Description: Electron backscatter diffraction (EBSD) image of aluminum cold spray deposition.

The Pascal Heap and Sort

Christina Taylor; Mechanical Engineering Department (ME)

Mentor/Advisor: Paul Hinker; Mathematics and Computer Science Department (MATH, CSC)
Co-Mentor/Advisor: Albert Romkes; Mechanical Engineering Department (ME)

ABSTRACT

Based on observations from the heap sort and Shell sort algorithms, a new heap data structure, the Pascal heap, is developed. This data structure serves as the basis for a new sorting algorithm, the Pascal sort. The sort is in-place, but unstable. As a comparison based sort, the Pascal sort falls short of the theoretical \(O(n \lg(n))\) runtime limit with an expected runtime of \(O(n^{3/2})\). However, the algorithm is capable of \(O(n)\) runtimes best-case scenario and will never exceed its \(O(n^{3/2})\) expected runtime worst-case scenario. These runtime bounds allow the sort to be competitive with theoretically faster \(O(n \lg(n))\) algorithms on certain data sets. The algorithm’s actual runtime behavior is studied via a C++ implementation against a variety of data sets. These results are then compared against the performance of a number of other common sorts, including the STL (Standard Template Library) sort function, in an attempt to better understand the algorithm’s actual runtime(s).
Covalent Crosslinking Alginate Based Polymers for use in Drug Delivery Systems

Jackson King; Chemistry and Applied Biological Sciences Department (CABS)

Co-Presenter: Collier Meersman; Chemistry and Applied Biological Sciences Department (CABS)

Mentor/Advisor: Tsvetanka Filipova; Chemistry and Applied Biological Sciences Department (CABS)

ABSTRACT

The aim of this study was to prepare a new covalently cross-linked biodegradable polymer composition of sodium alginate and glycerol using citric acid as a cross-linked agent. Normally calcium chloride is used for the cross-linking of alginate-based polymers. Calcium chloride, however, has side effects that include nausea, upset stomach, and tissue damage. Citric acid is commonly used to prevent the formation of kidney stones and could be used as a natural alternative to calcium chloride in the synthesis of alginate-based polymer compositions for drug delivery systems. The influence of the amount of citric acid and the time of release of the tuberculosis drug Rifampicin for the alginate/glycerol polymer composition was studied. The work previously reported with this research proves that under aqueous conditions the desired polymer can be produced to fulfill the parameters needed for a drug carrier system. The antibiotic can be entrapped within the polymer during crosslinking, which can then be administered orally. Crosslinking was confirmed using transform infrared (FTIR) spectroscopy. The optimized cross-linked polymer composition was found by slowly dissolving the varied polymer compositions in water. In order to find the optimum composition, UV-Vis Spectroscopy was used to determine the concentration of Rifampicin within solution after varying times.

References

This experiment was done in order to find more ways to optimize particle size. The reason for this is so that particles can deposit and reside in selective parts of the body. In this case, the main goal is for the particles to remain in the respiratory system. Particle synthesis is done using flash precipitation, which is a process that creates polymeric particles that can be formulated to contain various drugs within them. In this work, we determined the influence of polymer concentration, amplitude of the ultrasonic atomizer, and the flow rate on microparticle size and polydispersity.

The experiment was conducted by loading a given concentrations of polystyrene, a model polymer, dissolved in methylene chloride into a gas tight syringe. A syringe pump controlled the flow rate through an ultrasonic atomizer which discharged into a large beaker filled with antisolvent, pentane. The resulting particles were collected by vacuum filtration and imaged by scanning electron microscopy (SEM). The SEM images were analyzed to determine the particle size distribution.

The tests were performed based on a range of polymer concentrations, ultrasonic atomizer amplitude, and the flow rate of the polymer being added to the anti-solvent. From these tests, it was determined that the only process parameter that significantly impacted particle size was the amplitude. Amplitude for this experiment ranged from 20% to 50%, while average particle size ranged from 869 nm to 3993.4 nm, with particle size being a geometric mean. As amplitude is increased, the average particle size also increases. Polydispersity, however, follows a more curved trend, with 50% amplitude still having the highest, but 35% falls behind both 50% and 20% amplitude.

These experiments provide a basis for the optimization of microparticle formation of a desired size, and identified that amplitude of an ultrasonic atomizer as the primary operating parameter which will control this
Neural Shrubs: Fusing Decision Trees and Neural Networks

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Co-Mentor/Advisor: Randy Hoover; Mathematics and Computer Science Department (MATH, CSC)

ABSTRACT

Decision trees and neural networks are two common machine learning techniques used to classify data sets. Decision trees uses a tree-like model of decisions and the outcomes. Neural networks are a set of algorithms, modeled loosely after the human brain to recognize complex non-linear patterns in a data set. While decision trees are quicker to train than a neural network, a neural network is more accurate, even for the same amount of training time as the decision tree. However, unlike decision trees, neural networks are hard to interpret.

The purpose of this study was to investigate a way to harness the power of a decision tree and a neural network through a novel technique called a Neural shrub. Neural shrub is an ensemble learning technique that partitions the space using a decision tree, followed by neural networks to improve classification rates. We will apply this technique on a variety of data sets and compare the prediction accuracy with a decision tree and a neural network. We will also discuss some future work as well as potential applications of neural shrubs.
Design of a Bio-Inspired Crawler

Michael Yoon; Mathematics and Computer Science Department (MATH, CSC)

Mentor/Advisor: Hadi Fekrmandi; Mechanical Engineering Department (ME)

ABSTRACT

In this paper the design, manufacturing and laboratory testing of a pipe crawling robot using a bio-inspired movement is presented. The robot consists of a modular design with four cylindrical modules for navigation which uses peristaltic locomotion. Two gripping modules at both ends along with two linear actuator modules in between create forward motion of robot in between gripping sequences. First the gripper modules are designed for radial adhesion and optimized to provide the maximum gripping force. Then a four-follower face-cam mechanism is used in the design of a separate nondestructive evaluation module. The bio-mimic design of robot not only provides significant adhesion required to carry NDE equipment but also it allows conducting multi-scale mechanism tasks. Inspired by peristaltic locomotion, the robot can perform gripping and inspection radial motions to adjust to variation of pipe diameter within 3-5 inches inside pipes sloped from 0 to 180 degrees. The crawler’s prototype is manufactured using aluminum through waterjet cutting process. A laboratory scale test set-up is manufactured for experimentation. Testing performance of the crawler shows that robot can accomplish horizontal and vertical motions in both upward and downward directions with adjustable gripping force. It also, demonstrated promising compatibility for more complex pipe transitioning.

References


Environmental Effects on Light Guide Polymers

John Wieland; Physics Department (PHYS)

Mentor/Advisor: Luke Corwin; Physics Department (PHYS)

ABSTRACT

The goal of this experiment was to test the environmental survivability of two possible light guide components for the Deep Underground Neutrino Experiment (DUNE) Single Phase detector. Four wavelength shifting plates and one coated acrylic bar were exposed to a variety of high humidity and high temperature conditions for an average of 700 hours. The wave shifted light produced when the plates and bar were exposed to 285nm light was then measured periodically to test their response to the environmental conditions. The resulting data were then processed using the ROOT analytical package. The testing demonstrated consistent wave shifting properties of the plates despite the environmental stresses.
Emanation and Diffusion of Radon Through Gasket Materials for SuperCDMS SNOLAB

Brandon DeVries; Physics Department (PHYS)

Mentor/Advisor: Richard Schnee; Physics Department (PHYS)

ABSTRACT

The SuperCDMS SNOLAB experiment, currently under construction, will attempt to directly detect dark matter particles. Shielding surrounding the experiment’s detectors will reduce interactions of particles from radioactivity and cosmic rays. A gas purge will remove radon from gaps in the shielding to reduce backgrounds further. Gaskets used to seal this purge volume must allow sufficiently low radon diffusion through them while emanating little radon into the purge volume. I will describe measurements of radon diffusion through gaskets made of EPDM, Zip-A-Way, and Silicone, inferred from the time dependence of radon concentration in a volume separated from a high-radon volume by the gasket in question. Results of these diffusion measurements and of the radon emanation measurements will be given in the presentation.

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Track Reconstruction in The BetaCage Screener for Radioactive Backgrounds

Michael Thompson; Physics Department (PHYS)

Mentor/Advisor: Richard Schnee; Physics Department (PHYS)

ABSTRACT

The search for dark matter and other sensitive experiments searching for interactions of rare elementary particles require screening of materials for radioactivity. The BetaCage is a proposed ultra-sensitive detector to screen for radioactive contaminants emitting alpha and beta particles from material surfaces, that would constitute unacceptable backgrounds for these experiments. A prototype version of the BetaCage is currently being commissioned at South Dakota School of Mines & Technology in order to further test the design and properties of the detector. Details of track reconstruction of alpha particles and beta particles will be discussed.
Integration of Lithium Rich Antiperovskite Electrolyte and Cathode Material in an All Solid-State-Battery

Joel Swanson; Chemistry and Applied Biological Sciences Department (CABS)

Mentor/Advisor: Alevtina Smirnova; Chemistry and Applied Biological Sciences Department (CABS)

ABSTRACT

The use of liquid organic electrolytes in lithium ion batteries causes serious safety concerns due to the high flammability, thermal instability, and low cyclability of the electrolytes. In response to these concerns, solid-state lithium-ion electrolytes are being investigated as replacements. The solid-state electrolytes are compatible with a lithium metal anode, allowing for large capacity, but require cathode optimization.

Electrochemical half cells were created in the CR2025 configuration with lithium metal as the reference electrode. A solid-state lithium-rich antiperovskite electrolyte membrane (200-400μm) was synthesized by casting lithium salts on carbon coated copper. The testing has since shifted from carbon coated copper to cathode materials, including metal oxides and commercially available cathodes.

Impedance spectroscopy was used to measure the ionic resistance and conductivity through the electrolyte membranes from 10mHz–200kHz. The ionic resistance of the electrolyte had a minimum of 4 kΩ at 100°C. This correlates to a peak ionic conductivity of 10^{-2.3} S/cm at 100°C and activation energy of 0.23 eV.

Lithiation and delithiation of the membrane was detected by cyclic voltammetry in the range of 0.05–1.00 V when testing at a rate of 0.1 mV/s. The phenomena was only detected in the elevated temperature range of 50–100°C. Cathode materials will be studied at higher potential ranges. Reversible charge and discharge of the half-cell was measured using rate capability. The cell was tested at C/20–C/10–C/5–C/20 rates at 50-100°C in the voltage range of 0.05–1.00 V.

Reversible charge and discharge was only observed at elevated temperatures. Cyclability of the half-cell measured at 100°C showed approximately 75% capacity retention over 700 cycles at C/5 rate.

A baseline of commercial cathode materials for impedance, rate capability, and cyclic voltammetry has been measured to aid in determining if the cathode materials incorporated with solid electrolyte are operating properly.

By integrating cathode material with this solid-state electrolyte, it is possible to achieve similar capacity to liquid lithium-ion batteries. This would maintain the performance of typical lithium ion batteries at a fraction of the weight while increasing the thermal stability and cyclability of the battery. Once optimized, solid-state lithium-ion batteries are expected to replace liquid lithium-ion battery cells.
Effect of Yttria Nano Particle Addition on the Microstructure and Mechanical Properties of Cold Sprayed Nickel

Joseph Lauzon; Materials and Metallurgical Engineering Department (MET)
Mentor/Advisor: Bharat Jasthi; Materials and Metallurgical Engineering Department (MET)

ABSTRACT

The main objective of this work is to develop in-situ stress corrosion repair of light water reactor (LWR) components using supersonic cold spray process. In a cold spray process, the metal powders are accelerated supersonically towards the substrate and the impact of powders will result in significant plastic deformation, mechanical interlocking and metallurgical bonding to the substrate material. Since cold spray is a solid-state process, most of the problems associated with liquid to solid transformations such as the thermal effects, oxidation, shrinkage, and tensile stresses are minimized or avoided. Pure nickel has excellent corrosion properties and would be a great material for corrosion repair of LWR components. However, pure nickel can undergo recovery and recrystallization when the cold spray repaired components are exposed to ~350°C, which may impact the mechanical properties. So, the main objective is to investigate the effect of yttria nano particle addition on the microstructure and mechanical properties of nickel cold spray deposits. Addition of yttria nanoparticles will pin the grain boundaries and prevent grain growth when the repaired components are exposed to high temperatures and provides the required thermal stability. The effect of post deposition heat treatment temperature and time on the microstructure and mechanical properties are analyzed and reported.
Graduate Oral Presentations

Application of ArcGIS Pro in Blast-Induced Ground Vibration Analysis in an Open Pit Copper Mine

Young Pan; Mining Engineering and Management Department (MEM)

Mentor/Advisor: Purushotham Tukkaraja; Mining Engineering and Management Department (MEM)

ABSTRACT

Pollen is a reliable proxy for evaluating floral content and reconstructing paleoenvironments of an area from lacustrine sediments. These findings may provide the foundation for an extensive pollen analysis of the sinkhole sediments and contribute to understanding the paleoenvironment of the Mammoth Site and surrounding areas. Pollen analyses were initially conducted in the 1980s at the Mammoth Site in Hot Springs, SD to study and understand the vegetation present. Although those samples contained pollen, sample contamination was suspected and the results were therefore, considered unreliable. New sediment samples were collected from the Mammoth Site and processed to reassess if pollen is preserved at the site. These findings, compared with the previous set of pollen analyses conducted at the Mammoth Site, will clarify if pollen is present and how it differs from previous the samples.

