbiologically influenced corrosion (MIC) compromises the integrity of many technologically relevant metals. Here, we report a protective coating based on *Citrobacter freundii* MIC21 biofilm for suppressing the MIC of underlying copper (Cu) surfaces. The tests were carried out using three identical corrosion cells varied in the type of working electrode (annealed Cu, 29.5 % coldworked, and 56.2% coldworked Cu). The counter and reference electrodes were based on graphite plate and Ag/AgCl, respectively. The electrolyte was based on lactate-c media inoculated with a co-culture of *Desulfovibrio alaskensis* strain G20 and *Citrobacter freundii* strain MIC21. The analysis based on scanning electron microscopy, energy dispersive spectroscopy, and X-ray diffraction revealed a compact biofilm matrix consisting of exopolymers, MIC21 cells, insoluble precipitates of Cu compounds. The passivating effects of the biofilm matrix was corroborated after observing the ennoblement of open circuit potential and enhanced corrosion resistance. The matrix offered at least 15-fold lower corrosion resistance after 60 days of exposure to media. The elastic modulus, a measure of mechanical strength, for this passivating matrix ranged as high as 0.5 to 1 GPa. Finally, we provide mechanistic insight into the antimicrobial and barrier properties of the matrix.

Corrosion performance evaluation of atomic layers of graphene on nickel surfaces exposed to aggressive microbial environments

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The inception of many industrial and environmental complications is caused by biofilms with the adhesion of bacteria to surfaces. These problems include Legionnares' disease cases following Flint water change, Genoa bridge collapse and Trans Alaska oil spill etc. Microbiologically influenced corrosion (MIC) results in an unanticipated attack on metals in a seemingly benign environment. Despite significant choices for preventing the abiotic forms of corrosion effectively, there exists a lack of reliable protective coating for combating corrosion of metals exposed to aggressive microbial environments. Microbiologically influenced corrosion, a dangerous corrosion form has been reported to result in colossal monetary losses. Here we focus on developing protective coatings based on atomic layers of graphene using nickel as a technologically relevant metal and genetically tractable *Desulfovibrio Alaskensis* 20 as a model for sulphate reducing bacteria. Here we report an unusual behaviour of polycrystalline nickel surfaces modified with a single layer of graphene. We report that the nickel surfaces modified with graphene layer undergo an accelerated corrosion (12-fold higher) when compared to pristine form of nickel. We present a series of electrochemistry and microscopy tests to unveil this counterintuitive behaviour. We also present strategies to obtain rationally designed graphene coatings for effectively combating the MIC of nickel surfaces.

Keywords: Multilayer graphene, nanoscale coating, electrochemical impedance, sulfate reducing bacteria

Properties and Performance Characteristics of Marginal and Unconventional Source Fly Ashes in Concrete

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Performance, reactivity, and durability properties of emerging sources of fly ash and bottom ash are assessed. A suite of off-specification, marginal, reclaimed, and beneficiated ashes with a wide range of physical and chemical properties are used as a partial replacement for cement to make concrete specimens. Testing conducted to assess the concrete specimens containing these ashes includes compressive strength and SAI (ASTM C39, ASTM C618), bulk uniaxial resistivity (AASHTO TP-119, ASTM C1760), surface resistivity (AASHTO TP 95), and chloride penetrability (ASTM C1202). Concrete specimens were cured and monitored over a temporal range of approximately 180-days, with measurements taken places at 1-, 7-, 28-, 56-, 91-, and 180-days. Results show that time-series surface and bulk resistivity (BR and SR) measurements may be used as an indicator of pozzolanicity or reactivity in concrete specimens containing these fly ashes. Additionally, results show that performance-based metrics of strength, reactivity potential, and chloride resistance capability of these emerging sources of fly ash used in concrete can be comparable to in-specification fly ashes depending on their properties.

Infrastructure Deterioration in Response to Molecular signaling mechanisms in Sulfate Reducing Bacteria. Effects of quorum sensing on graphene coating performance exposed to *Desulfovibrio alaskensis* G20.

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Biofilms of sulfate reducing bacteria have been reported to destroy robust metals including steel. They use a process known as microbiologically influenced corrosion (MIC) to causing wreaking havoc on civil infrastructure including bridge and water pipelines. The MIC accounts for up to 50 percent of the total corrosion costs to the economy. Quorum sensing (QS), an interesting phenomenon in bacteria allow them to communicate with each other and collectively induce genotypic and phenotypic changes. Some of the induced changes include formation of a thicker biofilms, increased virulence and biocorrosion. Such QS mechanisms have been reported to be a key reason for enhanced biofilm formation and microbially induced corrosion observed in sulfate-reducing bacteria (SRB). Our objective is to validate the inducing effect of QS molecule (e.g., n-Acetyl homoserine lactone; AHL) on MIC resistance of a single-layered graphene coating used to protect underlying copper surfaces exposed to *Desulfovibrio alaskensis* G20 (DA-G20). We hypothesized that augmentation of n-AHL facilitates the rate of MIC on metal surface, subsequently increasing biofilm density. To validate our hypothesis, two corrosion cells were fabricated and continuously monitored for corrosion resistance of graphene coated copper. DA-G20 was used as a model for SRB. A working concentration of 20 μg/mL AHL was maintained in electrolyte based on Lactate-C media. An identical cell lacking AHL augmentation was used as a control. The MIC behavior were measured using Open circuit potential (mV), electrochemical impedance spectroscopy (EIS) behavior, and linear polarization resistance (ohm.cm^2) for 48 hours. The corrosion rate (mpy) for the test cell is 10-folds higher than control. Similarly, the potential value (V) of the test cell is four-folds higher than control/reference. These observations validate our hypothesis and giving a significant direction. Considering these observations, our future studies will evaluate the possibility of using Quorum Quenchers (antagonistic to AHL) for minimizing MIC rates. The fundamental knowledge from this study can be used to rationally design graphene coatings that can quench QS mechanisms while serving as a protective barrier against corrosive moieties involved in corrosion.

Human Action Classification by Mapping Tensors on Grassmann Manifold

Cagri Ozdemir

Advisor: Dr. Randy C. Hoover

Action classification is a significant problem within the field of human-computer interaction (HCI). Most real-world data is multidimensional and arises in many application areas of video analytics, computer vision, and image processing. This type of data can be naturally represented as a tensor (i.e., multidimensional cube of numbers). We introduce a new framework for action classification by representing a third-order data tensor (a video frame) as a point on a Grassmann manifold using the tensor singular value decomposition (t-SVD) and tensor product (t-product). We define the geodesic distances between third-order tensors on the manifold for action video classification task via several different discrete linear transforms. Once the distances are computed, a simple nearest neighbor search can be used for action classification on the manifold. In addition, we introduce the geometric structure of a defined orthogonal third-order tensors obtained via the t-SVD on a Grassmann manifold. Experimental results are presented from the Cambridge Hand-Gesture dataset and the University of Texas at Dallas Multimodal Human Action Dataset (UTD-MHAD) and show that the proposed method outperforms the state-of-the-art using the Tucker decomposition-based manifold learning method in terms of action video classification.

A Novel Industrial Coolant Utilizing MXene Nanofluid with Improved Thermal Conductivity

Mingyang Mao Electrical Engineering
Haiping Hong Electrical Engineering

In recent years, industrial coolant has developed an emerging edge. The incessant research to develop a nanofluid alternative to traditional industrial coolant because of its superior thermal conductivity. In addition, MXene nanofluids has gained immense interest as superior heat transfer fluid in industrial coolant usage in recent years. In this research, two types of nanofluids: MXene/water nanofluid and MXene/ethylene-glycol/water nanofluid with 5 different concentrations of 0.1, 0.2, 0.3, 0.4 and 0.5 wt% of MXene are fabricated and the optimum concentration is used to check the performance of a nanofluid coolant. The layered structure of MXene and high absorbance of prepared nanofluids have been perceived by SEM and UV–vis respectively. A maximum improvement of 30.6% in thermal conductivity is observed for 0.5 wt % loading of MXene in MXene/water nanofluid compared to the base fluid. In addition, improvement of 27.3% in thermal conductivity is observed in MXene/ethylene-glycol/water nanofluid. In conclusion, it can be demonstrated that MXene dispersed nanofluid might be a great prospect in the field of industrial coolant applications since they can augment the heat transfer rate considerably which improves system efficiency.