Figure. Permitted Charges in Different Areas within the Open Pit Design Limit And Vibration Prediction Evaluation in Structure Areas
Optimizing the Production Schedule at Barrick’s Turquoise Ridge Operation Using a Deterministic Method

Akshay Chowdu; Mining Engineering and Management Department (MEM)

Mentor/Advisor: Andrea Brickey; Mining Engineering and Management Department (MEM)

ABSTRACT

Underground mine production scheduling is a multifaceted and time-consuming job. In modern underground mining, industry practice is to use genetic algorithms and other heuristics to create feasible production schedules. We present an alternative to this approach and discuss implementation results at Barrick’s Turquoise Ridge operation in Nevada. In addition, we also present the process of converting the mine design to an equivalent mathematical model and the solution method used to generate a 10-year production schedule at daily fidelity. The results show a significant increase in Net Present Value, while achieving ore production targets within current resource limitations, e.g., processing capacity, equipment. The presentation also highlights the operational benefits of utilizing this tool and methodology.
A Game-Theoretic Procedure for Allocation of Traffic Lanes to Highway Users in Federal and State Highway Cost Allocation Studies

Andrew Brown; Civil and Environmental Engineering Department (CEE)

Mentor/Advisor: Dr. Saurav Kumar Dubey; Industrial Engineering Department (IE)

ABSTRACT

The goal of this research project is to use mathematical theory of decision making known as game theory to enhance a federal, state and local highway infrastructure asset management tool known as Highway Cost Allocation (HCA). An HCA study is used to divide highway expenditures among different types of road users grouped into vehicle classes. Examples of vehicle classes include passenger cars, busses and trucks. The scope of the problem involves the process used to ascertain demand for traffic lanes. Extensive studies performed on vehicle volume distribution suggest trucks constitute only a fractional portion of highway traffic in relation to passenger cars. Allocation of capacity-enhancing capital costs made by highway agencies, such as the cost of adding new lanes to an existing road for alleviating congestion will be of primary research interest. These costs must be attributed to road users contributing most to the increase in traffic volume. Given total number of traffic lanes, concept of Shapley value will be used to assign number of lanes to vehicle classes. The efficacy of the procedure will be evaluated against existing practice of using Passenger Car Equivalent-weighted Vehicle Miles Traveled (PCE-weighted VMT) as a basis for allocating cost of added lane capacity.

References:


Time-Lapse Seismic Imaging of Induced Hydraulic Fractures at Sanford Underground Research Facility Using Continuous Active Source Seismic (CASSM) Techniques

Colton Medler; Geology and Geological Engineering Department (GEOE, GEOL)

Mentor/Advisor: Dr. William Roggenthen; Geology and Geological Engineering Department (GEOE, GEOL)

ABSTRACT

In recent years, the surge in renewable and non-renewable energy production has highlighted the need for new methods and techniques to more efficiently extract energy from the subsurface. Enhanced geothermal systems (EGS) and unconventional oil and gas have become hot topics for research because of their vast potential as a resource and the uncertainty in the techniques used to extract them. Subsurface resources present many challenges, particularly related to creating properly designed fractures (size and position) to enhance reservoir properties (permeability, connectivity, etc.). A cross-hole seismic survey was performed at Sanford Underground Research Facility (SURF) before, during, and after six fracture stimulation tests in an environment resembling established EGS sites. The six tests were completed to initiate and propagate an emplaced fracture using low flow rates. One technique used for monitoring the fracturing process was continuous active source seismic monitoring (CASSM), which is a technique created by researchers at Lawrence Berkeley National Lab (LBNL) that increases the temporal resolution of a survey by fixing source and receiver positions. CASSM data were analyzed for changes in velocity of the direct P- and S-waves. The results indicate that CASSM not only delineated the fractured zone, but also provided information about the processes occurring during and after pressurization, as well as limitations on the size of the fracture.
Automatic Variationally Stable Analysis for Finite Element Computations

Eirik Valseth; Mechanical Engineering Department (ME)
Mentor/Advisor: Dr. Albert Romkes; Mechanical Engineering Department (ME)

ABSTRACT

The concentration of minerals from ores consumes an immense amount of water. For instance, 1.27 million tons of copper were produced from US mines in 2017, and this required roughly half a billion tons of water. Additionally, the locations of most ore deposits in the US are in arid regions in the southwest where water already is a scarce resource. In an effort to reduce the demand for water in mineral processing, it has been proposed to develop engineered microspheres with surface chemistry tailored to adhere to dry mineral particles in order to significantly reduce the water consumption. To aid in the design of a mineral separator utilizing this technology, a computational tool is to be developed to predict the separation of the minerals. Toward this purpose a mathematical model is to be developed based on the so-called Cahn-Hilliard equations. The numerical analysis of these equations can be challenging due to nonlinearities present in the equations, which can lead to numerical instabilities. The goal of this work is to develop a computational tool, called the automatic variationally stable finite element (AVS-FE) method [1].

The AVS-FE method uses a first order system integral formulation of the underlying partial differential equations (PDEs) and, in the spirit of the discontinuous Petrov-Galerkin (DPG) method by Demkowicz and Gopalakrishnan [2], employs optimal test functions to ensure the discrete stability of the method. The AVS-FE method employs globally continuous FE trial spaces and discontinuous test spaces spanned by the optimal test functions. The broken topology of the test spaces allows us to compute numerical approximations of the optimal test functions locally, in a completely decoupled fashion, i.e. element-by-element. The test functions can be computed with sufficient numerical accuracy by using the same local p-level as applied for the trial space.

We present 2D numerical results for highly challenging problems in engineering science, which show optimal asymptotic convergence rates and present results for goal-oriented a posteriori error estimate.

References

Design of Integrated Command Center for Improved Mine Rescue Response

Ankit Jha: Mining Engineering and Management Department (MEM)

Mentor/Advisor: Dr. Purushotham Tukkaraja; Mining Engineering and Management Department (MEM)

ABSTRACT

Underground mines are fraught with many hazards, and accidents are not uncommon. In spite of the detailed planning and execution, mines had accidents all around the world. Decision making in a rescue operation is tedious as time available to make a decision is limited. Several research organizations have developed detail procedures to be followed in rescue operation. Mine rescue handbook is one such document which outlines detail actions to be initiated during mine rescue. This presentation illustrates design of a comprehensive GIS based command center based on tasks outlined in mine rescue handbook. Database management is used to aggregate data obtained from various sources to improve decision making during rescue. Additionally, GIS capabilities are utilized in obtaining meaningful results that can be used by rescuers in handling the situation.
Inertial Motion Capture of the Jackleg Drill: A Biomedical Analysis in the Underground Mining Industry

Madison Larsen; Biomedical Engineering Program

Mentor/Advisor: Dr. Adam Piper; Industrial Engineering

ABSTRACT

Mining is an occupation where employees are at risk of work-related musculoskeletal disorders (WMSDs). WMSDs are prevalent in the mining industry due to the workers being exposed to risk factors such as, heavy lifting, overexertion, repetitive motion, and awkward postures. One common mining industry task with significant WMSD risk factors is the operation of the jackleg drill. The jackleg drill is a handheld, rotary, percussion rock drill which uses a reaction leg to provide stability and thrust. The jackleg drill is used to provide ground support, or position dynamite in the rock face. The objective of this research is to characterize the biomechanics and kinematics of different tasks performed while operating the jackleg drill. Four employees at the Sanford Underground Research Facility volunteered to wear 15 non-invasive and wireless inertial motion capture sensors (IMUs). The IMU sensors measured the linear and angular accelerations and positions of 20+ body segments and joints. The subjects were observed while operating the drill in their normal work environment. Seven tasks performed while operating the jackleg drill were identified in this study: adjusting the airleg, carrying the drill, standby time, drilling with the drill bit, drilling with the bolt, removing with the drill bit, and removing with the bolt. A total of 58 minutes, 208,800 individual recording frames, of data were collected and analyzed. The data was recorded in the MVN BIOMECH AWINDA system and analyzed using the Rapid Upper Limb Assessment tool (RULA) and the Rapid Entire Body Assessment tool (REBA). Joint angles were also classified based on the categories of risk defined in an unrelated study by Nipun et al. This prior study focused on trunk flexion, trunk lateral bend, shoulder flexion and abduction, and elbow flexion. Our results show that the task of carrying the drill places the operator under the most MSD risk. Carrying the drill had a RULA score of 7 out of 7 for all frames, and a mean REBA score of 8.7 out of 15. Adjusting the airleg was the task that had the second highest risk, specifically for the left shoulder. This task required asymmetry with a high degree of left shoulder flexion in order to make the adjustment. Adjusting the airleg received a mean RULA score of 6.327 (right side), and 6.834 (left side); and a mean REBA score of 7.265 (right side), and 8.081 (left side). The risk involved with both the drilling tasks and removing tasks depended highly on where the bolt/hole needed to be placed. It was found that having to drill or remove the jackleg from a position near or above the operator’s head had a heightened risk compared to drilling in the operator’s power zone. It is recommended that when carrying the drill, a team approach be used to lift the drill. When adjusting the airleg, it is recommended the operator alternates which side is used for the adjustment. If possible, a rock bolt drill should be used to place bolts above the operator’s head. If a rock bolter is not applicable, this task should be spread among multiple employees to limit the exposure of any one employee to the awkward postures. Future work to better this research should entail refining the proposed worker rotation schedule and include an analysis of risks for an employee assisting the jackleg operator. Overall this research will help combat WMSD incidence rates found in the mining industry.
Rise Time Discrimination of Helium-3 Proportional Counters

Tyler Borgwardt; Physics Department (PHYS)

Mentor/Advisor: Dr. Frank Strieder; Physics Department (PHYS)

ABSTRACT

The IceCube Neutrino Telescope not only studies the fundamentals of neutrino physics but also Extensive Air Showers (EAS) caused by cosmic ray particles. With data collected at the south pole and special simulations with CORSIKA and IceCube software, the two are analyzed and used to develop theories of fundamental physics. The most critical component of the analysis is the correct reconstruction of the events. IceTop and IceCube are used as separate detectors in many analysis’, and IceTop is often thought of as a veto for InIce event selection. This research takes the two detectors and treats them as one during a cosmic ray shower reconstruction. This work details the necessary steps that are needed to accomplish this new reconstruction. One innovation here is the use of two signal models for the lateral distribution functions that describe the spread of charge detected in IceTop. This will use information from both the Electomanetic and Muonic components of the Cosmic Ray Shower. Another step is the improvement of the angular resolution within IceCube and IceTop is worse as the energy of the shower increases. This is determined to be from the reconstruction of the EAS front curvature which was modeled at a very early stage of the IceCube experiment. This is evaluated and updated to improve the angular resolution. The goals of this work is to provide great geometric reconstructions of cosmic rays at a large range of shower inclinations. Another will be the reconstruction of the parent cosmic ray’s energy and composition, given the increased amount of information that will be accessible.
Life Cycle Assessment Modeling of Integrated Crop Livestock Systems

Prashansa Shrestha; Civil and Environmental Engineering Department (CEE)

Mentor/Advisor: Dr. James Stone; Civil and Environmental Engineering (CEE)

Co-Mentor/Advisor: Dr. Heidi Sieverding; Civil and Environmental Engineering (CEE)

ABSTRACT

Sustainability of agricultural production systems is evaluated using life cycle assessment (LCA). Agricultural and environmental systems must target food, land use, economics, and greenhouse gas emission. Land use is largely affected by anthropogenic activity. While the process of expanding land sources is limited, land-based global food demands are increasing. A kilo of grain is not the same as a kilo of beef products but must equate as farm coproducts, despite their spatial and temporal variability. Global food demand, dietary preferences, crop and livestock yields, residue, and land use each play a significant role in increased greenhouse gas emissions. The general hypothesis is that there are fundamental restrictions to the sustainable expansion of agricultural systems. Introducing, CU allocation methods enabled equitable comparison of grain and meat and provided a more representative metric for modeling adoption of integrated crop livestock (ICL) technique for sustainable agricultural production systems. The residue or manure treated as waste in BAU systems, can balance ecosystem grazing cattle in annual crop field. The emission due to application of N-fertilizer is reduced by 50% per year in ICL. The hay/grass production cost (20-50$/AUM) is reduced during winter grazing. Results indicate that the integrated agricultural management system can holistically reduce environmental impact. The represented model results can be used as guidance by dryland producers and policy makers.
The ever-present threat of biological weapons has encouraged the development of novel pyrotechnic formulations. These formulations release gaseous iodine upon combustion that acts as a potent active agent capable of countering bio-agents (e.g. anthrax). Typical reactive materials formulation contains an iodate and a metal fuel, usually aluminum powder. However, the percentage of free iodine generated is relatively low and aging of these formulations remains an issue.

In this work, boron carbide based biocidal formulations with NaIO₄ serving as the primary oxidizer are explored and the role of particle size on the combustion velocities, iodine output, and combustion products are detailed. Formulations are studied with and without the addition of binder and the role of particle size detailed toward developing 3-D printable energetics. It was shown in this study that the effect of changing the boron carbide particle size had nominal effects on both the combustion velocity and iodine recovery. However, promising results have been established by reducing the particle size of the oxidizer, NaIO₄. The NaIO₄ was milled to an D₉₀ value of 30.30 μm resulting in iodine recovery close to 90%, much higher than any formulation seen thus far. By reducing the particle size even farther to under 25 μm while maintaining the same fuel content, iodine recovery was up to 100%. Iodine quantification was done using UV-VIS, simultaneous differential scanning calorimetry and thermogravimetric analysis (DSC/TGA), heat of reaction, X-ray diffraction (XRD) and combustion characteristics will be discussed.
Novel Surface Modification Approaches for Bioelectrocatalytic and Biocorrosion Applications

Mohammad Jamil Islam; Civil and Environmental Engineering Department (CEE)

Mentor/Advisor: Dr. Venkataramana Gadhamshetty; Civil and Environmental Engineering Department (CEE)

ABSTRACT

In bioelectrochemical systems (BESs), the bio-electro catalytic activity of the working electrode is strongly determined by the surface properties of a working electrode. The biofilm growth on the electrode surface, biological interactions with surfaces, and the resulting biofilm phenotypes are influenced by the surficial properties (chemical composition of electrode, surface charge, surface area, surface roughness, wettability and porosity), and these dynamics reflect both on spatial and temporal scale. The bioelectrocatalytic capability of an electrode (anode or cathode) can therefore be enhanced using the surface modifications approaches. For example, the immobilized surfactants on the electrode will enhance the effective surface area, reduce the electrode impedance, improve the kinetics or redox reactions, and facilitate the overall current density. This presentation will discuss examples of surface modification approaches in two of our ongoing research projects; they include: (i) enhanced bioelectrocatalytic activity of electrodes in microbial fuel cell using graphene oxide, and (ii) improved corrosion resistance of steel using a coating based on maleic anhydride functionalized graphene in epoxy coating (MAGE).

The first example discusses the use of active graphene mixture to immobilize *Rhodobacter sphaeroides* on metals (nickel) and non-metals (carbon cloth). The modified surfaces yield conductive surfaces to promote the growth of *R. sphaeroides* biofilms in microbial fuel cells. The results were demonstrated using the polarization studies and electron impedance spectroscopic techniques. Scanning electron micrographs revealed thicker biofilm and pili formation, indicating efficient extracellular electron transfer. Real-time PCR based gene transcript profiling revealed significant up-regulation of genes including cytochrome oxidase and pilus assembly proteins in the biofilm, compared to the planktonic cells. Ongoing research on transcriptomic analysis would reveal the molecular insights of *R. sphaeroides* grown on Gr/Ni surfaces and their differential gene expression profiles. These studies will establish the genome to phenome relationships of *R. sphaeroides* in microbial fuel cell applications.

The second example is based on microbial corrosion experiment using the mild steel (MS) coated with MAGE (MAGE-MS) and MS coated with epoxy (MS-epoxy) (control), we exposed it to lactate C medium containing aggressive sulfate-reducing bacteria *Desulfovibrio alaskensis* G20 which is known to corrode steel used as oil pipelines. Characterization techniques (FTIR and Raman) showed formation of amide bonds suggesting the successful bonding between epoxy and MAGE. The contact angle measurement showed increased hydrophobicity for MAGE-MS compared to MS-epoxy. The electrochemical corrosion test (linear polarization resistance) showed three orders of magnitude lower corrosion rate for MAGE-MS compared to MS-epoxy. The capacitance values for MAGE-MS obtained from electrochemical impedance spectroscopy showed at least one order of magnitude lower capacitance values compared to MS-epoxy indicating that the addition of MAG into epoxy matrix hindered the diffusion of corrosive biogenic metabolites (HS\(^-\) and H\(^+\)).
Transparent Titanium Dioxide Nanotubes: Processing, Characterization, and Application in Establishing Cellular Response Mechanisms

Jevin Meyerink; Biomedical Engineering Program
Mentor/Advisor: Grant Crawford; Materials and Metallurgical Engineering Department (MET)

ABSTRACT

Titanium dioxide (TiO2) nanotubes have gained significant attention as potential osteogenic surface treatments for titanium-bone implants. The exact mechanism by which TiO2 nanotubes guide cell adhesion and the subsequent biochemical and mechanotransduction signaling cascades that ultimately dictate cell fate is limited. We report on the use of transparent TiO2 nanotube platforms in conjunction with advanced bioimaging techniques such as lattice light sheet microscopy (LLSM), FRET-based molecular tension sensors, and enzymatic activity assays to elucidate the effects of TiO2 nanotube diameter on the dynamic intracellular processes that occur during the stages of cell adhesion. Transparent TiO2 nanotube platforms were fabricated using physical vapor deposition and anodic oxidation to provide imaging substrates for microscopy that required light transmittance for the illumination of live-cells and have been used to quickly locate cells in during LLSM. Pre-osteoblasts, macrophages, and mesenchymal stem cells (MSCs) are being investigated using LLSM and transiently transfected with various fluorescent protein-tagged structural and signaling proteins associated with early stage cell adhesion, including: adhesion proteins, cytoskeletal proteins, cytoskeletal-associated regulatory proteins, and mechanosensitive Hippo signaling proteins.
Thermoplastic DiFTS Composites Incorporating Recycled Fibers

Krishnan Veluswamy; Materials Engineering and Science Program

Mentor/Advisor: David Salem; Composites and Polymer Engineering Laboratory (CAPE)

ABSTRACT

A manufacturing process - CNAM-DiFTS (Discontinuous Fiber Thermoplastic Sheet) - has been developed for incorporating discontinuous recycled fibers in thermoplastic sheets. The fibers in the sheets are oriented and demonstrate high length retention, providing anisotropic composite properties with high strength and stiffness. The distribution and orientation of fibers in the sheets were characterized by micro-X-Ray Computed Tomography, and the mechanical properties of composites laminated from different semi crystalline DiFTS were determined as a function of fiber loading and fiber type. The moldability of DiFTS laminated sheets was demonstrated in the form of various thermoformed and compression molded parts. In this way, high performance composites, for structural and semi-structural applications may be produced using chopped fiber from recycled sources.

In the first part of this study, we analyzed the compounding of two different thermoplastic polymers (polypropylene and polyamide 6) with recycled chopped carbon fiber. Which contributed to the optimization of extruder operating conditions for uniform mixing and dispersion of fibers in the molten polymer. Produced DiFTS composites where then characterized for rheological and viscoelastic properties under different temperatures and strain rates conditions for further understanding the molding process capabilities. In the second part, DiFTS composites were evaluated for its mechanical properties as per ASTM standards. NDT characterization techniques like Micro X-ray Computer tomography (Micro XCT), Scanning Electron microscopy (SEM), Microscopic analysis were used to evaluate and validate fiber orientation, mode of failure, and fiber length retention in the DiFTS composites material.

Figure 1: DiFTS molding process (a), fiber pull-out in PP with 15 wt.% carbon fiber (b).
Direct numerical simulations of particle-laden channel flow with the walls kept at different temperatures are performed. The position, velocity and temperature of each particle are computed in time with a Lagrangian approach, whereas the turbulent carrier flow is computed with a Eulerian approach. The two-way couplings between particles and carrier flow in the heat and momentum equations are taken into account.

In most of the previous numerical studies, the heat transfer between the particles and solid walls is assumed to be only through the carrier flow without any near wall modification for the particle-to-fluid heat transfer. The focus of this study is on the direct thermal interaction between the solid walls and dispersed particles in the vicinity of the walls.

To consider such effect, two different mechanisms are considered. The first one is the solid-to-solid particle-to-wall conduction, in which the time of collision, and the contact area are calculated based on the elastic Hertzian contact equations. The second mechanism is the particle-fluid-wall conduction, in which the heat from/to the particles is conducted to/from the wall via the thin layer of fluid between the wall and particles. This second mechanism of conduction is only effective when the time scale of the conduction (through the fluid) is smaller than the time of residence of particles near the wall. This heat transfer mechanism is considered for particles which their distance from the wall is less than half of their radius. Because of the effect of viscous sublayer particles in this distance from the wall flow almost parallel to the wall. There is a significant portion of particles in this regime which their residence time is bigger than characteristic diffusion time constant $\tau_c = \frac{L^2}{\alpha}$. That means the heat energy has enough time to diffuse throughout the distance of $L$ between the particle and the wall which happens through the fluid lens with thermal diffusivity of $\alpha$. The particle-fluid-wall conduction is calculated based on an extension of the approach proposed by Rong and Horio [1] for the heat transfer between colliding particles.

These two models have been implemented in our in-house Eulerian-Lagrangian solver for the simulation of dispersed particles in a non-isothermal vertical turbulent channel flow. The turbulent channel is at a Reynolds number of 180 based on the channel half-width and friction velocity. The carrier flow is air and the dispersed particles are copper with a mass loading of 0.57 and a dynamic Stokes numbers of 192, 60 and 24. It is shown that the solid-to-solid particle-to-wall heat transfer depends on the average wall roughness, and it is inversely proportional with the wall roughness. For the average roughness of a steel pipe and the number and size of particles considered in this study, the direct particle-to-wall heat transfer was smaller than the indirect particle-to-wall heat transfer. The overall heat transfer between the wall and particle-laden flow is calculated based on the sum of the convective heat transfer between the solid wall and the carrier flow, and the heat transfer between the wall and the particles. The Nusselt number of the suspension is also modified accordingly based on this overall heat transfer.

Design and Simulation of a 9 MeV Gamma-Ray Calibration Source for Deployment into the DUNE Liquid Argon Based Far Detector at Sanford Lab

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Mentor/Advisor: Juergen Reichenbacher; Physics Department (PHYS)

ABSTRACT

The Deep Underground Neutrino Experiment (DUNE) is scheduled to have its first 10 kton liquid argon detector module at Sanford Underground Research Facility (SURF) operational in 2024. SURF is located in the former Homestake Mine in Lead, SD. The final DUNE far detector will be comprised of four individual 10 kton liquid argon modules. Knowing the detector response to low-energy signals from supernova and solar neutrinos is key for being able to record such data in the first place and for the interpretation of the weak electronic signals from these astrophysical sources. Requirements for a deployable calibration source are that it be survivable at cryogenic liquid argon temperatures (87 K), that the entire source body does not float, that it can be deployed and retrieved through sealable flanges with 20 cm diameter at the top of the detector cryostat, and that it still has enough neutron moderator material to initiate (n, gamma) nuclear reactions on an encapsulated target. Such produced gamma-ray energies can be high enough to achieve sufficient penetration probabilities into the inner active region of the detector. Moreover, escaping neutrons from the source body must become negligible. Last but not least, the source must produce pure enough high energy gamma-rays at a fine-tuned rate for efficient daily calibration of the detector response to electromagnetic gamma-ray interactions without event pile-up in the electronic read-out time window. The baseline design is a 9 MeV gamma-ray calibration source that employs encapsulated Cf-252 providing spontaneous fission neutrons to initiate 58Ni(n, gamma) reactions on a natural nickel target inside a cylindrical Delrin moderator body that just fits through the flange. Results from computer simulations are presented that aim at validating the calibration source concept and the deployment scheme before actual construction of the source is initiated.
Measurement of the $^{13}\text{C}(\alpha,n)^{16}\text{O}$ Cross Section at Low Energies

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Mentor/Advisor: Dr. Frank Strieder; Physics Department (PHYS)

ABSTRACT

The s-process is responsible for creating half of all the elements in the universe heavier than iron. Details of the s-process determine key factors of stellar evolution and elemental abundance throughout the universe. A key to understanding the s-process is the $^{13}\text{C}(\alpha,n)^{16}\text{O}$ reaction. Owing to the low reaction yield and relatively high backgrounds in most laboratories, measurements of the reaction cross section have not previously been possible in the energy range of astrophysical interest. CASPAR (Compact Accelerator System for Performing Astrophysical Research) at SURF (Sanford Underground Research Facility) will be the first to perform measurements of the reaction cross section at the relevant energies. Efforts to achieve this measurement and ancillary work will be discussed.
Neutron Calibration and Simulation for the LZ Dark Matter Experiment

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ABSTRACT

The LZ Dark Matter Experiment will perform the most sensitive direct search for weakly-interacting massive dark matter particles (so-called WIMPs). The experiment will be located underground at SURF (Sanford Underground Research Facility) in Lead/SD. The LZ central detector will not only be an order of magnitude larger than the previous LUX inner detector decommissioned at the same location, but its sensitivity for direct dark matter searches will be even 100 times better than LUX. If WIMPs exist, they 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 and the delayed charge detection is characteristic for such a nuclear recoil and differs significantly from an electron recoil produced by undesired background reactions. However, the precise knowledge of the critical ratio value, for which the electron recoil dominated regime transitions into the nuclear recoil dominated regime, is key.

Dedicated neutron calibration sources such as the DD-generator gun, AmLi and Cf-252 neutron sources, as well as a new mono-energetic Y/Be neutron source are essential tools to precisely map the nuclear recoil (NR) region. That way it can be demonstrated what a possible WIMP detection would look like in the LZ detector.

A simulation and analysis software package is employed to study the physics interaction and detection of signals and backgrounds in the LZ liquid xenon time-projection-chamber (TPC). Mock data challenges, prior to LZ getting real data, serve as important validation of the full simulation and data analysis chain, such that there will be a quick, competitive turn-over, once LZ gets its first real data in 2020. One of the first crucial calibration measurements right after liquid xenon filling will be the increase of the electron lifetime during the initial purification stage. A cosmogenically activated natural isotope $^{131m}$Xe that decays away once the detector is shielded underground from cosmic rays, will be utilized for this first calibration measurement. Further, staged data for calibrations will involve neutron source deployments to map out the NR signal band and gamma-ray source deployments to map out the electron recoil (ER) background band.

In addition to performing extensive computer simulations, the precise neutron fluxes of the various neutron calibration sources have to be characterized before the actual deployments of the sources will be performed. It has to be assessed beforehand, if they are suitable and what the detection efficiency in the detector is. A new neutron telescope, utilizing He-3 proportional counter tubes, has been developed within the framework of the LZ project.
Biobattery+Supercapacitor Hybrid Devices Powered by Municipal Wastewater

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ABSTRACT

Development of high-performance electrochemical energy storage devices that offer high power density and long cycling life is important to modern society. Here we demonstrate a proof-of-concept for a biobattery-supercapacitor hybrid device that is powered by microorganisms and typically discarded wastewater. This device relies upon the use of hierarchically structured 3D nickel foam coated with plasma exfoliated graphene nanosheets (Gr/Ni foam) as a bioanode. A two-compartment microbial fuel cell served as a model for biobattery. The tests were carried out in identical biobattery reactors varying in the type of the bioanode: Gr/Ni foam (test), Ni foam (control 1), and graphite felt (control 2). An electroactive microbial consortium was used as the biocatalyst, municipal wastewater as the anolyte and ferricyanide as the catholyte. The Gr/Ni bioanode the biobattery power output to 2582 mW/m² which was 152-fold higher than the Ni and other commercial alternatives. The SEM tests revealed that the Gr/Ni architecture promotes biofilm formation. A series of electrochemical impedance spectroscopy, cyclic voltammetry, and charge/discharge cycle tests revealed that the Gr/Ni/biofilm interface promotes the formation of the electrochemical double layer, consistently yielding nearly 250 mAh capacity for over 100 cycles using biological media as the electrolyte. The capacitance of the Gr/Ni/bioanode interface (1.94 F/cm²) was 110-fold higher compared to the controls. The capacitance value increased when the electrolyte based on chemically defined media was replaced with a strong base.
Microstructure and Mechanical Properties of Thermally Aged Chromium Electrodeposits on Copper Substrates

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Mentor/Advisor: Dr. Cabot-Ann Christofferson; Chemistry and Applied Biological Sciences Department (CABS)

Co-Mentor/Advisor: Bharat Jasthi; Materials and Metallurgical Engineering Department (MET)

ABSTRACT

Copper is the ideal structural material for low background experiments due to its radiopure nature and the ability to be purified further through electroforming. However, copper’s inherent ductility makes it difficult to use for the hardware requiring threading without the application of a coating to prevent galling. Currently vacuum deposited parylene polymers are applied but does not stand up to multiple usages along with compromising the cleanliness of the original starting material. Chromium could be an attractive coating because of added strength to the copper through precipitation while not adding contamination. Electrodeposition of chromium onto copper substrates is investigated as a method to strengthen the substrates without alloying. Parameters of the electrodeposition were varied to optimize the mechanical properties of the copper-chromium system. These parameters include voltage, current density, and plating time. Parameter variation was based on previous work that utilized electrodeposition to attempt to alloy chromium and copper. Post plating microstructures and mechanical properties testing was performed. A thermal aging process was designed and applied to improve the chromium adhesion and to strengthen the copper-chromium system further. Post heat treatment microstructures and mechanical properties testing was performed. Once optimized the parameters will be applied to copper rods and screws allowing for further testing of radiopurity control.