On the Study of a Low Profile Triple-Band Meander Line Antenna for Wireless Applications

Tania Islam, Electrical Engineering

Dr. Sayan Roy, Electrical Engineering

Abstract: The recent advancements in wireless technologies have enabled modern transceiver systems to communicate high-speed data within various devices and networks. Driven by the needs of applications and bandwidths, these devices and networks often require to be low-cost, low-profile, lightweight and resonated at multiple frequencies for applications such as WLAN, RFID, WiMAX, etc. Recently, researchers have proposed different such multi-band antennas. In this presentation, a compact microstrip meander line antenna has been represented with a size of **36×30×1. 524** mm3. The proposed antenna resonates at three different frequency bands which include **4.48-4.529 GHz** radio communications, **5.037-5.098 GHz** Wi-Fi applications, and **5.821-5.876 GHz** WLAN applications. The antenna geometry comprises a well-built vertically and horizontally coupled slotted structure at the trace plane with a continuous reference ground plane to achieve the desired applications bandwidths. The proposed design has demonstrated a satisfactory antenna return loss, gain, along directional radiation patterns in both fields at all three frequency points thus making itself suitable for various wireless applications.

Here, an improved low-profile triple-band meander line antenna is proposed with resonating frequency points at 4.52 GHz, 5.07 GHz, and 5.85 GHz along with improved gain ranges from 2.30 dB to 6.96 dBi and an efficiency of 76.5%, 93%, and 92%, respectively. A broadband horn antenna was used here as a fixed gain transmitter located at the far-field and the measured radiation patterns of the fabricated antenna exhibit a directional behavior with a little back lobe at 4.52 GHz and 5.07 GHz, and an omnidirectional behavior at 5.85 GHz.

Throughout the overall experiment, the measurements show a good agreement with the simulated return loss and radiation pattern with high gain and efficiency, thus validating the proposed antenna for use in radio communications, Wi-Fi, and WLAN applications.

On the Use of a Microstrip Meander Line to Reduce Mutual Coupling between a Patch Antenna and a Transmission Line on Printed Circuit Boards

Tasin, Nusrat & Department of Electrical Engineering
Dr. Sayan Roy & Department of Electrical Engineering

A microstrip meander line (MML) design is proposed in this study to reduce the unwanted mutual coupling between a closely placed patch antenna and a transmission line on a printed circuit board at 5.3 GHz. The distance between the transmission line and patch antenna is considered as 6mm. A microstrip meander line has been placed between the PA and the transmission line to reduce the coupling. Through full-wave modeling, simulation, optimization, and prototype fabrication, the proposed design resulted in achieving an improved reduction of the mutual coupling of 10 dB at 5.3 GHz. Additionally, the effect on mutual coupling has been investigated for different trace lengths of MML.

Title: Bayesian active learning for high-throughput screening of 2D materials

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Abstract: Two-dimensional materials such as hexagonal boron-nitride have shown considerable promise in several fields including surface protection, optical sensing, nanoscale fabrication, and flexible electronics [1-4]. These applications originate from the unique chemical and physical properties of these materials, and their low form factor makes them appealing for space-constrained deployment. In order for these materials to achieve optimal performance, they must be grown under conditions which produce the best properties for the application; typically, these are large, homogenous, crystals free of point defects [2]. One aspect of these growth conditions is the substrate, which previous studies [5] have shown has a notable impact on the crystal which is produced. The determination of this optimal growth substrate is difficult however, as the sample space is too large for a full factorial experiment, but it is likewise undesirable for a domain expert to perform manual analysis of each test sample. For this reason, we propose an active learning framework to (1) study the relationship between the material property to be optimized and the substrate conditions on which it is grown and (2) efficiently determine the optimal substrate conditions. This process will be performed using test samples representing a subset of the sample space, from which the available optima will be discerned and subsequent test cases extrapolated. Active learning has previously been applied to similar material property optimization [6-12] tasks, granting us great confidence that the application of this technology should yield profitable results. The planned development of this learning framework consists of three stages. Initially, a simple material property, such as surface hardness, will be selected and a limited sample space will be fully mapped; this will be used to develop the algorithm in offline analysis. Once this development concludes, the algorithm can be applied to direct an operator during sample property measurement and guide the generation of subsequent test samples. The culmination of this system would be a fully autonomous imaging system which can find the best substrate conditions within a given sample without human involvement. Currently, we are within the first stage outlined above. A literature review of the previous AL applications within material and biological sciences has been conducted, and we are presently conversing with material science colleagues to fabricate the requisite test samples. Once developed, this will be used to build the preliminary learning algorithm.

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A Novel Direction of Arrival Estimation Technique Based on Nullforming and Nullsteering Theory

Firas Slewa, Dawod / Department of Electrical Engineering
Sayan Roy / Department of Electrical Engineering

The large diversity and broad proliferation of cutting-edge wireless applications made the requirement for smart wireless systems becomes a necessity. Nowadays, most of the surrounding objects are passively controlled while only a few of them are actively or remotely controlled. This phenomenon is expected to be reversed in the coming era. Hence, a requirement for smart controlled environment becomes more required than before. Given that we are opening now to smart cities, the internet of things (IoT), industry IoT,5G, wireless power transfer (WPT), and many other smart wireless applications, the requirement for a more efficient and more smart network became inevitable. Thus, here comes the importance of the Direction of Arrival (DoA) that provides the feature of estimating the direction of the incident signals impinging on a designed antenna array. DoA plays a crucial role in the smart antenna array design, namely, a multiple-input-multiple-output (MiMO) antenna system by feeding this antenna with angles of the signal of interest (SOI) and then steering its narrow beam toward those signals. In this poster, a novel technique has been introduced for estimating the direction of arrival (DoA) of an incident signal based on the nullforming and steering theory. On the contrary to the operation of conventional beamforming, the proposed method creates a deep and precise null that is then steered toward all the possible directions to estimate the minimum power that indicates the direction of the incident signals. What is more, this new method can outperform conventional beamforming as the resulting null is much narrower than conventional beams. Finally, this proposed nullforming and steering theory has been proven successful by both analytical and simulation validation using MATLAB Simulink model and integrated software-defined radio from Ettus Research (USRP N200).

Fossil dissolution rates at varying pH: A pilot study

Colleen Sullivan, Geology and Geological Engineering Department
Sarah Keenan, Geology and Geological Engineering Department

Fossils exposed at the surface are an integral component of paleontologic study. However, due to acidic precipitation throughout the United States, the long-term stability of these fossils is in question. Apatite, an abundant mineral in bone, exhibits pH dependent dissolution- dissolution increases as pH decreases. This characteristic of apatite becomes concerning in light of acidic precipitation trends. The goal of this study was to determine vertebrate fossil dissolution rates at varying pH. It was hypothesized fossils dissolve in acidic solutions and dissolution rates increase as solution acidity increases. It was also expected dissolution would occur on the three-week time scale of the experiments.
Three fossil vertebrae were cut into thirds to conduct the experiment in triplicate. The experiment was completed in a closed reaction vessel. The fossils were completely submerged in a tap water solution for 21 days with 0.1N hydrochloric acid (HCl) used to adjust the solution to the desired pH of 4, 5, or 6. The pH was maintained manually by adding HCl to the system every two hours from 08:00 to 18:00.
Fossil dissolution was quantified by mass loss; differences in pre- and post-dissolution elemental water chemistry and fossil chemistry; differences in pre- and post-dissolution fossil mineralogy; and thin section analysis of histologic structure degradation. All three fossils at each pH exhibited mass loss despite concomitant precipitate formation. The elemental chemistry results indicated elevated concentrations of phosphorus released into solution, which indicated fossil bone apatite dissolution since apatite was the only mineral in this system expected to contain phosphorus. The mineralogy indicated dissolution through the loss of gypsum in all post-dissolution samples. Thin section analysis showed degradation of trabeculae in all post-dissolution images. These findings constitute the first quantitative analysis of fossil dissolution rates that provide insights relevant to fossil conservation efforts, preservation biases, and taphonomic processes.

Geographic and temporal variation in the morphology of diagnostic tooth characteristics in Mesohippus and Miohippus

Author: Carolyn Kocken - Mentor: Dr. Darrin Pagnac

Distinguishing *Mesohippus* from *Miohippus* has challenged paleontologists for many years as the diagnostic characters are vague and subjective. Unassociated cranial and postcranial material make linking identifying characters problematic. Based on these unclear diagnostic characters, many have argued for the synonymy of *Mesohippus* and *Miohippus*. Prior studies have supported this recommendation, but their research has been geographically and temporally limited. This study addresses morphologic variation among *Mesohippus* and *Miohippus* fossil teeth from four sites, John Day Fossil Beds National Monument in Oregon (30-23.8 Ma), Badlands National Park in South Dakota (37-23 Ma), Toadstool Geologic Park in Nebraska (37-30 Ma), and the Renova Formation in Montana (30-23 Ma), creating a larger and more geographically diverse dataset than in past studies. Utilizing nonparametric tests for significance, ordered logistic regression, non-metric multidimensional scaling, and bivariate plots, I analyzed the M1 and P4 occlusal surface for statistically significant groupings based on genus across the sites and North American Land Mammal Ages (NALMA). Additionally, hypostyle condition was assessed by genus, site, NALMA, and correlated with tooth height to determine variability in this feature. I have concluded that while there is some geographic and temporal variation, these genera should be synonymized, with *Miohippus* taking priority, and that hypostyle type is correlated with tooth height.