Figure 1. Preliminary microstructure displaying problems with hot mount for electrodeposited samples.
Detection of the Inhibitors Furfural, 5-Hydroxymethylfurfural (HMF), and Corresponding Metabolites Produced by Saccharomyces Cerevisiae D5A During Aerobic and Anaerobic Batch Fermentation

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ABSTRACT

Previous research has shown the dilute acid pre-treatment of pine wood produces inhibitors (furfural and 5-hydroxymethylfurfural) that decrease specific cell growth rate and ethanol productivity during subsequent fermentation. Yeast strains that are able to metabolize these inhibitors have been shown to produce different metabolites, forming 2,5-Furandimethanol (FDM) and furfuryl alcohol under anaerobic conditions or 5-Hydroxy-2-furancarboxylic acid (HFC) and 2-furoic acid under aerobic conditions. The goal of this study was to determine whether the yeast strain D5A produces these same metabolites under microaeration vs anaerobic conditions. It was found under the anaerobic conditions of sealed serum bottles, detectable amounts of FDM and furfuryl alcohol were produced from HMF and furfural, respectively. HFC and 2-furoic acid were similarly produced in aerobic batches grown in shake flasks. These additional aerobic pathways may partially explain why furfural and HMF are metabolized faster under microaeration (-150 mV redox potential) conditions (0.25 g furfural/L/OD/hr vs 0.13 g furfural/OD/hr for anaerobic fermentation). Faster furfural and HMF metabolism ultimately leads to greater ethanol productivity with microaeration (1.32 g ethanol/L/hr vs. 0.51 g ethanol/L/hr for anaerobic fermentation).
Net-Energy Analysis of a Three Stage, Bio-Electrochemical Module for Municipal Wastewater Treatment

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Mentor/Advisor: Dr. Venkataramana Gadhamshetty; Civil and Environmental Engineering Department (CEE)

ABSTRACT

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Here we present a comprehensive energy analysis of novel bioelectrochemical treatment train that integrates thermophilic fermentation (Stage I), microbial fuel cell (Stage II), and ultrafiltration processes (Stage III). The first stage uses thermophiles originally isolated from cattle manure for generating hydrogen using chemical oxygen demand from wastewater. The first stage reduced the COD from ~ 200 mg/L to 53 mg/L. The stage II further reduced the COD to the limits defined by the NPDES permit. The stage III served as a polishing unit to eliminate remaining COD, microbial debris, foulants, and a range of metals. A 30-kDa poly (ether sulfone) ultrafiltration membrane (Microdyn-Nadir® UH030 P) used in the stage III was rendered hydrophilic and foulant-resistant using mussel-inspired dopamine chemistry. We will present a net energy analysis of the three staged process (jointly termed as bioelectrochemical module) and compare the energy performance with contemporary activated sludge process. The latter was modeled under two scenarios; one that does not use UV disinfection but accommodates energy recovery, and a second that uses UV disinfection but does not facilitate energy recovery. The study revealed the net energy benefits of the module, primarily due to its ability to minimize oxygen and pumping requirements.
An Exploration of Barium Molybdate as an Alternative Oxidizer in the Traditional Tungsten Delay

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Mentor/Advisor: Dr. Lori Groven; Chemical and Biological Engineering Department (CBE)

ABSTRACT

In recent years, current fielded delay formulations, such as the traditional tungsten delay, are facing an increased scrutiny due to their environmentally hazardous components (i.e., BaCrO$_4$, PbCrO$_4$, KClO$_4$) and byproducts. With the increased scrutiny and added usage regulations, there is now an immediate need for viable replacements. Previous work in this area has explored various alternate compositions (i.e., Mn/MnO$_2$, W/MnO$_2$, W/SrMoO$_4$/KClO$_4$/DE). However, these alternate systems have not been able to match the tuneability of traditional delay. This is a direct result of not fully understanding the full role that barium chromate and potassium perchlorate play in the delay’s performance.

To further understand the significance of the barium chromate, barium molybdate was chosen as a replacement oxidizer. Using the data from this study in combination with a previous study involving strontium molybdate, the effect of barium chromate on the traditional tungsten delay can be further detailed. In this work, we are studying the thermal properties, the inverse burning rate, kinetics, combustion products and gas generation of the barium molybdate delay and comparing them with the performance of the traditional tungsten delay and the strontium molybdate delay formulation. These comparisons will allow for a greater understanding of the barium chromate delay and aid in further development of environmentally begin alternatives.

The investigation of the barium molybdate delay will include a comparison of delay formulations from 20 to 70 wt% W, with 10 wt% KClO$_4$, 5 wt% diatomaceous earth, DE, and remainder barium molybdate. Samples were analyzed with thermogravimetry differential scanning calorimetry, DSC-TGA, to compare the thermal properties and determine reactivity. Inverse burning rate, by-product analysis and gas generation measurements were gathered for 20 to 70 wt% samples. Thermal kinetic analysis was conducted on 40 wt% W at 20, 10, and 5°C using the Kissinger method, resulting in an activation energy value of 124 kJ/mol. Temperature profile kinetics was also performed on 20, 40, and 60 wt% W delay formulations and activation energy values were determined through Boddington methods. An understanding of the role played by barium chromate is presented along with proposed reaction mechanism.
Mechanochemical Synthesis of a Biocidal Co-Crystal

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ABSTRACT

Agent defeat weapons are a modern method for neutralizing biological weapons while minimizing the exposure of friendly personnel. Formulations for agent defeat weapons are often composed of physical mixtures of high iodine containing oxidizers and fuels. This work explores the co-crystallization of AP and Ca(IO$_3$)$_2$ through scalable synthesis on a LabRAM. The formation of a co-crystal was assessed through a combination of powder x-ray diffraction (PXRD), Raman spectroscopy, and adoption of a new crystal morphology. The thermal, impact, friction, and electrostatic sensitivity was evaluated. The combustion performance and iodine release were compared to a physical mixture using 25 wt% THV bound formulations with a fuel/oxidizer content of 11.45 wt% B$_4$C and 88.55 wt% AP/Ca(IO$_3$)$_2$. Co-crystallization resulted in a molecular intimacy between AP and Ca(IO$_3$)$_2$ that exhibits in improved combustion and iodine release, in an atmospheric environment, when compared to a physical mixture.
Investigating the Influence of Microstructure on the Thermal Stability of Ag Inclusions in Self-Lubricating Coatings

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Mentor/Advisor: Dr. Grant Crawford; Materials and Metallurgical Engineering Department (MET)

ABSTRACT

Reduction of friction and wear at high temperatures is often achieved through the use of solid lubricants. For improved performance and functionality, self-lubricating coatings have been extensively studied in which solid lubricant phases are continuously supplied to the surface from inclusions within the coating. To investigate the influence of coating microstructure on solid lubricant activation, VSiCN and VSiCN-Ag coatings were deposited by plasma enhanced magnetron sputtering (PEMS). Amorphous phase composition was varied between depositions. The resulting coating microstructures were characterized using energy dispersive X-ray spectroscopy, scanning electron microscopy, and X-ray diffraction. Hardness and elastic modulus were measured using nanoindentation. Potential methods to determine the influence of coating structure on Ag inclusion thermal stability and transport are discussed.
The Hungry Hungry Cell – Evaluation of FcγR Mediated Phagocytosis in Macrophages

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Co-Mentor/Advisor: Dr. Brandon Scott; Nanoscience and Nanoengineering Department (NANO)

ABSTRACT

Macrophages are a member of the innate immune system and are responsible for clearing pathogens, debris, and dead or dying cells by phagocytosis, i.e., ‘cell eating’. By utilizing antibody labeled targets a FcγR phagocytic response is induced in macrophages. During the phagocytic response, both receptor-antibody interaction and actin driven membrane dynamics occur as to internalize antibody labeled sheep erythrocyte targets. As to examine this response, lattice light sheet microscopy is utilized to examine the plasma membrane of the macrophage as well as the membrane and antibody of our erythrocytes as high resolution, volumetric images both temporally and spatially with minimal disturbance of the cell. With the acquired data evaluation, a phagocytic event is completed through analysis of a three-dimensional time sequence, i.e., ‘a movie’. In these renderings we take full advantage of our high spatiotemporal resolution as to track the trafficking of our target during internalization, alongside the methods by which the target is annihilated. Future work will define the frequency of target destruction pathways deformation, ripping, oxidation, shredding of antibody from the target surface. Ultimately the goal in this work is to define the membrane and cytoskeletal organization that leads to the internalization and trafficking of antibody-coated particles.

Figure 1. Surface rendering of a FcγR mediated phagocytic event where antibody labeled sheep erythrocytes are in free fall through imaging media to contact macrophages adhered to a glass coverslip. During this event the sheep erythrocytes are presented in light blue representing their membrane and the macrophages in purple representing their membrane.
**Combined AFM and FLIM Imaging of Intracellular Forces and Mechanotransduction in Chondrocytes**

**Divya Kota;** Nanoscience and Nanoengineering Department (NANO)

Mentor/Advisor: Dr. Steve Smith; Nanoscience and Nanoengineering Department (NANO)

**ABSTRACT**

Osteoarthritis (OA) is one of the leading chronic, degenerative diseases in the world, causing joint pains and disability in patients with no known cure. OA is characterized by progressive degradation/loss of articular cartilage, important for maintaining healthy joints. Even though we know mechanical forces on chondrocytes (the only cells in ECM of cartilage) are important for preventing OA, surprisingly little is known about the mechano-biochemical signaling in chondrocyte cells, and how it’s influenced by the mechanical loads on articular cartilage in day to day life. Here, we address integrin based mechanotransduction in chondrocyte cells. Forces in the piconewton (pN) range are known to influence both healthy cartilage maintenance as well as diseased joint tissue. Integrin based mechanotransduction studies using Atomic Force Microscopy (AFM) reveal the range of interaction forces at the single-molecule level, as well as the total adhesion forces impacting cell behavior. The influence of those forces is further understood through fluorescence lifetime imaging microscopy (FLIM), revealing the force and tension generation within cells. Using AFM, we measured single-molecule interaction forces of 50-100pN on live cells. The external application of 60 pN force to chondrocytes mediated through integrins results in an average force of 7 pN within the vinculin adhesion proteins distributed across a single cell.

**Keywords:** Chondrocyte, Osteoarthritis (OA), Integrin, Mechanotransduction, Atomic Force Microscopy, Fluorescence Lifetime Imaging Microscopy (FLIM), Vinculin, Tension Sensor Module (TSM).
Influence of Composition on Physiochemical Properties of Lactic Acid and Sebacic Acid CoPolymers

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ABSTRACT

Continuously growing pharmaceutical device demand has necessitated the search for synthetic biodegradable materials which have a wide range of physiochemical properties. Synthetic biodegradable polymers, such as polyesters and polyanhydrides, are well investigated for biomedical applications due to their biocompatibility. Polyesters and polyanhydrides have different physiochemical properties such as: degradation time, degradation method, and thermal properties. These synthetic biodegradable polymers can breakdown into individual monomers inside the body through hydrolysis. Poly(ester anhydrides)s are hybrid polymers which have wide range of properties.

In this work we synthesized random copolymers through polycondensation using D,L-lactic acid (LA, (polyesters)) and sebacic acid (SA, (polyanhydrides)) monomers. Six distinct random copolymers were synthesized by varying the ratio of LA to SA monomers. The physiochemical properties such as molecular weight, structure, thermal properties, degree of crystallinity, and microphase separation were characterized by, $^1$H-NMR, FT-IR DSC, TGA, XRD, and AFM respectively. Findings revealed the critical role of composition on the resulting properties of copolymer P(LA:SA). molecular weight, melting temperature, degree of crystallinity increased with increase in sebacic acid concentration. AFM results revealed the existence of microdomains in copolymer with highest sebacic acid concentration. Future applications of this work include the synthesis of nanoparticles of P(LA:SA) copolymers, investigation of the degradation kinetics, and incorporation of therapeutics for controlled release.
Therapeutic Application of Triplex DNA Binding Agents in Targeted Deletion of Expanded (GAA)n•(TTC)n Repeats in Friedreich Ataxia

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Mentor/Advisor: Dr. Richard Sinden; Biomedical Engineering Program

ABSTRACT

The expansion of repeats in genomic DNA is associated with more than 30 human neurodegenerative diseases, including Friedreich Ataxia (FRDA), an autosomal recessive neurodegenerative disease, caused by (GAA)n expansion in intron 1 of the frataxin gene on chromosome 9. Expansion results in low levels of the frataxin protein, which causes mitochondrial failure leading to cell atrophy and ultimately cell death. (GAA)n•(TTC)n repeats can form different types of DNA triplex structures in vitro and in cells. The genetic instability of the repeats increases with the increasing repeat length and the instability may be related to the formation of alternative, triplex, DNA structures. Certain DNA intercalating or binding agents can promote the formation and stabilization of triplex DNA.

Here, we address the hypothesis that treatment with triplex stabilizing agents can promote deletion of expanded (GAA)n•(TTC)n repeats in FRDA lymphoblast cells. Repeat deletion may result from the formation of stable triplex DNA. Stable triplex DNA may induce targeted gene editing by normal cellular DNA repair mechanisms, reducing repeat lengths and restoring frataxin production. Alternatively, triplex DNA can block DNA replication, and deletion may result from resolution of the block during replication restart.

We have analyzed three compounds that can bind and stabilize triplex DNA (coralyne, tryptanthrin, and neomycin). Using an E. coli model system, coralyne was most effective at increasing the rate of deletion of (GAA)30•(TTC)30 repeats; neomycin showed a smaller increase, and 4-aza-tryptanthrin a minimal, if any, effect. Aim 1 involves identification of concentrations of DNA binding agents that result in repeat deletion with minimal toxicity in human cells. In normal and heterozygous FRDA cells, coralyne inhibited the growth rate to similar levels, while a homozygous FRDA line was more sensitive to coralyne at 1 ug/mL. Growth of the heterozygous cell line was unaffected by addition of neomycin concentration up to 300 ug/mL. Allele lengths are detected by PCR analysis using published procedures. In initial dose dependent studies, neomycin selectively reduced the population of expanded alleles, with no effect on the normal length alleles. Analyses to-date show that normal-length alleles were unaffected by treatment with coralyne. Analysis of the effect of other triplex binding agents on reducing the length of expanded alleles is on-going. Aim 2 involves synthetic efforts to produce and evaluate compounds that can act as dual intercalator/groove triplex DNA binders. Groove binding moieties, such as polyamines, are being incorporated into the structures of coralyne and multiple tryptanthrin analogues to increase the degree of triplex stabilization and repeat deletion.

Current approaches to treating Friedreich Ataxia, caused by decreased levels of the frataxin protein, include a) improving mitochondrial function; b) increasing frataxin expression; and c) gene therapy. Although numerous compounds are in varied stages of development and testing as candidate drugs, yet none are approved. No treatments exist for the genetic basis, DNA repeat expansion, of FRDA or many other repeat-expansion neurodegenerative disorders.

Our novel potential therapeutic approach involving targeted deletion of expanded (GAA)n•(TTC)n repeats should increase frataxin expression, restoring mitochondrial function, and prevent or delay the onset of FRDA. Targeted repeat deletion may provide a general genome editing approach that may delay or prevent the progression of other repeat expansion diseases at an early stage of development, e.g. Huntington Disease.
Spatial-Temporal Imaging of Auxin to Cytokinin Ratio During Nodule Development in Soybean (Glycine max) by Two-Photon Induced Fluorescence

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Mentor/Advisor: Dr. Steve Smith; Nanoscience and Nanoengineering Department (NANO)

ABSTRACT

Legumes have a symbiotic relationship with rhizobia, which supply nitrogen to the legume while the legume provides a carbon source for the rhizobia. The legume forms a specialized root organ called a nodule, which is infected by the symbiotic rhizobia. Two phytohormones, auxin and cytokinin are key regulators of nodulation in soybean. The binary vector DR5::GFP-NLS (auxin) and TCSn::TdT-NLS (cytokinin) was transfected into the plants, expressing green (GFP) and red (TdT) fluorescent proteins in proportion to the local auxin and cytokinin concentration in each cell. A nuclear localization signal (NLS) was added to the construct to concentrate the fluorophores in the nucleus. We use multi-photon induced fluorescence microscopy to volumetrically map the spatial variation of these key regulatory phytohormones, and computational methods to quantify the absolute and ratiometric variations in auxin/cytokine and their spatial and temporal variations during nodule development. Plant microRNA 160 participates in auxin signaling via negative regulation of auxin response factor (ARF10/16/17). In this study, we knocked down miR160 using short tandem target mimic (STTM160) and investigated the auxin to cytokinin ratio using nuclei segmentation at different stages of nodulation in soybean.

Figure 1: Multi-photon induced fluorescence images of GFP and TdT fluorescent proteins showing spatial-temporal variation of auxin and cytokinin in developing root nodules (upper) and statistical analysis of their ratios (lower) in stage 1 to 2 for wild type of Glycine Max/W82.

References


Environmental Controls on Banded Versus Cellular Organization of Mesoscale Snow Squalls in Western South Dakota

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ABSTRACT

Snow Squalls are defined as mesoscale bursts of heavy snow characterized by gusty winds, and visibility below a quarter of a mile. They are fast-moving systems that generally impact an area for less than an hour but can cause hazardous driving conditions and have proven difficult to forecast. Past research has focused on the mesoscale and synoptic-scale environmental conditions associated with these systems and have identified both banded (more common) and cellular snow squall organizations. To date, however, there has been little study of what governs the organizational mode of these features. The primary aim of this project is to address this knowledge gap by investigating the organizational structure and development of snow squalls in Western South Dakota.

Forty snow squall cases were identified between 2012 and 2017 using surface weather observations from Rapid City, Philip, Spearfish and Custer, South Dakota. WSR-88D radar data were used to determine the mesoscale structure of the snow squalls. Banded cases were defined as having lengths longer than the average width of any given echo, and cellular cases had a length to width ratio close to one. This produced 22 banded, 11 cellular, and 7 mixed cases that had characteristics of both banded and cellular systems. Thirty of the cases occurred between 16z and 00z (4PM – 12AM local standard time) suggesting a connection to diurnal heating. Banded cases were more likely to occur during colder months (November – February), while cellular cases occurred during warmer months (February – May). Rapid Refresh model analysis (RAP) data were used to determine synoptic patterns, forcing mechanisms, vertical shear, and static stability associated with each type of snow squall. By the end of this project we expect to better understand the environmental parameters that control banded versus cellular structure and have a better understanding of the meso-gamma scale and meso-beta scale structures within snow squalls.

This presentation will focus mainly on the environmental characteristics related to snow squall development and organization. The initial classification into banded and cellular cases will be defined and representative cases presented. With a better understanding of snow squalls, we hope to provide aid for forecasting snow squall events that can cause significant transportation impacts.
Developing a Soil Temperature Assimilation Capability Within the NASA Land Information System

John Eylander; Atmospheric and Environmental Sciences Department (AES)

Mentor/Advisor: Dr. William Capehart; Atmospheric and Environmental Sciences Department (AES)

ABSTRACT

Land surface models fulfill an important role in numerical weather prediction computing the surface energy budget to estimate sensible and latent surface heat fluxes that support boundary layer atmospheric processes, as well as generating estimates of soil moisture, surface runoff, and a number of other products. The weather and climate modeling community use global and regional Land Data Assimilation Systems (LDAS) to gather, compute, and integrate the necessary inputs to generate analyses of land surface model conditions that initialize prediction systems. One such LDAS system, the NASA Land Information System (LIS), has the capability to assimilate satellite-measured surface properties using a variety of assimilation techniques including ensemble Kalman filtering, extended Kalman filtering, and a number of optimal interpolation techniques as a way of updating land surface model state predicted variables. The primary measurements assimilated in LIS are soil moisture measurements generated from passive microwave satellites, however, while soil moisture has long been a target for the assimilation community improving the estimate of soil temperature and evapotranspiration via assimilation has lagged. This presentation will provide an overview of LIS, describe the software configuration and land surface hydrology models that will be used as part of the research plan, describe the soil/surface temperature assimilation capability being developed, and state the desired outcomes from the research effort.

References


Groundwater management plays an important role in the development of water resources. As cities grow, so does their need for more water. The overall goal of groundwater management is to prevent excessive use of groundwater resources while still meeting water demands. A subproblem within groundwater management is the placement of wells. Given a groundwater resource and a set number of wells, the challenge is to determine the best places to install the wells. A solution for the well placement problem can help cities and industries design well fields for extracting groundwater economically and efficiently. Algorithms used to solve this optimization problem include particle swarm optimization and differential evolution. These algorithms can generate well-field solutions with constraints. However, their use includes the tuning of a number of hyperparameters. On top of solving the optimization problem of interest, additional computational power is required for tuning these hyperparameters. To handle the computational burden, this study proposes a modified version of the Extremal Optimization algorithm (EO), and applies it to groundwater management for the first time. EO works by modifying the components of a solution that contribute the least to its overall performance. EO has no optimization parameters, thereby eliminating the need for hyperparameter adjustments. This work presents an algorithm called EO-WPP, which extends EO to the domain of continuous spatial problems. The EO-WPP algorithm was set to search for a well-field configuration that maximizes cumulative output while respecting a global drawdown constraint. In the first testing phases of this work, EO-WPP was applied to a problem of simple geometry and a simple synthetic model in order to study its performance and its emergent spatial behaviors. EO-WPP then was applied to a field problem involving the Aberdeen groundwater model in South Dakota. The results show that EO-WPP was able to generate a series of possible of well fields that can be used to pump effectively groundwater from the Elm aquifer.
**Innovative Condensation Method for Cooling Chambers and Its Applicability for Atmospheric Water Generator (AWG) Using Renewable Sources**

Sandesh Acharya; Electrical and Computer Engineering Department (EE, CENG)

Mentor/Advisor: Dr. Magesh Rajan; Electrical and Computer Engineering Department (EE, CENG)

Co-Mentor/Advisor: Dr. Rajesh Shende; Chemical and Biological Engineering Department (CBE)

**ABSTRACT**

Water scarcity has been the burning issues in this world where fresh water for drinking and carrying out everyday chores remains scarce and is faced by many countries. The project aims to solve this problem by generating water through the atmosphere by harnessing wind and solar energy and improving condensation method as an innovative solution. The research is focused on the cooling of atmospheric air below the dew point in order to extract water and meet the WHO requirements for per person. The cooling is achieved through modules which are powered by around 1.2 billion people, or almost one-fifth of the world’s population, live in areas of scarcity. Another 1.6 billion people, or almost one quarter of the world’s population, face economic water shortage where countries lack the necessary infrastructure to take water from rivers and aquifers (FAO, 2007). Around 700 million people in 43 countries suffer today from water scarcity. (Global Water Institute, 2013). We could see that a large number of populations have scarce of water availability and moreover, fresh drinking water has been a major issue in today's world. The concept (prototype developed) aimed to generate the water from the atmospheric, at least meeting the water requirements for the individual person (as per WHO). On further addition, the project will be built on a large scale to provide the water to a group of people or the community in large volumes through the use of renewable energy resources. A major reason to implement an atmospheric water generator is for (especially) emergency and medical purposes.

The figure shows innovative coil structure cooling chamber powered through solar leaf like structures along with the rotating turbine blades (at top of chamber). The air is passed through the pump action by wind and is circulated through the copper coils that are placed inside the cooling chamber. Upon reaching below the dew point, the copper coils gets more cooled and water droplets start to falls and is collected in the vessel.

**References:**

1. Dr. Rajesh Shende (E: Rajesh.Shende@sdsmt.edu)
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ABSTRACT

Linear mesoscale convective systems (LMCS’s) are systems of thunderstorms that are capable of producing flash-flood-inducing heavy rainfall, damaging straight-line winds, and occasionally large hail and/or tornadoes. LMCS evolution is difficult to predict, especially when systems move over rough terrain. Previous studies have focused on how LMCS’s are affected by quasi-two-dimensional terrain features, such as a mountain range. However, there has been limited study of how LMCS’s are affected by isolated terrain, such as the Black Hills in Western South Dakota. A particular challenge is predicting the changes in structure and intensity that are often observed as storms that form in eastern Wyoming cross the Black Hills into South Dakota. To aid in filling this knowledge gap, the goal of this project is to document changes in LCMS structure and intensity as these systems cross the Black Hills and assess the potential role of the terrain compared to changes in environmental fields known to control LMCS evolution.

Archived radar data were analyzed for the months of May through September over 2007-2017 to identify cases of mesoscale convective systems interacting with the Black Hills. A group of 179 cases of LMCS’s crossing the Black Hills were identified, each meeting the criteria of radar reflectivity 40 dBZ or greater and a width-to-length ratio of at least 1 to 3. Each system’s structure and intensity were allowed to vary as long as the criteria was met at some point in the transition across the Hills. Each case was then divided into three time periods: Upstream, Over, and Downstream representing upstream from the Black Hills, crossing the Black Hills, and downstream from the Black Hills, respectively. Within each of these partitioned zones, the cases were manually categorized based on the system’s dominant convective modes such as: Single Cell, Multiple Cells, and Width-to-Length Ratios of 1 to 2, 1 to 3, and 1 to 4 or greater.

This presentation will detail the classification of these cases, and quantify changes in intensity as LMCS’s encounter the Black Hills. Changes in intensity will be compared with changes to the background environmental conditions with an aim toward isolating terrain effects from the MCS responding to environmental heterogeneity. Ultimately, through improved understanding of the interactions between MCSs and underlaying terrain, this research aims to further improve short-term forecasts of MCSs and their associated severe weather.
Evaluating Geomorphic Characteristics of Remotely Classified River Systems in the US Great Basin

John Costello; Civil and Environmental Engineering Department (CEE)

Mentor/Advisor: Dr. Scott Kenner; Civil and Environmental Engineering Department (CEE)

ABSTRACT

Rivers are often defined as linear, continuous structures that increase in size in the downstream direction, however, recent studies have questioned whether this concept adequately accounts for the discontinuities caused by natural variation and human influence. Alternatives to the River Continuum Concept (RCC), a downstream gradient, call for a discontinuum or patches. Functional Process Zones (FPZs) can be used to classify these patches. For this study, FPZs were classified and mapped along three rivers in the Great Basin (USA) using a GIS protocol and statistical grouping methods. River reaches within the resulting FPZs were sampled based on the modified EMAP protocol to test whether significant hydrogeomorphic differences existed across scales, including between FPZs, within a single watershed, and among watersheds in the Great Basin region. Cluster analysis was used to initially group FPZs using metric subsets (channel morphology, bank morphology, Substrate, fish cover, large woody debris, riparian, human influence, canopy density) of geomorphic characteristics measured in the field. Then using Principal Component Analysis (PCA) the number of variables in each subset were reduced to determine a smaller number of characteristics that best represent that subset. The strongest variables from each of the different subsets are used all together to determine if FPZs are similar or different from a geomorphic perspective. Our study reveals that FPZ type (upper wide, upper confined, lower wide, lower confined) can be grouped by hydrogeomorphic characteristics examined by PCA or Cluster analysis. When using specific metric subsets both the ideas of a continuum and patchiness can be supported.
Radiological Simulations and Prototype Data Analysis for the Deep Underground Neutrino Experiment (DUNE)

Jason Stock; Physics Department (PHYS)

Mentor/Advisor: Dr. Juergen Reichenbacher; Physics Department (PHYS)

ABSTRACT

The far detector of the long-baseline neutrino experiment DUNE will be sited underground at the Sanford Underground Research Facility (SURF) in Lead/SD. Neutrinos were first postulated by Wolfgang Pauli in 1930, and were discovered in 1956. They are subatomic particles with no electric charge and almost zero masses that are the subject of intense study in particle physics. They occur in three known flavors: electron-, muon- and tau-neutrinos. A neutrino that is produced in one flavor could be detected further away as another flavor. Resolving all parameters and mechanisms governing these neutrino-oscillations is a main goal of the planned long-baseline neutrino experiment DUNE, aside from supernova neutrino detection and fundamental proton decay search.