Inferring habitat trends of Miocene North America using multivariate ungulate ecometrics

Rudolph Hummel, Department of Geology and Geological Engineering
Dr. Darrin Pagnac, Department of Geology and Geological Engineering

The Miocene Epoch (23.03-5.33 million years ago) of North America is characterized by a transition from closed, forested habitats to open, grassy habitats. This habitat turnover is linked to cooling, aridification, and ungulate ratiations, but its timing is poorly understood. One method used to reconstruct past habitats is ecometrics, wherein relationships between anatomy and environment are quantified for modern communities of organisms and used to infer paleoenvironment based on fossil assemblages. Past vertebrate ecometrics studies have been bivariate, comparing one anatomical trait to one environmental trait at a time. Using discriminant function analysis and multiple linear regression, I developed sixteen novel multivariate ecometric models utilizing three modern ungulate anatomical traits (body mass, hypsodonty, and calcaneal gear ratio) with two climatic variables (vegetation cover and mean annual precipitation). These models were used to predict modern vegetation cover and precipitation for both global and Sub-Saharan African spatial datasets. I then collected fossil anatomical trait data from online databases and museum collections for nineteen North American sites and formations split approximately between the Barstovian (medial Miocene) and Hemphillian (late Miocene) North American Land Mammal Ages. I used the most successful multivariate ecometrics models (identified using cross validation and adjusted R^2 values) to predict vegetation cover and precipitation at each fossil site, then used a two-tailed t-test to identify climatic trends between Barstovian and Hemphillian sites. Besides helping to inform our understanding of North American habitat turnover, this study demonstrates the potential of vertebrate multivariate ecometrics in future Neogene paleoenvironmental reconstruction.

Date: March 4th, 2022
To: Graduate Research Symposium
From: Divine Kavunga, Beck Bruch, Cory Stone, Maryam Amouamouha, Travis W. Walker
Subject: Production of Nanofiber Membranes Using Centrifugal Spinning

Abstract

Nanofibers that are formed into nonwomen mats can be utilized as a separation medium in Membrane-based technology, considering their high separation efficiencies and relatively low costs. Additionally, their small diameter, high surface-to-volume ratio, high porosity, unique mechanical behavior, and ability to efficiently capture nanoparticles provide promising opportunities for water and wastewater treatment. In this project, a centrifugal spinning (CFS) setup is designed, built, and operated to develop centrifugal nanofiber membranes. The designed CFS includes two nozzles that are mounted on a DC motor and a series of collector posts that can be placed at different radial distances. Different ultrahigh weight polymers, including dissolved polyethylene glycol (PEO) and polystyrene (PS 208) at different concentrations, are spun under similar conditions. The design and proper spinning parameters, including nozzle-collector distance, nozzle diameter, and rotational speed of the centrifuge, were studied to control and investigate the structure, morphology, and strength of the nanofiber. The centrifugal fibers later follow a thermal post-treatment to increase their packing density, and Graphene-oxide will be used to improve the mechanical properties of the centrifugally span membranes. Filtration and antimicrobial performance and properties will be analyzed.

Recycling Enriched Germanium from an Etchant Solution

Ana Sousa, Materials Engineering and Science Ph.D. Program

Bharat Jasthi, Department of Materials and Metallurgical Engineering

Cabot-Ann Christofferson, Department of Chemistry Biology and Health Sciences

Over the decades, many rare events searches are trying to prove the theory that the neutrino is also its own anti-particle, proving that the lepton number is not conserved through observing this event called neutrinoless double beta decay ($0\nu\beta\beta$). If observed, a further understanding of why there exists more matter than antimatter in the universe could be explained. The MAJORANA Demonstrator, GERDA, LEGEND200, and now LEGEND1000 are examples of these types of experiments that use the specific isotope germanium (^{76}Ge), exhibiting excellent resolution for observing this rare event.

A large quantity of ^{76}Ge is needed to have a significant signal since it is used both as the source and detector. It is necessary to guarantee low background in radiation to capture the signal of the $0\nu\beta\beta$, and one of the ways to ensure this is using ultrapure materials. Thus, the Ge must go through an enrichment process that certifies the composition of 92% of the ^{76}Ge isotope, resulting in a more favorable signal-to-background ratio.

During the Ge detector fabrication, many losses occur, such as cuttings and grindings with lubricant/water, detector blank crystal pulling, Ge contaminated with other metals, low purity Ge, and Ge removed in the etchant solution. Regarding this last loss, there is not yet a developed process to recycle any etching solution, and this is the focus of this research.

Approximately 5% of the input material is lost during the etching process, since LEGEND1000 needs to produce 1100kg of enriched ^{76}Ge, the projected loss is 55kg. Knowing that the material cost is \$100/g, thus, developing a ^{76}Ge recycling process from the etchant solution has an economic potential to save up to \$5.5 million. Thus, even a yield recovery of 20% would be significant. Therefore, different routes for recycling this material will be explored during this research.

Title: Microstructure and Mechanical properties of Oxide Dispersion Strengthened Nickel Cold Sprayed Coatings

Author: Kole Vollmer - Mentor: Dr. Bharat Jasthi

The main objective of this work is to investigate the microstructure and mechanical properties of Oxide dispersion strengthened (ODS) nickel cold sprayed coatings. ODS materials have recently been investigated and considered for next generation nuclear reactors due to their high temperature mechanical properties. This is achieved by finely dispersed nano scale oxide particles (eg: Y_2O_3, ThO_2 and Al_2O_3), in the materials matrix, which can impede the recrystallization and grain growth at high temperatures. In the present work, commercially pure nickel was determined to provide good corrosion properties while also providing excellent cold sprayability. Cold spray (CS) is a solid state process which can be used for in-situ repair of components. ODS Ni powders used for CS were produced using a low-energy mechanical alloying method and consisted of 0.8 wt% Y_2O_3 and Ni to balance. Scanning electron microscopy (SEM) along with Energy dispersive X-ray spectroscopy (EDS) was used to characterize the ODS powders. Preliminary results suggest that the particle size decreased with increase in milling time and uniform distribution of Y_2O_3 on nickel particles was observed only after milling for 168 hours.

Keywords: ODS nickel; yttria; low-energy mechanical alloying; cold spraying; energy dispersive x-ray spectroscopy

The Influence of Solvent Selection on Nitrocellulose-based, Perchlorate-Free Red-and Green-light Illuminants

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Abstract

Nitrocellulose (NC) has been used since the late 1800's in numerous energetic formulations; however, the effect of processing agents (solvents, etc.) on performance has not been thoroughly detailed. For illuminate applications, this is critical as spectral purity and dominant wavelength must meet specifications. In this effort, six processing agents (water, ethanol, isopropyl alcohol, ethyl acetate, acetone, and tetrahydrofuran) are evaluated and the effect they have on the NC fibers and subsequent performance is detailed. XRD and FTIR analysis indicate that the choice of processing agent directly effects the molecular integrity of the NC fibers due to the inhibition of NO_2 bonds as well as freeing of hydrogen bonds between polymer chains during solubilization. Time stepped FTIR analysis indicated that the weak nitrate ester bond (R-ONO_2) is targeted when processed in tetrahydrofuran, ethyl acetate, or acetone, and if heavy solvent interaction occurs, can lead to the autocatalytic decomposition of NC, when heat treated at 110 °C. Spectral performance is detrimentally impacted as a result of such interactions. While all six processing agents for red-light illuminant formulations met the military requirements (i.e., spectral purity and wavelength), only ethanol and isopropyl alcohol processed formulations met the military required wavelength of 540 ± 20 nm for green-light illuminants. The IPA processed formulations exhibited the best results with spectral purity values of 69.0% and 94.8% for green and red-light illuminants, respectively.

A Novel Approach to Produce Reactive Ni-Al Nanocomposites via Acoustic Milling

Madilyn Fesenmaier (MES Grad)
Dr. Groven (CBE) and Dr. Crawford (MET)

Metal-based reactive composites are of interest as structural energetic materials for use in a variety of defense applications including ammunition, shells, and munition. The Ni-Al metallic system has been extensively studied for defense applications because a large energy release occurs upon the formation of nickel-aluminum intermetallics. Reaction onset temperature and energy can be lowered through processing techniques, such as high energy ball milling. This research focused on the evaluation of acoustic milling as an alternative method for processing Ni-Al powders. The influence of milling time, intensity, and media size on the resulting microstructure and energetic properties of milled powder were evaluated. Microstructure characterization was conducted using scanning electron microscopy, energy dispersive x-ray spectroscopy, and x-ray diffraction. Energetic properties were evaluated using differential scanning calorimetry and high-speed imaging.

Comparing helium and nitrogen cold spray aluminum coatings using mechanical testing and X-ray diffraction

Author: Nathan Staley - Mentor: Dr. Grant Crawford

Understanding and improving cold spray coatings are important goals for aerospace repair and additive manufacturing industries. The connection between residual stress, mechanical behavior, and carrier gas species needs to be understood to produce more sustainable cold spray technology. 6061 aluminum alloy cold spray coatings were produced using helium and nitrogen gas as carriers. Metal matrix composite coatings comprising zirconia particles embedded within a 6061 aluminum alloy matrix, were also produced using nitrogen gas. Mechanical properties of the coatings were characterized using uniaxial tensile testing, three-lug shear adhesion testing, and microhardness evaluation. Coating residual stress was measured as a function of depth using electropolishing in conjunction with X-ray diffraction. The relationship between cold spray conditions, coating composition, mechanical properties, and residual stress profiles will be discussed.

Cold Spray Deposited Aluminum-Zinc-Indium as a Novel Sacrificial Anode Coating

Author: Roy Kesterson - Mentor: Dr. Grant Crawford

Aluminum-Zinc-Indium alloys have been of particular interest in use for cathodic protection. However use of this alloy as a sacrificial anode coating deposited via cold spray has not been previously established. This work examines the influence of powder characteristics on the efficacy of cold spray depositions on steel and aluminum substrates for multiple Aluminum-Zinc-Indium powders, and identifies the corrosion behavior of the depositions on both steel and aluminum substrates. Two Aluminum-Zinc-Indium powders were deposited on both aluminum and steel substrates. Powders were characterized using powder size analysis, scanning electron microscopy, and inductively coupled plasma spectroscopy. The depositions were characterized using adhesion testing, Vickers microhardness, microscopy, open-circuit potential, potentiodynamic polarization, and zero resistance ammetry.

Physical Vapor Deposition of Solid-State Li-ion Battery Cathodes and Electrolytes

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Abstract

As the search for improved energy storage methods progresses, all-solid-state batteries (ASSB's) prove to be a promising alternative to conventional lithium-ion batteries which have reached the limit of their technological capabilities. The next-generation lithium-ion batteries are expected to be eco-friendly, long-lasting, safe, demonstrate high energy density, and provide ultrafast charging. However, these much-needed properties require significant efforts to uncover and utilize the chemical, morphological, and electrochemical properties of solid-state electrolytes and cathode nanocomposites. This project utilizes physical vapor deposition (PVD) technology to deposit solid-state battery materials. PVD allows ASSB cathodes and electrolytes to be deposited as dense, thin films, decreasing the size and amount of material needed for batteries. Another advantage of using PVD technology is the ability to layer multiple electrochemical cells in a single process. This is a more efficient method of stacking multiple cells in series to achieve the desired voltage. This work uses lithium oxyhalide electrolytes and lithium iron phosphate cathodes, which were both deposited using radio frequency power and magnetron sputtering sources in a vacuum chamber. This method results in enhanced cathode/electrolyte interfaces that allow exceptionally high charging rates (> 4000C), while maintaining electrochemical stability of solid-state electrolyte in the presence of lithium metal anode and lithium iron phosphate-based cathode. The cells exhibit long cycle life (> 1800 cycles at 100^{o}C) and offer a promising route to the next-generation all-solid-state battery technology.

Energetic and Optically Responsive Cargo in Porous Walled Hollow Glass Microspheres for Anti-Counterfeiting Applications

Author: Kirstie Gildemeister - Mentor: Dr. Grant Crawford

Counterfeit goods are increasingly entering global supply chains and illicit actors are becoming more adept at deceiving consumers and inspection. Development of new anti-counterfeiting technologies is required to combat this illicit market. In this research, porous walled hollow glass microspheres (PWHGMs) were utilized as inert and modified containers for energetic and optically responsive materials. The energetic material system was produced by loading a saturated aqueous solution of ammonium perchlorate in the PWHGMs using an iterative vacuum loading method. The PWHGMs with AP cargo were rinsed and coated with hydroxyl-terminated polybutadiene (HTPB). HTPB coated PWHGMs resulted in a system that remains unreactive until tampering allows for the AP and HTPB to react. Loading efficiency of the AP cargo was quantified by measuring solution conductivity, SEM analysis, UV-vis response, and performing precipitation gravimetry after AP loading in the PWHGMs. A second materials system was developed in which β-$NaYF_4$: 48%Yb/2%Tm upconversion nanoparticles (UCNPs) were loaded into PWHGMs to produce a tamper sensitive, covert, security feature. The PWHGMs serve as a container for the optically responsive UCNPs such that an opaque coating can be applied to the PWHGM surface without modifying the UCNPs. The optical response of the UCNP/PWHGMs was captured via a modified digital camera and using a 980 nm laser. Further hyperspectral imaging and SEM/EDS on focus ion beam (FIB) milled samples was performed on the UCNP/PWHGMs.

Microstructural processing and phase stabilization analysis of off-stoichiometric Fe-Mn-Ga shape memory alloy for energy harvesting

N. A. Adoo and N. M. Bruno

Abstract

Metamagnetic shape-memory alloys (MSMA) are a group of Heusler materials which have gained attention due to their multifunctional capabilities derived from their wide-range tunable thermal, magnetic, electrical, and structural/mechanical properties. These unique characteristics are largely associated with reversible martensitic transformation (MT) and metamagnetic phase transition resulting in large magnetic field-induced strains (MFIS) and pseudoelasticity correlated to a large inverse Magneto-caloric Effect (MCE), making them highly useful in devices such as energy harvesters, sensors (actuators), among others. Despite their multifunctionality, fabrication of these materials is challenging because they are brittle and a non-transforming phase stabilizes with slow cooling. FeMnGa MSMAs have been shown to exhibit higher ductility and better overall energy conversion capabilities compared to NiMn-based SMA. However, FeMnGa SMAs are characterized by large transformation hysteresis due to the stabilization of mixed microstructural phases, which interrupts the reversible phase transition. This work has identified a range of compositions for the FeMnGa ternary alloy and investigating ways to engineer stable microstructural phases that guarantee low transformation hysteresis to enable the alloy contend for future engineering applications.

Geofingerprinting of Columbite-Tantalite Ores

Author: Samuel Kessinger - Mentor: Dr. Jon Kellar

Following the enactment of the Dodd-Frank Act in 2010 (section 1502) US companies have been required to report utilization of so-called conflict minerals from the Democratic Republic of Congo (DRC). The conflict mineral coltan, an ore consisting of elements tantalum and niobium, is central to Dodd-Frank legislation. Thus, track-and-trace methodologies are necessary to define the provenance of such conflict minerals. In the current research effort XRF (X-Ray Fluorescence) spectroscopy and LIBS (Laser Induced Breakdown Spectroscopy) have been used to identify elemental fingerprints of coltan samples with known provenances. Individual mineral spectra were used in conjunction with machine learning classification algorithms. It was demonstrated that the algorithms were able to classify samples, using each sample's individual spectra, culminating in the determination of a sample's provenance.

Influence of buffer layers on the mechanical and microstructural properties of BN thin films deposited using Pulsed Laser Deposition

Venkata Ananth Kandadai, Materials and Metallurgical Engineering
Bharat K Jasthi, Associate Professor, Materials and Metallurgical Engineering

The main objective of this work is to investigate the effect of buffer layers (Cu and Ti) and deposition temperatures (room temperature RT, 300°C, 500°C, and 800°C) on the microstructure and mechanical properties of boron nitride (BN) thin films deposited using the pulsed laser deposition (PLD) process. The surface roughness of the BN coatings was analyzed using Confocal Laser Scanning Microscope, and results suggest that surface roughness increased with the deposition temperature. The microstructural characterization of BN thin films was carried out using Scanning electron microscopy SEM revealed that the different thin film growth modes were observed as a function of buffer layers and deposition temperature. RAMAN spectroscopy shows the presence of the hBN phase (with E_{2g} ~1366 cm^{-1}) in deposited BN thin films. The FWHM of RAMAN spectroscopy shows that the crystallinity of BN thin films decreases with an increase in temperature, which is correlated to microstructural properties. The narrowest peak width of 37 cm^{-1} was observed for BN thin films deposited on Si and Ti as a buffer layer at room temperature. The mechanical properties such as the hardness and modulus of the hBN nanofilms were characterized using the nanoindentation technique, which doesn't show the significant difference in BN/Si and BN/Ti/Si; however, BN/Cu/Si shows poor mechanical properties due to its least dense structure. The contact angle measurements of BN thin films show hydrophilicity ($\theta<90°$), and BN/Cu/Si shows an increasing trend with deposition temperature, which can be attributed to its higher surface roughness.