In order to ensure experimental success, radiological backgrounds must be modelled in computer simulations to validate the radiological requirements on detector materials. This work is a vital input for the design of DUNE’s detector and read-out electronics, and validation analysis of neutrino detection performance as well as proton decay sensitivity. As the experiment moves out of the design phase and into construction, the electronic systems and computing resources for event triggers must be finalized. Low-energy backgrounds will drive DUNE’s expected data rates. The radiological background studies done here at SDSM&T are key in this effort, as are the software and simulation tools we have developed. I will present on the ongoing effort in the study of radiological backgrounds needed to ensure DUNE is able to accomplish all of its physics goals, as well as first results with DUNE prototype data that can be applied to a future neutrino oscillation analysis with DUNE.
Evaluation of Radon Emanation and Diffusion for SuperCDMS SNOLAB

Michael Bowles; Physics Department (PHYS)

Mentor/Advisor: Dr. Richard Schnee; Physics Department (PHYS)

ABSTRACT

The SuperCDMS SNOLAB dark-matter experiment, now under construction, will use Si/Ge detectors as targets in an effort to detect scattering dark matter particles. A radon purge shield, used to reduce the background from gamma rays emitted by radon daughters within the experiment's lead shield, must be constructed with gaskets having low radon emanation and diffusion. I will describe the radon emanation system at SDSM&T as well as a low-cost set-up to measure radon diffusion and solubility. I will present measurements of radon emanation, diffusion, and solubility of gasket materials and describe improvements for radon emanation measurements under development.
ABSTRACT

The Super Cryogenic Dark Matter Search (SuperCDMS) experiment at SNOLAB will use solid-state germanium and silicon cylindrical detectors to measure ionization and phonons produced by the scattering of dark matter particles. The dominant expected background at low energy for SuperCDMS SNOLAB is from radon daughters that have plated out onto detector surfaces. Therefore, understanding and mitigating plate-out rates during detector fabrication, assembly, and installation is critical. A study of radon-daughter plate-out during detector polishing and assays of plate-out onto detector hardware provide limits on backgrounds. I will describe the construction and commissioning of the SuperCDMS SNOLAB radon mitigation system, which is built upon the design of the SD Mines prototype radon mitigation system that has achieved a 4000× reduction of radon to a cleanroom activity of ~20 mBq/m^3, and show the resulting expected background from radon daughters for the experiment. Recent results from an etch to reduce otherwise dominant sidewall backgrounds without damaging sensors on the detector faces will also be described.
Improved Survivability through Low Friction Wear Resistant Laser Clad BAM Alloy (AlMgB14+ Alloy) Coatings; Evaluated and Compared to Common Cast Alloys

James Tomich; Materials Engineering and Science Program

Mentor/Advisor: Dr. Bharat Jasthi; Materials Engineering and Science Program

ABSTRACT

In 2008, a remarkable material called BAM (AlMgB14) was described as slick like Teflon, hard like diamond, and nearly half the density of steel, at that time it was projected by the DOE that BAM surfaces could “reduce U.S. industrial energy usage by 31 trillion BTUs annually by 2030, with a savings of $179 million a year.” An emerging new class of high temperature, wear resistant, low friction materials called BAM alloys (AlMgB14+Metal Alloy) are shown to reduce wear and friction with minimized susceptibility to chemical attack and significant bond strength. These materials are synthesized and applied via Laser Powder Directed Energy Deposition (LPDED) process to form coatings that finish at approximately 1.5 mm thick. Two select formulations of BAM alloy materials, a Nickel based BAM alloy (AlMgB14+ Ni Alloy) and an Aluminum based BAM alloy (AlMgB14+ Al Alloy) are applied to ANSI 4140 Steel and 6061 T6 Aluminum using LDID. The resulting coating are investigated and compared to Grey Cast Iron (GCI) and cast aluminum A356. Sliding wear tribology testing, ASTM G77, is used to assess dynamic coefficient of friction and wear resistance in lubricated and dry conditions with unidirectional sliding contact against ANSI 4620 steel counter ring surfaces in a Falex block-on-ring sliding wear test apparatus.

In 400°F 0w30 oil, contacting surfaces sliding at 0.5 m/s under step loading up to 85 Ksi contact stress shows the BAM alloys reduced dynamic friction by 30% when compared to GCI and A356 cast alloys. More notably, the Aluminum coated BAM alloy exhibited over 900 times the wear resistance of the A356 in the sliding study. When evaluated with dry sand abrasion testing, ASTM G65B, an aluminum BAM alloy coating of 6.63 mm³ volume loss trumps the 344.9 mm³ volume loss measured for A356 cast aluminum. These gains are attributed to the dense and continuous phases of the consolidated BAM structure, its known low friction behavior, and minimal local regions of metallic phases. The nickel formulation significantly outperforms the wear resistance of GCI with 135.7 and 35.8 mm³ volume loss respectively. These recognizable advancements in low friction wear performance coatings have the potential to revolutionize the materials possibilities needed to improve sustainable production and reduce energy consumption with improved part lifecycle and decreased friction losses.

Effect of Post Processing on Additively Manufactured WE43 Magnesium Alloy

Leila Sorkhi; Materials Engineering and Science Program

Mentor/Advisor: Dr. Grant Crawford; Materials and Metallurgical Engineering Department (MET)

ABSTRACT

Magnesium and magnesium alloys have been used as biodegradable implants due to their excellent biocompatibility, comparable mechanical properties to the natural bone, and their unique ability to naturally degrade in the physiological environment. The biodegradation rate of magnesium alloys, however, is often too high, resulting in the loss of implant mechanical integrity and high hydrogen gas evolution causing subcutaneous gas accumulation. Additive manufacturing offers the potential to develop compositionally gradient biodegradable implants and complex implant designs for improved biological function. In this talk, we report on the effect of hot isostatic pressing and heat treatment on additively manufactured WE43 magnesium alloy specimens fabricated using laser powder deposition. Microstructure characterization was performed using optical microscopy, scanning electron microscopy, and energy dispersive x-ray spectroscopy and compared to a wrought commercial alloy. Microhardness and uniaxial tensile testing was performed to evaluate the mechanical properties of the samples. Finally, corrosion behavior was evaluated using potentiodynamic polarization methods in simulated body fluid.
Cold Spray of Nanostructured Ni/Al Composite Powders

Ryan Macy; Materials and Metallurgical Engineering Department (MET)

Mentor/Advisor: Dr. Lori Groven; Chemical and Biological Engineering Department (CBE)

Co-Mentor/Advisor: Dr. Grant Crawford; Materials and Metallurgical Engineering Department (MET)

ABSTRACT

Metal-based reactive composites are a leading contender for use as structural energetic materials but are limited by high ignition thresholds. Recent studies of the Ni/Al reactive system have shown that high-energy ball milling and wet grinding of these materials can create coarse and nano-laminated structures within the particles. Typically, this reactive system has an ignition temperature around 900K; however, as the fraction of nano-laminated to coarse microstructure increases the ignition temperature can be tailored to as low as 500 K. By reducing the ignition temperature, it becomes much more difficult to process the material into structural parts by conventional techniques. Moreover, because the melting temperature of aluminum (993 K) is greater than the self-ignition temperature, cold processing techniques must be used in manufacturing. Cold spray technology uses kinetic energy, rather than thermal energy, to form deposits making the technique an ideal candidate to produce Ni/Al and other structural energetic materials. This study investigates cold spray technology as a potential additive manufacturing technique to produce structural energetic materials. Cold spray was used to deposit a physical mixture of Ni/Al powder and milled Ni/Al nano-laminated composite particles. The microstructure, mechanical properties, and combustion behavior of the as-deposited materials were then characterized.
Hallow Manganese Oxide Catalysts for Enhanced Oxygen Reduction in Bio Electrochemical Systems

Bhuvan Vemuri; Civil and Environmental Engineering Department (CEE)

Mentor/Advisor: Dr. Venkataramana Gadhamshetty; Civil and Environmental Engineering (CEE)

ABSTRACT

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³Surface Engineering Research Center, South Dakota School of Mines and Bio electrochemistry system (BES) is an emerging field of science that investigates interactions between living cells and electrodes or capacitive materials. The BESs yield a variety of bioprocesses that use chemical energy of organic wastes to produce electricity, energy carriers such as hydrogen and methane, or valuable commodities including chlorine and sodium hydroxide. BES is referred by the acronym MXC where X stands for the application of interest. For example, F in MFC is fuel cell and the abbreviation MFC refers to microbial fuel cell. Typical components of MFC include anode, cathode and a membrane. A carbon cloth or graphite felt are being used as cathode in the MFC’s, but their performance is limited by using a solution like potassium ferric cyanide as catholyte which is an expensive chemical. A lot of research’s has done to develop an air breathing cathode to reduce the costs and to improve the performance of the MFC’s. In this study we use hallow Mn₃O₄ nanoparticles coated glassy carbon to verify their ORR activity. Mn₃O₄ nanoparticles have been used for catalyzing oxygen reduction reactions (ORRs) in fuel cells. These nanoparticles have been reported to be less expensive when compared with platinum catalysts. The use of Mn₃O₄ nanoparticles is less explored in microbial fuel cell (MFC) applications. The morphology of the resulting Mn₃O₄ nanoparticles influence their performance towards ORRs.

Figure 1. Microbial Fuel Cell
**Development of an In Vitro Pulmonary Epithelial Model**

Karissa M. Kjenstad; Chemical and Biological Engineering Department (CBE)

Co-Presenter: Charles Hibbeln; Chemical and Biological Engineering Department (CBE)

Mentor/Advisor: Dr. Timothy Brenza; Chemical and Biological Engineering Department (CBE)

**ABSTRACT**

Lung cancer is a major problem in the US, causing an estimated 234,030 deaths in 2018 and constituting 25.3% of all cancer related deaths [1]. Pulmonary drug delivery provides a mechanism for the controlled release of cancer treating agents, like paclitaxel, to the lungs while supporting a less invasive delivery procedure than traditional methods. In order to develop effective pulmonary drug delivery systems, physiologically relevant preclinical models are needed. Current models utilize *in vitro* and *in vivo* animal models, which are difficult to extrapolate into predictions of response in the human respiratory system.

The goal of this work was to characterize Calu-3 cells, an epithelial cell line derived from human adenocarcinoma cells. This cell line has been used to develop an *in vitro* model of the conducting airways of the respiratory system. Protocols were developed to culture confluent cellular monolayers on transwell membranes as both liquid-covered cultures and air-interface cultures. Parameters evaluated for both cultures included growth kinetics, cell viability, and transepithelial electrical resistance (TEER), a measurement of functional tight junction formation.

Future work will involve analyzing the transport of sodium fluorescein across the epithelial barrier. Fluorescein will be measured in the basal compartment of the transwell over time to determine permeability of the cellular monolayer. Conventional and immunological staining methods will be used to analyze mucus secretions and tight junction protein expression of the cellular monolayers. Once characterized, this *in vitro* model will be utilized in evaluating pulmonary therapeutic transport and efficacy.

**References:**

**Role of Hydraulic Conductivity Connectivity for Modeling Contaminant Plume Migration in Fluvial Deposits**

Wyatt Tatge; Geology and Geological Engineering Department (GEOE, GEOL)

Mentor/Advisor: Dr. Liangping Li; Geology and Geological Engineering Department (GEOE, GEOL)

**ABSTRACT**

One challenge in hydrogeology is to accurately characterize the heterogeneity of fluvial deposits because it shows strong spatial variation in hydraulic conductivity which is a key parameter in groundwater flow and transport modeling. A component of this heterogeneity is the connectivity of hydraulic conductivity. The question is how this connectivity affects the migration of contaminant plumes in an aquifer. Deterministic and stochastic modeling methods are routinely used to characterize the heterogeneity. In the deterministic modeling, hydraulic conductivity will be characterized as one “best” zoned representation of fluvial deposits. The connectivity is not well represented in this method. The stochastic modeling uses advanced multiple-point geostatistics, where the connectivity is explicitly modeled through a training image (i.e., the conceptual model). In this study, a synthetic example will be used to compare these two approaches for characterization of hydraulic conductivity. We further compare the flow and transport behavior. The results show that the stochastic model is more accurate to characterize the connectivity in terms of transport plume migration.
**Bridging the Gap in Creativity Between Students, Educators, and Practitioners**

**Kristin Lerdal; Civil and Environmental Engineering Department (CEE)**

Mentor/Advisor: Andrea Surovek; Mechanical Engineering Department (ME)

**ABSTRACT**

Despite the emphasis in recent years on developing creative and innovative engineers (e.g. NAE 2004), there is a general lack of emphasis on developing students’ creative skills in engineering curricula. There are many reasons for this perception of engineering as a field lacking in creativity, but what is alarming about this perception is its consequences. In a study looking at factors to predict persistence and achievement in engineering undergraduates, Atwood and Pretz found that students who rated themselves as “highly creative” were only 52% likely to persist in engineering while those who ranked themselves as “not very creative” were 95% likely to persist (2016). This study, among others, raises two questions: is there a measurable difference between the creativity of engineering students, educators, and practitioners, and how can engineering education be improved to better prepare students for creative problem-solving in their careers?

One approach to answering these questions is through assessing the problem-solving processes of engineering practitioners, educators, and students. Through identifying differences between these groups, the gap between academia and industry can be bridged to produce engineers who are adept at solving the ill-structured problems that live within the engineering domain. As part of this study, self-assessments of creativity will be correlated with problem solving approaches using a mixed-methods approach to determine if the creative person is directly related to the problem-solving process in ill-structured problems.

To measure individual creativity, the Kaufman Domains of Creativity (KDOCS) is employed in this study. The KDOCS was selected because it is easy to administer, low-cost, validated, and covers five domains of creativity: everyday, academic, performance, scientific, and artistic. Respondents rate their self-perceived creativity level for 50 different tasks within these domains to produce five sub-scores for their creativity within each domain, as well as a composite score to rate each respondent’s general creativity with regard to their peers. The rating system is a 5-point Likert scale, with 1 correlating to “much less creative” and 5 correlating to “much more creative” (Kaufman 2012). Average responses between the three subject groups for three domains of creativity (everyday, scholarly, and scientific) will be compared through t-tests and p-tests. In particular. The initial results will be used to establish if students, academics or practitioners self-identify as more creative and how their creativity breaks down by domain, with specific interest in everyday, scholarly and scientific creativity.

This study is funded by NSF DUE grant DUE #1712195, “Collaborative Research: Bridging the gap between academia and industry in approaches for solving ill-structured problems.”
The Structural Integrity of the USS Arizona

Amanda Booton-Popken; Civil and Environmental Engineering Department (CEE)

Mentor/Advisor: Dr. William Cross; Materials and Metallurgical Engineering Department (MET)

Co-Mentor/Advisor: Dr. Marc Robinson; Civil and Environmental Engineering Department (CEE)

Co-Mentor/Advisor: Dr. Michael West; Materials and Metallurgical Engineering Department (MET)

ABSTRACT

The USS Arizona is a National Treasure and should be monitored and protected. The USS Arizona was built in 1915, renovated in 1930, and sunk in 1941 during the Japanese attack on Pearl Harbor. When the USS Arizona sunk, it took with it 1,144 sailors and marines, as well as an almost full fuel oil tank. Most of the servicemen were still inside when the USS Arizona sunk, as well as an estimated half million gallons of fuel oil.