Cold Atmospheric Plasma Induced Defects in 2-D Graphene: Pathway to Improved Functionalities

Christian, Leckband & Mechanical Engineering Department
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Bheemasetti, Sravani
Dr. Kalimuthu Jawahar
Dr. Gadhamshetty Venkata

Advisors:
Dr. Parsoon Diwakar & Mechanical Engineering Department

The purpose of this study is to explore the effects of Cold Atmospheric Plasma (CAP) on a 2-D graphene layer and defect modification using Raman spectroscopy and contact angle measurement. Does CAP modify existing defects cause changes in hydrophobicity or hydrophilic properties of 2-D graphene? A Cold Atmospheric Plasma (CAP)is introduced for a specific amount of time to the 2-D graphene layer. Next, the CAP introduced sample was analyzed using Raman spectroscopy to quantify changes in defects in the 2-D layer. Further, the wettability of the graphene coatings was analyzed by a contact angle goniometer; the obtained water droplets were analyzed to estimate the water contact angle. Upon analyzing the Raman data, the peak at 1870 cm-1 for the 30second exposure of Cold Atmospheric Plasma decreases, corresponding to the water contact angle for the sample. The 30sec exposure results in a hydrophilic, with approximately a 180-degree water contact angle. The material becomes hydrophobic again after 60 seconds of exposure and returns almost to a similar hydrophobic property. The material properties could be changing because of 2 different mechanisms. The first is that an ionized oxygen atom is causing an interstitial defect in the lattice of the graphene structure. The second is that a hydroxyl group is attached to a broken bond between carbon atoms in the graphene structure. Further studies are in progress to explore the exact mechanism of surface changes when 2D graphene is exposed with CAP.

Machine Learning assisted Laser Diagnostic Methods for Analysis of Exhaust Particulate Matter in Standard Fuels and New Biofuels

Thomas Machamer Mechanical Engineering

Mentors: Prasoon Diwakar & Micah Lande

In this study, a novel method of conducting near-real-time analysis of products of regular fuels, as well as biofuels is presented. This method will use microneedle electrodes to collect soot and exhaust particulate matter which will then be monitored by laser-based diagnostics including laser-induced breakdown spectroscopy, laser induced incandesce, Raman spectroscopy and spark-induced breakdown spectroscopy. This system will support the analysis of particulate matter, including ultrafine nanoparticles with the intent to reduce their formation due to the health risks they can create. Additionally, machine learning will be implemented to produce results faster allowing the system to be more intuitive to increase its convenience for real world applications. Collection times are also to be varied to analyze general soot output for short time intervals as well as overall pollutant production for long term use.

Making Learning Goals More Apparent Across the Curriculum for Mechanical Engineering Fundamentals and Depth Courses

Author: Adrianna Larson - Mentor: Dr. Micah Lande

Mechanical engineering education consists of a broad set of topic areas balanced across the introductory courses, capstone design, and engineering coursework. As a result, students are exposed to multiple branches of modern engineering and related fields of study. Yet, even within class sections, a variety of approaches often make classes seem like completely different content, even when they are using the same learning guidelines. Classes can be taught by professors within the same department and still impart radically different lessons to the students. Often, the pedagogical approaches by each faculty may make it less than clear to students as to the connections among and across classes and topic areas. The technical depth is spread across the engineering fundamentals and upper-level depth courses, with many prerequisite chains covering multiple breadths.

This paper explores how technical content is organized within a course, both laterally across courses taken simultaneously and longitudinally across semesters. This paper also discusses how different pedagogical approaches are implemented, particularly in the fundamentals and depth courses. Documentation analysis of class descriptions and appraisal of learning goals using Bloom's Taxonomy provides a categorization of the framework of learning activities.

This paper has implications to inform how our academic unit communicates the structure and organization of our course structure and content. There also may be some amount of expert blindness of the collective faculty with some assumption about how learning experiences connect and build on each other, which may not be as immediately evident to students. It is hoped that this class-level granularity can help better illustrate what and how mechanical engineering undergraduate students learn.

The Application of Machine Learning on Mars Laser-Induced Breakdown Spectroscopy

James Gormley, South Dakota School of Mines and Technology Department of Mechanical Engineering
Prasoon Diwakar, South Dakota School of Mines and Technology Department of Mechanical Engineering

The study of Mars has been a focus in space exploration for over 60 years. These missions have included flybys, satellites, and surface rovers with a wide array of instruments. One such instrument is the ChemCam aboard the Curiosity Rover. ChemCam is a Laser-Induced Breakdown Spectroscopy (LIBS) instrument used to identify the chemical and mineral composition of the Martian surface. This instrument has provided over 9 years of LIBS data and is valuable in understanding the different mineralogy of various planetary regoliths.

The goal of this study is to develop a machine-learning (ML) based analysis technology for Mars site characterization operations with the capabilities of identifying mineralogy, elemental composition, and classify various geological areas for Martian samples. Building on existing data from ChemCam and integrating new ML data analytics the proposed tool will use a system of LIBS and trained algorithms to achieve the stated goal. This combination of spectroscopy and machine learning techniques will improve the efficiency of gaining insight from scientific studies on Mars.

Implementing Adaptive Neural Network and Extended Kalman Filter in Autonomous Underwater Vehicles on Internet of Underwater Things

Author: Md Niamul Quader - Mentor: Dr. Hadi Fekrmandi

Abstract:

Improving the performance by detecting the faults and failures in low-cost autonomous underwater vehicles (AUVs) systems is crucial in various environments like oceanographic survey, autonomous docking, and shallow-water mine, mapping the seafloor. In this study, we applied the Adaptive Neural Network (ANN) and Extended Kalman Filters (EKF) to the depth-plane model of the AUV to identify the effectiveness of the fault detection strategy. The significance of this method is demonstrated by detecting an incipient fault in the depth sensor, and ANN has sufficient time to adjust or learn the system's changes and the system's ability for prompt detection and isolation of a variety of sensor faults. Moreover, we will use the Internet of underwater things (IoUT) for tracing our model and enable the monitoring and exploration of the maritime environment for various purposes. Further study is needed to develop experimental validation and verification of the proposed algorithm.

Keywords: Internet of Underwater Things (IoUT), Adaptive Neural Network (ANN), Extended Kalman Filter (EKF), Nonlinear model, Sensor.

The Effect of Trapped Fumes on Clearance Time in Underground Development Blasting

Akash Adhikari, Mining Engineering and Management
Purushotham Tukkaraja, Mining Engineering and Management

Previous studies on blast fumes, carbon monoxide, nitrogen dioxide clearance, and workplace re-entry time have overlooked the effects of toxic gases trapped in the muckpile. The currently available models for calculating the mine re-entry times assume that all post-blast fumes are emitted upon detonation. However, recent studies reported that as much as 60% to 70% of the fumes or gases produced during an underground development blasting could remain trapped in the adjacent rock mass or in the muckpile. Trapped fumes are slowly released, and when disturbed, high concentrations are released, representing a possible risk during the digging and transportation of the muckpile. In this study, mathematical models were developed using Computational Fluid Dynamics to understand the behavior of the trapped fumes and their effect on mine re-entry time. The three scenarios considered for this study include i) gas emission source with no muckpile volume, ii) gas emission source with non-porous muckpile volume, and iii) gas emission source with porous muckpile volume. The estimated re-entry times in all three scenarios were compared to see how porous media affects dilution time. It was observed that Scenario 3, with fumes trapped in the muckpile took significantly longer clearance time (more than double) as compared to Scenarios 1 and 2.

Directing Extracellular Matrix Assembly using Hyaluronic Acid Binding Peptide Functionalized Surfaces

Beth Blake, Tugba Ozdemir

Fibrous capsules are formed around the implant surfaces by myofibroblasts which differentiated from resident fibroblast and can cause implant rejection. Differentiated myofibroblasts along with giant cells deposit excessive collagen which is a fibrillar component of extracellular matrix (ECM). Functionalizing implant surfaces with bioactive peptides with antibacterial activity, cell adhesion moieties, or anti-immunogenic activities shown success in the past. We hypothesized that, by functionalizing the implant surfaces using peptides that instruct the way cells deposit ECM has the potential to change fibrotic ECM formation. To test our hypothesis, we chose a biomimetic peptide sequence from Hyaluronic acid binding proteins (HABP) that exists in cell membranes. Hyaluronic acid (HA) is a proteoglycan known to have roles in collagen deposition and fibril organization. The proposed strategy involves introducing HABP onto surfaces through 3-Aminopropyl(triethoxysilane) (APTMS) mediated chemisorption followed by cell derived ECM assembly. Human primary dermal fibroblasts (HDFs) were cultured to 70% confluency, and then 50,000 cells/154mm^2 HDFs were seeded onto the functionalized surface; after 11 days, an extraction buffer was used to remove cellular debris from deposited ECM. Methylene blue staining was used to verify the presence of HA. Confirmation of collagen I deposition from HDFs was performed using immunofluorescence labeling and SEM. HDFs were fixed on HABP functionalized surfaces, followed by permeabilizing and primary antibody labeling. Fluorescence labeled secondary antibodies were used to detect collagen using a fluorescence microscope. ImageJ was used to analyze collagen alignment and density from fluorescent and SEM images. We tested fibroblast morphology, HA deposition along with collagen deposition, thickness and orientation. We found that fibroblasts organized an aligned morphology on HABP coated surfaces compared to untreated surface and scrambled peptide controls. Currently our investigations are ongoing to detect changes in ECM assembly.

Functionalized carbon nanotubes-reinforced anti-static and anti-corrosion aircraft coatings

Ding Lou, Department of Nanoscience & Nanoengineering
Advisor: Dr. Haiping Hong, Department of Electrical Engineering

Electrically insulating aircraft coatings increase the likelihood of dangerous charge buildup due to static electricity accumulation and cannot protect from lightning strikes. People currently use carbon fibers (CFs) as conductive fillers to provide sufficient electrical conductivity for the anti-static protection for aircraft. However, these micro-sized CFs are hard to disperse, making the application of the coating layer extremely unprofitable and time-consuming. In addition, the CFs-based anti-static coating layer is applied on top of a rain-erosion coating layer. There is a need to develop a multifunctional coating system that provides both electrostatic and rain-erosion protections.

In this study, an electrically conductive coating consisting of a durable aircraft rain-erosion coating and functionalized multiwalled carbon nanotube (MWNT-OH) filler is developed to prevent static charge buildup and increase lightning strike survival. The sheet resistance of the coating samples was measured using a four-probe setup. The sample containing 2.0 wt.% MWNT-OH yielded a sheet resistance of 16.8 Mohm/square, and the sample containing 3.0 wt.% MWNT-OH generated a sheet resistance of 0.2 Mohm/square. Both of these two samples fell in the range of the resistance requirement of anti-static protection. In the meantime, these nanofiller-reinforced coating samples maintained rain-erosion protection as good as the base coating. In addition, electrochemical methods were used to evaluate the anti-corrosion properties of the coating samples. The corrosion rate of the sample containing 2.0 wt.% MWNT-OH was calculated to be 6.3×10^{-5} mm/year by potentiodynamic polarization scan. The impedance modulus of the sample increased by three orders of magnitude compared to the base coating. It is worth noting that ethanol was introduced as a solvent, which significantly improved the dispersion of the nanofillers.

Reversing the Epithelial−Mesenchymal Transition in Metastatic Cancer Cells Using CD146-Targeted Black Phosphorus Nanosheets and a Mild Photothermal Treatment

Presenter: Jinyuan Liu Nanoscience and Nanoengineering

Advisor: Congzhou Wang Nanoscience and Nanoengineering

Cancer metastasis leads to most deaths in cancer patients, and the epithelial mesenchymal transition (EMT) is the key mechanism for cancer metastasis. During EMT, epithelial cancer cells evolve into a mesenchymal phenotype through the suppression of epithelial markers, upregulation of mesenchymal markers, and reorganization of actin cytoskeleton, which endow cancer cells with strong migratory and invasive capabilities. Cluster of differentiation 146 (CD146) are closely linked to metastasis propensity of several cancers and a poor prognosis. It was found that CD146 acts as an EMT inducer via activation of a small GTPase protein (i.e., RhoA), and the RhoA activation regulates reorganization of actin cytoskeleton and expression of EMT transcriptional factors, thereby triggering the EMT process. Here, we present a nanomaterial-based approach to reverse the EMT in cancer cells by targeting CD146, using engineered black phosphorus nanosheets (BPNSs) and a mild photothermal treatment. We demonstrate this approach can convert highly metastatic, mesenchymal-type breast cancer cells to an epithelial phenotype (i.e., reversing EMT), leading to a complete stoppage of cancer cell migration. By using advanced nanomechanical and super-resolution imaging, complemented by immunoblotting, we validate the phenotypic switch in the cancer cells, as evidenced by the altered actin organization and cell morphology, downregulation of mesenchymal protein markers, and upregulation of epithelial protein markers. We also elucidate the molecular mechanism behind the reversal of EMT. Our results reveal that CD146-targeted BPNSs and a mild photothermal treatment synergistically contribute to EMT reversal by downregulating membrane CD146 and perturbing its downstream EMT-related signaling pathways. Considering CD146 overexpression has been confirmed on the surface of a variety of metastatic, mesenchymal-like cancer cells, this approach could be applicable for treating cancer metastasis *via* modulating the phenotype switch in cancer cells.

ELECTROMECHANICAL STUDIES OF STRETCHABLE STRAIN SENSORS BASED ON CONDUCTIVE NANOFIBROUS FILMS EMBEDDED IN PDMS

Authors:

Obiora Onyilagha, Department of Nanoscience and Nanoengineering

Dr. Zhengtao Zhu, Department of Biology, Chemistry and Health Sciences

Flexible and stretchable strain sensors were developed to measure strain associated with human motion. These strain sensors were based on a system of conductive nanofibrous films embedded in Polydimethylsiloxane (PDMS) substrate. The conductive nanofibrous films were made of materials of varying stiffness: carbon, a ceramic (silica coated with poly(3,4-ethylenedioxythiophene)), and a polymer (polyvinylidene fluoride coated with poly (3.4-ethylenedioxythiophene)). The mechanical and piezoresistive properties of each type of strain sensor was systematically studied. Our results showed that the strain sensor with the highest Young's modulus exhibited the highest sensitivity to strain and the least stretchability (maximum strain) and vice versa. These results would be useful in the design of strain sensors with desired sensitivity and stretchability. for wearable applications.

Macrophage membrane dynamics and local geometry are influenced by the presence of CD47 on targets during FcγR-mediated phagocytosis

Yoseph Loyd Nanoscience and Nanoengineering

Robert Anderson, PhD Nanoscience and Nanoengineering

Brandon L. Scott, PhD Nanoscience and Nanoengineering

Fcγ receptor-mediated phagocytosis in macrophages occurs as FcγRs recognize antibodies bound to the target surface generating an “eat” signal resulting in the internalization of the target through actin driven membrane extensions. Opposing “don’t eat” signals exist to hinder phagocytosis of weakly opsonized native cells. Advanced microscopy and image analysis pipelines enable the acquisition of volumetric timeseries with diffraction-limited resolution and sufficient temporal resolution to quantify membrane dynamics. Through these techniques we refine our understanding of how “don’t eat” signaling by CD47 influences target internalization and the macrophage membrane dynamics during phagosome formation. Using antibody-labeled sheep red blood cells (RBC) as targets exclusively displaying “eat” signals, we show that the macrophage lamella wraps tightly around the target and additional membrane protrusions develop nearby the forming phagocytic cup. Additionally, local transient increases in membrane ruffling activity occurs at the site of internalization. Using mouse RBCs which generate the species matched CD47 “don’t eat” signals in addition to “eat” IgG signals resulted in a reduction in membrane dynamics at sites of phagocytosis; however, target internalization is unchanged. Finally, we used the anti-CD47 antibody, Miap301, on wildtype mouse RBCs which resulted in increased membrane dynamics that resembled phagocytosis of sheep RBCs. These results indicate that CD47 dampens the phagocytic response but while not impeding the internalization of the small targets.