The structural integrity of the USS Arizona is important because when it inevitably collapses, it will release the rest of the fuel oil, which will damage the local environment. The National Institute for Standards and Technology (NIST) prepared a finite element model that recreates the USS Arizona’s hull and interior structural elements between frames 70 and 90; the model had wave loading attempted to learn the pressure wave that could be withstood by the ship at different points in its degradation.

An analytical tool, a parameter study, was developed to relate the corrosion rate and concretion rate to the stresses on the internal beams, but this identified critical future work. The parameter study, using the unverified corrosion and concretion rates, determined that the structure, at worst case, the ship should’ve had partial collapse in 1996, at best case, the ship may have until 2110 until partial collapse.
South Dakota is known for containing a wealth of fossil resources. One rock unit that is particularly fossiliferous is the Pierre Shale. The Pierre Shale contains marine fossils from the Western Interior Seaway deposited during the Late Cretaceous, and outcrops across much of the western side of the state. Although it contains numerous vertebrate fossils, it is also damaging to them, due to post-depositional taphonomic processes. Taphonomy is the study of processes that impact an organism after it dies (Behrensmeyer et al., 2000). This includes processes such as erosion and secondary mineralization, which can damage a fossil bone, preventing the collection of data. With an understanding of the patterns of taphonomy in the Pierre Shale, conservation and preservation can be better targeted in collections. Using specimens from collections and the field, data such as mineralization, weathering, breakage, and color were collected from a variety of taxa. Based on preliminary data, gypsum and other secondary mineralization is pervasive. Gypsum alone is found on 97% of the 34 specimens examined so far, covering an average of 32% of the surface area of specimens. Understanding the modern taphonomic processes that impact fossils is vital to our understanding of the fossil record. Processes like mineralization can destroy or alter fossils in the field, forever changing the data that can be gathered or causing the fossil to be lost entirely.

References

**Testing for Diversity Changes in Muricidae (Gastropoda) From the Pliocene – Pleistocene of Florida**

Peter Daley; Geology and Geological Engineering Department (GEOE, GEOL)

Mentor/Advisor: Dr. Laurie Anderson; Geology and Geological Engineering Department

**ABSTRACT**

At the Pliocene - Pleistocene boundary (2.58 Mya) the US Atlantic Coastal Plain experienced a major turnover event in mollusk taxa, due to both migrations and extinctions. This event, considered a minor extinction event, was likely a product of the onset of the Northern Hemisphere glacial cycle. Previous research indicates that the gastropod family Muricidae, representing a group of marine predators that bore through the shells of their invertebrate prey (primarily other mollusks) is of particular interest because it is a diverse group with previous studies indicating it was impacted by this extinction event in temperate latitudes where the effects of the glacial cycle were most pronounced. Research for this group from the subtropics, such as from peninsular Florida, is limited. Here, I test the hypothesis that Muricid diversity in Florida was impacted by this event in association with falling local ocean temperatures at the Plio-Pleistocene boundary. Muricid fossils from four lithostratigraphic and/or biostratigraphic units that spanned the Pliocene-Pleistocene boundary were examined. The Tamiami Formation (Fm.) (~2.5-4.2 Mya) represents the upper Pliocene, the Caloosahatchee Fm. (~1.6-2.5 Mya) the lower half of the Pleistocene, the Bermont Beds (~.4-1.5 Mya) the middle to upper Pleistocene, and the Fort Thompson Fm. (~.07-.27 Mya) the very uppermost Pleistocene. The resulting dataset represents 17 muricid genera from 32 samples from these four biostratigraphic units. Rarefaction curves for each unit indicated that the lower three units had broadly similar species richness values (richness S). However, the Fort Thompson Fm. stands out with a rarefaction curve with a high angle and a very low richness S value, indicating that although it was not as well sampled as the other units, it still had a lower diversity. An ANOVA with Mann-Whitney post-hoc pairwise comparisons also indicates no significant differences in diversity between the Tamiami Fm., Caloosahatchee Fm., and Bermont Beds, but that diversity in the Fort Thompson Fm. was significantly different from the other three units. Thus, with no major change in diversity at the Pliocene-Pleistocene transition, the diversity of Florida’s muricid assemblages shows no influence from the beginning of the glacial cycle and related climate change. It is possible instead that subsequent, colder pulses in the glacial cycle played a role in the loss of diversity seen in the Fort Thompson Formation.
Comparing Paleontology Databases Using Biodiversity Records of Marine Predators from the Late Cretaceous

Ryan Bozer; Geology and Geological Engineering Department (GEOE, GEOL)
Mentor/Advisor: Dr. Laurie Anderson; Geology and Geological Engineering Department (GEOE, GEOL)

ABSTRACT

Paleontological databases are excellent sources for obtaining fossil occurrence data, but choosing the ideal database for a project can be challenging, as most databases have not been tested for differences in terms of biodiversity records. The Paleobiology Database (PBDB) and iDigBio (IDB) are two platforms that provide paleontological data. PBDB collects data from published papers submitted by researchers. IDB is an National Science Foundation (NSF) funded database that receives specimens records (whether or not previously published) directly from associated institutions, such as museums and universities. Because these databases pull their records from different sources it is hypothesized that observed biodiversity will also be significantly different. In this study, records from these two databases using two exemplar taxa, Ammonoidia and Mosasauridae, were compared to assess biodiversity differences during the Late Cretaceous (100-65 million years ago) in the Western Interior Seaway (WIS). Ammonoidia and Mosasauridae were selected as they were nektonic predators in the WIS, but provide the distinction between vertebrate and invertebrate preservation within and between the datasets.

Records were selected from a study region encompassing Colorado, Kansas, Montana, Nebraska, South Dakota, and Wyoming, all of which were submerged in the seaway during the Late Cretaceous. Data included 708 Ammonoidia and 47 Mosasauridae occurrences from PBDB and 76 Ammonoidia and 71 Mosasauridae occurrences from IDB. Rarefaction was used to visualize diversity curves based on the occurrences obtained, which showed greater diversity in PBDB for both taxa. An Analysis of Variance (ANOVA) and bootstrapping were used to determine if there were any statistical significance differences within and between the databases for the two taxa.

After culling the data to only include shared taxa, an ANOVA indicated there were significant differences between Ammonoidia genera (p-value = 0.005), but not between Mosasauridae (p-value = 0.12). At this time results indicate that the choice of database platform does effect measured biodiversity, but further testing is required to produce informed guidelines for selection and use of the databases.
Microplastic Pollution in South Dakota Waterways

Brianna Crawford; Chemistry and Applied Biological Sciences Department (CABS)

Mentor/Advisor: Dr. Lisa Kunza; Chemistry and Applied Biological Sciences Department (CABS)

ABSTRACT

Water treatment plants introduce hundreds of thousands of gallons of treated wastewater into South Dakota’s waterways daily and wastewater effluent is one of the main sources of microplastic pollution. Although, microplastics research in freshwater systems is increasing, the status of microplastics in South Dakota’s main waterways remains unclear. To highlight waterways with varying human population density and discharge, we will examine Rapid Creek, Cheyenne River, Big Sioux River, and Missouri River surface water and sediments. Our site selection will also bracket the waste water treatment plants to examine their contributions of microplastics. Microplastic concentration for surface water samples will be quantified for approximately 1500L of sample collection via a 35µM net. To collect sediment samples, we will use a stove pipe and suspend sediment. For both surface water and sediment samples, organic matter digestion and suspension of microplastics will occur in the laboratory prior to using fluorescent microscopy for enumeration. To identify qualitatively the types of polymers, we will use a FTIR with ATR attachment. Microplastics are ubiquitous to the environment, yet little is known of the effects microplastics have on exposed organisms. We examined silver carp collected from the Missouri to quantify their accumulation of microplastics. Silver carp are filter feeding organisms directly through their mouth, but also have sponge-like pads on their gills that filter out tiny zooplankton and phytoplankton for food. Our dissections were designed to target the gill rakers, gastrointestinal tract, and liver. Our examination of microplastics in SD waterways will provide the baseline data necessary for comparison with other waterways across the country.
**Preparation of Core-Shell Stealth Nanoparticles Based on Amphiphilic PEG-PSA-PEG Triblock Copolymers**

**Joseph Hilsendeger;** Chemical and Biological Engineering Department (CBE)

Mentor/Advisor: Dr. Timothy Brenza; Chemical and Biological Engineering Department (CBE)

**ABSTRACT**

Amphiphilic triblock copolymers are at focus of extensive scientific research due to their unique properties and applications. These triblock copolymers can undergo self-assembly into various nano-architectures such as spheres, cylinders, and polymericosomes. Poly ethylene glycol (PEG) is a hydrophilic polymer that has been used in medical applications to enhance the amphiphilic nature of the block copolymers. A significant property of a PEG decorated surface is that it can minimize protein absorption and bio-recognition. Poly sebacic anhydride (PSA) is synthesized by the polycondensation of sebacic acid. The presence of anhydride bonds in the polymer backbone allows for hydrolytic degradation. This has led to the use of PSA as a controlled release therapeutic carrier in biomedical applications.

In this work we synthesized and characterized PSA homopolymer of multiple molecular weights. The tri-block polymer (PEG-PSA-PEG) was synthesized through the conjugation of mPEG-amine to PSA using carbodiimide chemistry. The molecular weight of mPEG-amine was kept constant. The structure of the PEG-PSA-PEG was determined by Fourier Transform Spectroscopy (FTIR), molecular weight by proton Nuclear Magnetic Resonance Spectroscopy (H-NMR), and thermal properties by Differential Scanning Calorimetry (DSC) and Thermogravimetry Analysis (TGA). Core-shell particles were prepared by dissolving the tri-block copolymers in selective solvents, which is a good solvent for one block but a poor solvent for the other block. The particle size of the core-shell particles was determined using Dynamic Light Scattering technique (DLS).

Future work with this system will involve the incorporation of therapeutics into the core of these self-assembled core-shell particles for controlled delivery.

**Keywords:** PEG, core-shell particle, amphiphilic block copolymers, self-assembly.

**References:**


Combustion of Various Fuel to Oxidizer Ratios

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Mentor/Advisor: Dr. Lori Groven; Chemical and Biological Engineering Department (CBE)

ABSTRACT

In our previous work we have shown that MgB2 was an excellent fuel in combination with sodium iodate. In this work we focus solely on the role MgB2 has with the binder. To determine how it reacts at different fuel to oxidizer ratios, inks will be created to study combustion of printed traces. Fuel to oxidizer ratios of MgB2 to binder (30/70, 40/60, 50/50, 60/40, and 70/30) are studied and compared to filament created for fused filament modeling. In addition to visually observing the combustion velocity the samples will also be tested in bomb calorimetry to determine how much heat is released. This data is compared to aluminum to determine which fuel is better to use in terms of long term stability and performance.
Efficacy and Biocompatibility of Degradable Microparticles for Drug Delivery

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Mentor/Advisor: Dr. Timothy Brenza; Chemical and Biological Engineering Department (CBE)

ABSTRACT

Background: Lung cancer is the most common and fatal cancer in the world. In 2018 alone, there were 2.1 million new cases of lung cancer worldwide [2]. Despite advances in current treatment options, the five-year survival rate for these patients is still only 18% [1]. New technologies need to be explored to help combat lung cancer and raise the survival rate. One such technique is targeted drug delivery using polymeric micro- and nanoparticles.

Objective: The first goal of this experiment was to determine the rate of drug release from Paclitaxel-loaded polyactic-co-glycolic acid (PLGA) microparticles and compare the results to previously determined in vitro particle toxicity in human lung adenocarcinoma cell line, A549. The second goal was to investigate the biocompatibility of novel random copolymers as a potential drug delivery system.

Approach: Paclitaxel-encapsulated PLGA microparticles were synthesized via ultrasonic atomization. The drug release profile was established by incubating the microparticles in phosphate buffered saline (PBS) and evaluating the drug release over time points of 4, 8, 12, 24, 48, and 72 hours. The biocompatibility of a novel random copolymer particles was evaluated based on the reduction of cell viability in the A549 lung cancer cell line by MTT assay over time points of 4, 12, 24, 48, and 72 hours.

Future Work: The Paclitaxel-encapsulation protocol in PLGA microparticles can be optimized based on the drug release data and its comparison to the in vitro toxicity data. Based on the biocompatibility results, the novel random copolymer can be developed into a drug delivery system as another potential treatment option for lung cancer.

References


ABSTRACT

Typically cancer is treated by using chemotherapy, radiation, hormonal medicines, surgery, or a combination of those. While they can be successful, the various treatments are not always effective and can have adverse side effects to the patients including deaths. Moreover, these therapies all tend to be very expensive. For these reasons, it is important to further investigate novel cancer treatment approaches which are effective, less toxic, and are affordable to patients.