Human endothelial leakiness induced by human serum albumin coated gold nanorods

Abstract for Student Research Symposium

Zhengqiang Li, Nanoscience and Nanoengineering

Advisor: Dr. Congzhou Wang

As the interior wall of human blood vessels, endothelial cells form a monolayer lining between the blood stream and the extra-blood tissue. This layer of cells, termed as endothelium barrier, acts as the door keeper or janitor to control not only the small molecules, such as water, saccharide, but also enzymes, lymphatic cells such as leukocytes to cross or transfer through this barrier layer. The loss of endothelium integrity can cause a variety of cardiovascular disease, including edema, atherosclerosis. Human serum albumin (HSA) has been proved to be an effective dysopsonin protein in the blood stream, where HSA coating on nanoparticle-delivery vehicles can prevent the immune response initiated by pristine nanoparticles and prolong the blood circulation time of the nanoparticles. Gold nanorods have been used in drug-delivery, nano-biosensor, and cancer therapy because of their biocompatibility, tunable size and optical property, and photothermal effect. Therefore, human serum albumin coated gold nanorods (HSA@AuNRs) seem to be a safe option for in vivo applications. However, there is an albumin-specific binding protein, named gp60, on the endothelial cell surface, which may promote the endothelium uptake of albumin-coated gold nanorods and induce the change of cytoskeletal structure of the cells, especially the actin network. These changes in actin network may result in endothelial cell deformation and cell-cell junction leakiness, which could be detrimental to the function of endothelial barrier. In this talk, I will present our preliminary results regarding gold nanorods synthesis and albumin coating, and evaluation of endothelial leakiness and actin remodeling induced by the endothelial uptake of low-dose HSA@AuNRs. The molecular mechanism of the HSA@AuNRs induced endothelial leakiness and actin remodeling will also be discussed.

Abstract

Hosein, Mirazi& Nano technology
PI, Faculty Mentor/Advisor Name: Dr. Scott Wood & NANO Technology

In our project we are making the scaffold based on very simple trick. We know that the main difference between synovial fluid and blood plasma is related to the main element which is HA (hyaluronic acid). The formulate of blood is:

So, we need to collect the blood at first and then by subtracting the WBC and RBC we could reach to the plasma. Then by adding the HA we could have the most similar component to the synovial fluid which is one the most important part of our joint in knee. Joint is composed by three different parts which are Bone, Cartilage, and synovial fluid. To have the same ingredient in our component, we collect the blood form the cow which has the most similar blood to the blood human. Especially from the economical point of view, it is free for us, and we do not pay any money for collecting this blood. after making the scaffold we need to put this scaffold next to the other important parts like bone and cartilage. For this purpose, we need to design a model which represents and simulate the human joint. Before that, it is worthy the technology for this purpose which is being used at this time is named, chip technology. This technology is highly recommended for some applications in the pharmaceutical companies or other researchers who are interested to mimic and imitate the different organs of human body indeed out of the body and after that do some analysis based on their approaches. In addition, by using this technology, researchers can see and evaluate the disease conditions and find the best treatment for those situations.

Investigating Contradictory Results in the Study of 12C+12C Interactions in Stellar Evolution

Abbi Elger, Physics
Frank Strieder, Physics

A common goal among in astrophysics is to develop and refine stellar models. Using particle accelerators, this can be achieved without leaving the comfort of Earth's surface. Carbon burning is third stage of stellar evolution after hydrogen and helium burning and a set of reactions which occur in massive stars with at least 8 solar masses. A deeper understanding of these reactions will in turn allow for a better understanding of the stellar model. We can estimate the energy and temperature which these reactions are most likely to occur by using the product of the Maxwellian distribution and tunneling probability. This range was found to be between 1 and 2 MeV for carbon burning. Unfortunately, for measurements of the rate of reactions at such low energies, the background and the low probability become dominating factors. Respecting the restrictions caused by the nature of the experiment, we can use extrapolation techniques to estimate the structure of the rate of reactions at low energies using data collected from $^{12}C+^{12}C$ collision experiments at higher energies. Despite several groups using the same sets of data to perform these investigations, there are significant disagreements on the structure of reaction rates and in the conclusions. My talk will review significant milestones in measuring carbon reactions, examine recent results, and illustrate a possible path forward in the study of these reactions.

Enhancing Energy Product of MnBi by Doping: Ab-initio Predictions and Experimental Verifications

Bhubnesh Lama, Department of Physics, SD Mines
Parashu Kharel, Department of Physics, South Dakota State University
Tula R Paudel, Department of Physics, SD Mines

High energy density magnets are preferred over induction magnets for many applications, including electric motors used in flying rovers, electric vehicles, and wind turbines. However, several issues related to cost and supply with state-of-the-art rare-earth-based magnets necessitate development of high-flux magnets containing low-cost earth-abundant materials. Here, by using first-principles density functional theory, we demonstrate the possibility of tuning magnetization and magnetocrystalline anisotropy of one of the candidate materials, MnBi, by alloying it with foreign elements. By using density functional theory in the high-throughput fashion, we consider the possibility of various metal and non-metal elements in the periodic table occupying empty sites of MnBi and found that MnBi-based alloys with Rh, Pd, Li, and O are stable against decomposition to constituent elements and have larger magnetization energy product compared to MnBi. Additionally, it is found that when C is doped in MnBi, it tends to go to the surface and enhances surface magnetization. In agreement with our predictions, experimental results show an increase in magnetization of MnBi upon including C. Combined with other favorable properties of MnBi, such as high Curie temperature and earth abundancy of constituent elements, we envision the possibility of MnBi-based high-energy-density magnets.

Title:
A new combined reconstruction for Cosmic Rays eventus using the IceCube experiment.

Author: Diana Leon Silverio - Mentor: Dr. Xinhua Bai

Abstract:
The IceCube Neutrino Observatory is the world's largest neutrino observatory located at the South Pole. IceCube detector is capable of measuring two components of the cosmic rays air shower. The electromagnetic component using a km2 surface array IceTop, and the high-energy muonic component using km3 in-ice array IceCube between 1.5 and 2.5 km below the surface. The combination of both arrays provides an opportunity for possible improvements of cosmic rays reconstruction based on a minimization of a unified likelihood function. This talk presents a preliminary investigation of possible improvements for Cosmic Rays reconstruction by using a combined reconstruction with Monte Carlo events for proton and iron primaries under two different containment conditions.

Seasonal Variation of Dark Matter Signals in the LZ Experiment at Sanford Lab

Jack Genovesi, Physics Department
Mentor/Advisor: Dr. Juergen Reichenbacher, Physics Department

Despite the lack of direct evidence, there is already an abundance of indirect evidence that points to a non-luminous new form of matter that exists in significant quantities throughout our universe. The theory of Weakly Interacting Massive Particles (WIMPs) provides an attractive new candidate particle for dark matter. It describes a relatively heavy electrically-neutral particle that only interacts through gravity and via the weak nuclear force. WIMPs would describe a halo of gaseous-like dark matter surrounding galaxies which would also solve the anomalous galactic rotation velocities of stars observed in all galaxies. Due to the rotation of our galaxy our own solar system experiences an induced “WIMP wind” if passing through such a dark matter distribution, which features a Maxwell-Boltzmann velocity distribution. We hope to either discover or refute WIMPs with the LUX-ZEPLIN (LZ) detector located at the Sanford Underground Research Facility (SURF). The LZ detector is an ultra-quiet dual-phase liquid xenon Time Projection Chamber (TPC) which will be used to acquire about three years worth of data. A potentially critical tool to differentiate WIMPs from other dark matter candidates and/or background is that due to the rotation of Earth around the Sun, there would be a seasonally changing detection rate with a unique signature for the WIMP dark matter compared to radioactive background contributions. With this in mind, a well-defined annual modulation of dark matter candidate events would provide a smoking gun in discovering WIMP dark matter.

Abstract for 2022 SDSMT Research Symposium

James Haiston

Design and Simulation of a 9 MeV γ-Ray Calibration Source for the DUNE Neutrino Experiment at Sanford Lab

Co-author: Dr. Juergen Reichenbacher
Mentor/Advisor: Dr. Juergen Reichenbacher, Department of Physics

The Deep Underground Neutrino Experiment (DUNE) is located at the Sanford Underground Research Facility (SURF) in the former Homestake Mine in Lead, SD. The DUNE detector will be comprised of four individual 10 kton liquid argon modules. The first module is scheduled to be operational in July 2026.

For DUNE it is important to understand the detector response to low low-energy neutrino events from both supernova and solar sources. The deployment of a calibration source which can mimic these low energy events is necessary to ensure that the signal response of the DUNE detector is well understood. The deployed nickel (n, γ) calibration source will be designed to emit clean 9 MeV gamma-rays induced by neutron captures on nickel to meet this task.

There are specific requirements to the deployment of a calibration source; the source must be able to endure cryogenic temperatures (87 K), it must not float, it must fit easily through the sealable flanges which have a relatively small diameter of 20 cm, and the moderator thus limited in size must still be efficient enough to thermalize neutrons so that the desired 58Ni(n, γ)59Ni reaction can occur and produce the desired 9 MeV γ-rays at a sufficient rate and purity for calibration purposes of DUNE.

Results from computer simulations utilizing the GEANT4 simulation framework are presented. Feasibility of a new compact nickel (n, γ) calibration source has been demonstrated by optimizing the configuration, location pattern and number of natural nickel rods placed inside a moderator made of high density plastic (Delrin) and by surrounding the entire assembly with a neutron absorbing boron loaded shell. Such a viable nickel (n, γ) calibration source can then simply utilize a commercially available AmLi (Americium Lithium) as internal neutron emitter. Further simulations of the calibration deployment in the DUNE detector are shown that demonstrate the clean detection signature of the optimized 9 MeV γ-ray calibration source.

Radon Monitoring for the Super Cryogenic Dark Matter Search at SNOLAB

Kevin Wykoff, Department of Physics
Dr. Richard Schnee, Department of Physics

Well-established astronomical observations indicate that dark matter accounts for approximately 85% of total matter in our universe. SuperCDMS (the Super Cryogenic Dark Matter Search) at the SNOLAB underground laboratory is a current effort to obtain a presently unachieved direct dark matter detection, a principal interest in experimental particle astrophysics. To succeed, the reduction of interactions from ^{222}Rn progeny is essential. Detectors must be assembled in radon-reduced clean rooms to avoid the deposition of long-lasting radon daughters on or near detectors. Here, such decay products can generate interactions that imitate dark matter. ^{222}Rn progeny can also generate gamma rays in air gaps within detector shielding resulting in similar false dark matter detections. The shielding is purged with low-radon liquid nitrogen boil-off gas, thereby reducing this background. To ensure satisfactory radon reduction, a robust system centered around radon concentration monitoring by a Rad7 detector has been established. This system consists of new and adapted code that will govern serial communication with the detector, as well as collection and storage of detector readings and self-diagnostic checks. A watchdog script sweeps the database where detector readings are migrated. The script also triggers alarms for cases where a predetermined radon concentration over a given time is surpassed and for cases of absent readings.

Magnetic Interactions and Electronic Structures of CrI_2 from First-Principles Calculation

Khimananda Acharya, SD Mines **-** Mentor: Dr. Tula Paudel

The recently discovered magnetism of two-dimensional (2D) van der Waals crystals has attracted much attention because of their potential for spintronics devices. Out of a handful of magnetic semiconductors, even fewer of them, including CrI_2, are successfully exfoliated. The exfoliated layers have properties very different from their bulk counterpart; in particular, their properties are easily tunable with an external field. Here, using density functional theory (DFT) calculations, we show that layers of CrI_2 layers can be readily cleaved, cleaved layers are dynamically stable, and they are ferromagnetic. We further extract magnetic exchange parameters from our ab-initio DFT calculations and, using Heisenberg Hamiltonian and Monte Carlo simulation, evaluate Curie temperature associated with the Ferromagnetic transition. We additionally study the evolution spin structures of these layers as a function of applied magnetic field using Micromagnetic simulations. Our work will contribute to the understanding of very recently exfoliated few layers of CrI_2 and the development of future spintronic devices.

Madan Timalsina
Oral presentation

Calibration of a Liquid Xenon Detector for the Search of Dark Matter with the LUX-ZEPLIN (LZ) Experiment at Sanford Lab

Co-author: Dr. Juergen Reichenbacher
Mentor/Advisor: Dr. Juergen Reichenbacher, Department of Physics

The 2nd generation direct detection dark matter experiment LZ will perform the most sensitive direct search for weakly-interacting massive particles (WIMPs). LZ is located at 4850 feet underground at the Sanford Underground Research Facility (SURF) in Lead, South Dakota. LZ is employing a two-phase xenon detector with ~7 tons target mass. WIMPs could interact in the cryogenic liquid xenon of the detector's core by bouncing into a xenon nucleus, which will then recoil and produce scintillation light and electric charge. The ratio of the directly detected scintillation light S1 and the delayed charge detection S2 is characteristic for such a nuclear recoil (NR) and differs significantly from an electron recoil (ER) produced by undesired background reactions. However, the precise knowledge of the critical ratio S1/S2, for which the electron recoil dominated regime transitions into the nuclear recoil dominated regime, is key.

Calibrations with neutron sources, such as DD-generator, AmLi, Cf-252, and Y/Be, are performed and analyzed to map out the NR signal region for WIMP search. Gamma-ray sources are utilized to map out the ER region characteristic for backgrounds. We have studied calibration data to map out the NR signal region and compared the results to a full detector simulation.

Magnetic and Mechanical Properties of Magnetically Soft Metal-Amorphous FINEMET Nanocomposites

Paul White, Physics Department
Dr. Tula Paudel, Physics Department
Dr. Nickolaus Bruno, Mechanical Engineering Department

The performance of high-efficiency electronics, including those employed in hybrid-electric aircraft propulsion systems, is controlled through the electromagnetic behaviors of magnetically soft metal-amorphous FINEMET nanocomposites that operate as filter inductors and transformers. These materials provide excellent electromagnetic noise suppression and contribute to energy savings allowing for a reduction in the size and weight of electronics. These materials generally have the composition of $Fe_{\sim72}(TM)Si_{22.5-X}B_X$ (atomic percent), where TM is a transition metal or a group of transition metals and their magnetic and mechanical properties are chemical composition-dependent. The as-cast FINEMET samples are amorphous glasses, and mechanically they are tough. However, upon annealing at a temperature below the crystallization temperature of 520^{o}C, even though the samples remain amorphous, they become brittle. X-ray diffraction (XRD) is being used to probe the short-range interaction parameters of the amorphous samples. XRD results are compared to ab-initio molecular dynamics results to find out the local composition and structural signatures controlling magnetic and mechanical properties.

Measurement of low-energy resonances in the $^{22}Ne(\alpha,n)^{25}Mg$ Reaction

Thomas Kadlecek, Physics
Dr. Frank Strieder, Physics

The $^{22}Ne(\alpha,n)^{25}Mg$ reaction is a key neutron source for the slow neutron-capture process. The reaction rate at stellar energies is most likely dominated by a resonance at 832 keV. Due to low resonance strengths at lower energies only upper limits have been previously determined for resonances below 832 keV. Recent measurements utilized the Compact Accelerator System for Performing Astrophysical Research (CASPAR), located on the 4850-feet level of the Sanford Underground Research Facility (SURF). These measurements were completed for the strengths of resonances at 832 keV and below.

Event Reconstruction and Analysis in ANNIE

Franklin Lemmons, Physics
Jingbo Wang, Physics

Lying along with the Booster Neutrino Beam (BNB) at Fermi National Accelerator Laboratory (FNAL), the Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a Gadolinium-doped water Cherenkov neutrino detector. It aims to determine the neutron multiplicity from neutrino-nucleus interactions in water and provide a staging ground for new technologies relevant to the field. These goals will improve our understanding of neutrino interactions with matter and help reduce the systematic uncertainties, thus benefiting the next-generation neutrino experiments. ANNIE is currently taking its physics phase data, and new analysis techniques are being developed. This talk will present the current status of ANNIE, and discuss the reconstruction and analysis techniques being developed.

Deep Underground Neutrino Experiment Calibration

Kole Pickner, Mechanical Engineering
Ian Helgeson, Mechanical Engineering
Jairo Rodriguez, Physics

Advisor: David Martinez Caicedo, PhD

The Deep Underground Neutrino Experiment (DUNE) is a worldwide, collaborative effort to understand more about the matter-antimatter asymmetry in the universe and potentially find a unified theory of matter and energy. Fermilab, located in Chicago IL, will use its particle accelerator to produce neutrinos that will travel through the earth (as neutrinos are able to pass through matter) to the Sanford Underground Research Facility (SURF) near Lead, SD. There, a large neutrino detector will be constructed, composed of a large volume of cryogenic liquid argon divided by two sets of high-voltage cathode and anode planes.

A DUNE prototype was constructed and tested at the European Council for Nuclear Research (CERN). A team of SDSM&T students and faculty is working with several U.S. Department of Energy laboratories to redesign a network of light diffusers that will calibrate the light collection system of the DUNE prototype at CERN. Each diffuser receives light from an attached optic fiber, reflecting it off of an internal mirror and out through two diffuser glasses. This diffuses light from the cathode plane assemblies to the light collection system on the anode plane assemblies.

The diffuser housings' geometry was updated to decrease production cost and increase effectiveness. An apparatus was designed and built at SDSM&T to cyclically test diffusers and fibers in a cryogenic environment. A rail was also designed to test light output through optic fiber. The DUNE prototype's calibration system plan was modeled in CAD and presented to and verified by international collaborators at CERN and other US institutions, A comprehensive installation guide was writte.

I will summarize all the SDSMT contributions to the design, construction, and future operation of the light calibration system and their importance to guarantee the correct operation of the light collection system for the DUNE prototype at CERN.