Electroporation (EP) and cold atmospheric plasma (CAP) both have shown potential for treating and killing cancer cells, both on their own, combined with one another, or combined with other existing treatments. EP applies short but very intense electrical pulses to cells or tissues. The electrical field changes the cell permeability and opens up pores in the cell wall. By applying controlled electrical pulses the effects from EP can be made reversible, which can be combined with nanodrugs or other approaches allowing effective treatment of cancer cells and tissues. CAP operates at a temperature that is considered ‘cold’ and is not harmful to human cells and tissue. CAP has been shown in other studies to kill cancer cells without affecting healthy cells and to shrink the size of tumors. CAP generates reactive oxygen and nitrogen species in the cancer cells which then trigger the intrinsic apoptosis pathway in the cells. While both EP and CAP have been studied separately as potential cancer treatments, the synergy of both the approaches together has not been explored. Additionally, due to the many different pathways of cell death, further investigation needs to be done to understand when, how, and how quickly the cancer cells die as a result of these treatments. In this study, synergistic effects of both the approaches on cancer cells is studied using breast cancer cell lines MCF7 and MDB 231. Multitudes of diagnostic approaches are proposed to be used to investigate cell death pathways. The proposed methods include flow cytometry, microscopy analysis, Western blot analysis, and others. Detailed approaches of tagging proteins with fluorescent markers to track the cell death pathways as a result of CAP and EP techniques will be discussed and presented.
Exploring the Feasibility of Laser-Induced Breakdown Spectroscopy for Radiocarbon Dating and Provenance Studies

Adam Zaman; Mechanical Engineering Department (ME)
Mentor/Advisor: Dr. Prasoon Diwakar; Mechanical Engineering Department (ME)

ABSTRACT

Organic material containing Carbon-14 can be dated using radiocarbon dating. When organisms are alive, they assimilate Carbon-12 and Carbon-14. Assimilation of Carbon-14 stops when the organism dies. Carbon-14 is an unstable isotope of Carbon that decays at a known rate. By comparing the ratio of Carbon-12 and Carbon-14 present in a sample, an approximation of the age of a sample can be determined. In addition to carbon dating, provenance of any sample organic or inorganic is of importance of anthropology studies and forensic studies. Typically, laser-induced breakdown spectroscopy (LIBS) is an elemental detection technique, however by application of longer delays and high-resolution spectrographs, molecular isotopes can be detected. Also, by application of statistical tools, provenance of sample can be performed. Organic as well as inorganic samples will be ablated via laser-induced breakdown spectroscopy (LIBS) to determine the presence of Carbon-12, Carbon-14 and other elements. In this study, feasibility of detection of molecular isotopes and provenance of samples will be explored theoretically and experimentally.
Application of Laser Induced Breakdown Spectroscopy for Analysis of Carcinogen and Heavy Metal Deposits in Agricultural Environments

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Co-Presenter: Tanner Farnsworth; Mechanical Engineering Department (ME)

Co-Presenter: Adam Zaman; Mechanical Engineering Department (ME)

Mentor/Advisor: Dr. Prasoon Diwakar; Mechanical Engineering Department (ME)

ABSTRACT

Pesticides and herbicides are widely used to treat crops for unwanted species living in the fields, however they also cause risk to surrounding ecosystems through processes such as run-off. Concern over the use of these products has led to further analysis of how they affect the agricultural environments they are used in and the health of those who consume the products they are used on. Long term exposure to pesticides is correlated an increase development of diseases such as cancer in humans. Understanding how much residual pesticide in fields may lead to better preventative care for those who apply pesticides and the adjacent environments. Possible methods for analysis of carcinogen deposits include Laser Induced Breakdown Spectroscopy (LIBS). This process can be used to ablate soil samples as well as crops to determine the concentration of heavy metals and carcinogens at levels that may be undetectable by other methods. This study explores the application of LIBS on various local soil types in Black Hill region and further details will be discussed.

1. South Dakota School of Mines and Technology, Rapid City, SD, 57701
Development of Magnetic Nanoparticles for Polymeric Theragnostic Nanoparticles

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Mentor/Advisor: Dr. Timothy Brenza; Chemical and Biological Engineering Department (CBE)

ABSTRACT

The magnetic properties of certain inorganic materials such as iron oxide, gold, and silver allow for the development of theragnostic nanoparticles. The nanoparticles can be detected by MR imaging for diagnosis and then used in tandem with specific electromagnetic frequencies for photothermal therapy or the optimization of drug release profiles.

The long-term goal of this work is to synthesize and optimize biodegradable, polymer theragnostic nanoparticles. Biodegradable polymer nanoparticles can be tailored for controlled release and targeted delivery of therapeutics. This can enhance therapeutic efficacy, reduce side effects, and enable the delivery of poorly water soluble therapeutics without the need for toxic solvents, as is the case with current methods. The incorporation of inorganic, magnetic nanoparticles within the polymer nanoparticles allows for tracking the particles in the body, photothermal therapy, and the optimization of drug release profiles all using external electromagnetic radiation.

In this project the magnetic iron oxide nanoparticles will be synthesized via nanocoprecipitation. The procedure outlined by Kang et al (1996) was used as a basis. Sources of iron(II) and iron(III) are dissolved into an acidic solution and then added dropwise to a very basic solution with vigorous stirring. The particles will then be isolated with a magnet and centrifugation. Characterization will be done using DLS for particle size and size distribution and SEM for size and morphology. Experimental parameters such as stirring rate, solution pH, iron ion sources, addition/drop rate, and temperature will be varied to optimize particle size and polydispersity.

In the future these iron oxide nanoparticles will be incorporated into polymer nanotherapeutics and their therapeutic efficacy and imaging capabilities assessed.
Predicting and Controlling Interfacial Failure Modes of Indium Tin Oxide Thin-Film Polymer Systems for Flexible Applications

Matthew Phillips; Mechanical Engineering Department (ME)

Mentor/Advisor: Dr. Mohammad Zikry; Mechanical Engineering Department (ME)

ABSTRACT

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The objective of this work is to predict and control the interfacial behavior of nano-sized indium tin oxide (ITO) films that are layered on polymer substrates. These nano-layered systems can be used for innovative applications such as solar cells, flat panel displays, and organic LEDs. The use of these film systems have been hindered by mechanical failure modes such as interfacial cracking between the film and the substrate, tensile channel cracking of the film, and compression-induced rupture. I used a finite element analysis to understand how the system behaves in tension, compression, and bending for different film layer thicknesses and polymer substrate material combinations. These results indicate that increasing the film thickness renders the film more prone to cracking than a thinner film and that polymers with significantly lower moduli than that of the film can add flexibility to the system and inhibit film cracking and interfacial delamination. The interfacial property mismatches between the film and the substrate can be used to control failure in ITO-substrate film systems for different loading regimes and applications which can provide guidelines for designing failure resistant thin-film flexible systems.
Microstructural Evolution of High Density W-Cermets Exposed to Flowing Hydrogen at Temperatures Exceeding 2000k

William Carpenter; Materials and Metallurgical Engineering Department (MET)

Mentor/Advisor: Dr. Marvin Barnes; Materials and Metallurgical Engineering Department (MET)

Co-Mentor/Advisor: Dr. Kelsa Benesky; Materials and Metallurgical Engineering Department (MET)

Co-Mentor/Advisor: Dr. Dennis Tucker; Materials and Metallurgical Engineering Department (MET)

ABSTRACT

Nuclear thermal propulsion (NTP) shows promising potential for crewed space exploration by enabling high specific impulse and thrust. The development of NTP systems presents unique fuel material challenges due to requirements for high operating temperatures, exceeding 2500 K, and chemical compatibility with a hydrogen (H2) propellant (coolant) during operation. NASA has been investigating ceramic-metal (cermet) fuels due to their high temperature capability and H2 compatibility of the refractory metal matrix. For this study, subscale tungsten (W) cermet specimens, with 60 vol% zirconia surrogate (ZrO2), were consolidated via spark plasma sintering (SPS). Sintered samples were tested at 2000°C for 60 minutes and 2500°C for 5 minutes in flowing H2. After testing, as produced and tested specimens were cross sectioned for microstructural examination using optical microscopy, scanning electron microscopy, and microhardness in order to understand the stability of the bulk cermet microstructure under the different conditions. While the specimens retained structural integrity throughout testing with minimal mass loss, the microstructural investigation revealed H2 attack and migration of ZrO2 particles. Overall, the W matrix showed minimal grain growth and embrittlement as a result of testing.

Fig. 1. Optical micrograph of W-ZrO2 cermet microstructure after exposure to flowing H2 at 2500° C for 5 minutes. Cracking and porosity are present within the ZrO2 particles. The porosity is present at grain boundaries and throughout the grains. New irregular ZrO2 morphologies and porosity are present within the W matrix.
Wiring for the Wireless: An Undergraduate Research Project Focused on Designing, Building, and Deploying an Inexpensive Environmental Sensor for Research Laboratory Use (RESPEC Undergraduate Research Grant)

Hannah Covey; Civil and Environmental Engineering Department (CEE)

Mentor/Advisor: Dr. Bret Lingwall; Civil and Environmental Engineering Department (CEE)

ABSTRACT

A common issue that arises during, or before, research projects is funding. Money can be tight during research projects and finding reliable instrumentation can be costly. For this reason, the following research project was conducted to find an environmental sensor that was inexpensive, reliable, and relatively easy to assemble in order to mass produce. This research is an electrical engineering/computer science-esque project conducted by a civil engineering student, along with the generous help of an electrical engineering student and faculty adviser. The final product demonstrates that with a little time and dedication, any researcher from any field, can work to make their own sensors. Although the sensors presented here were designed for the purpose of collecting temperature, humidity, and barometric pressure data, the concept can be applied to sensors of all kinds.

The design for this sensor was started from the bottom with no initial design for housing, power, or wiring schematics. For simplicity, an Arduino microcomputer paired with an Adafruit temperature, humidity, barometric pressure sensor was proposed. Multiple ideas were discussed for data collection including simply collecting the data directly from the device, Bluetooth connection so the data could be retrieved at a distance, and finally simple micro SD card storage within the device. This proposal was then designed for production using wiring diagrams provided by Adafruit and open source coding for data collection and storage. Choosing parts for sensor production was done with cost in mind. Buying in bulk, where possible, was one of the main goals in order to keep the cost down. Housing for the device needed to be inexpensive, durable, easy to install, and practical for outdoor deployment. First, PVC plumbing fittings were proposed for durability and ease of building. However, these pieces were far more expensive then simple plastic containers. The best option for price and reliability in the end was simple household Tupperware.

The final product was a successful sensor prototype that was then mass produced and deployed at three different testing sites within the Black Hills of South Dakota. With the generous volunteer work of multiple SDSM&T faculty members and students this research was conducted in order to inspire persons looking for an affordable instrumentation method, an educational weekend hobby, or a guide for beginning the journey of wiring and basic coding.
Production of Nanocellulose from Corn Stover by Enzymatic Hydrolysis Without Pretreatment

Sindhu Sureshsingh; Nanoscience and Nanoengineering Department (NANO)

Mentor/Advisor: Dr. David Salem; Nanoscience and Nanoengineering Department (NANO)

ABSTRACT

Cellulose is a polysaccharide composed of a linear chain of β-1, 4 linked D-glucose units, it has high degree of polymerization and is most abundant organic polymer on the earth. Cellulose is obtained from numerous sources such as wood, eucalyptus, sisal, cotton, coconut fibers, wheat, corn, it can also be produced by bacteria. Corn is one of the abundant crops produced in USA. Corn Stover, is the above ground, non-grain portion of the crop which is currently large available source of biomass. The components in lignocellulosic mass are strongly intermeshed and bonded through covalent or non-covalent bonds which causes recalcitrance of biomass and makes it difficult to extract. Due to unique properties of nanocellulose, it has wide range of applications in paper industry, pharmaceutical formulations, cosmetics, electronic displays, packaging material, biomedical field and several other applications. Nanocellulose obtained by enzymatic hydrolysis is of high purity, devoid of chemicals, low capital outlay. For this new method need to be developed using enzymes like hemicellulase, laccase which degrade lignocellulosic biomass. Hence attempts are made to develop enzyme cocktail to degrade lignocellulosic biomass using wild type enzymes or recombinant enzymes without pretreatment of biomass and to obtain pure cellulose which can be further processed to Nanocellulose.

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The Very Thirsty Macrophage: The Dynamics of Macropinosome Formation and Trafficking

Shayne Quinn; Nanoscience and Nanoengineering Department (NANO)

Mentor/Advisor: Dr. Robert Anderson; Nanoscience and Nanoengineering Department (NANO)
Co-Mentor/Advisor: Brandon Scott; Nanoscience and Nanoengineering Department (NANO)

ABSTRACT

Understanding the signaling mechanisms controlling the innate immune system provides the opportunity to develop targeted immunotherapies. This study focuses on the role of different proteins involved in membrane dynamics and the formation of micron-sized vesicles called macropinosomes. Live cell fluorescence microscopy data were collected using lattice light sheet microscopy (LLSM) providing high spatial and temporal resolution with minimal background fluorescence or photodamage. The cells used in the study are transduced fetal liver macrophages (FLM) co-expressing mNeonGreen localized to the plasma membrane, and mScarlet localized to either f-Actin (f-Tractin) or the phosphoinositols PIP2 and PIP3 (AKT^{PH}, Pleckstrin homology domain of protein kinase B). Actin is an important component of the cytoskeleton involved in cell motility including membrane ruffling; however, to our surprise, tractin had a temporal lag in localization to large ruffles. The phosphoinositols PIP2 and PIP3 are involved in cell signaling, membrane trafficking, and membrane/cytoskeletal interface. There is a burst of AKT^{PH} localization following closure of the macropinosome, and cell-cell contact; consistent with previous results. Future work with actin and PIP2/PIP3 will utilize different fluorescent probes to determine if the tractin localization is an artifact of the probe, and further understand the role of PIP2/PIP3.

Figure 1: Above shows 3D views of an FLM. The left image shows the membrane as a transparent surface in blue, and AKT^{PH} localization in white. The right image shows a mesh rendering of the membrane surface in blue, and AKT^{PH} in white highlighting internal macropinosomes.
Detecting the Pressure and Bulk Composition Effect on the AI-OH Absorption Band of White Micas: Case Studies in Northwest Turkey

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Mentor/Advisor: Dr. Gokce Ustunisik; Geology and Geological Engineering Department (GEOE, GEOL)

ABSTRACT

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Dioctahedral white micas are common constituents of many metamorphic rocks from low to ultrahigh pressure conditions. Experimental studies, along with phase equilibrium modeling, have established a solid framework for interpreting compositional variation in sodic and potassic white micas by constraining the pressure and temperature (P-T) conditions of metamorphism and have shown that the celadonite content of white mica is strongly dependent upon pressure.

Visible and near-infrared (Vis/NIR, 350-2500 nm) spectra of metapelites have documented that variation in the wavelength position of the Al-OH absorption band (~2200 nm) of white micas is a direct function of octahedral cation substitutions, primarily the aluminoceladonite exchange. Therefore, variations in Vis/NIR spectra of metamorphic rocks with white micas provide first-order quantitative data regarding P-T conditions accompanying metamorphism. The results of this study will answer the following questions: 1) Do changes in P at a given T in a metamorphic terrane affect the spectroscopic and compositional variations in white micas? and 2) If there is a P control, at constant T, then what would be the effect of the phase assemblage of bulk rocks on white mica spectra and crystal chemistry with respect to the interpretation of metamorphic conditions?

Results from the Çamlıca Metamorphics, Sakarya Zone, and Tavşanlı Zone of northwest Turkey have shown direct evidence for the correlation between Al-OH absorption band and white mica composition over different metamorphic terranes. We will report on micro-infrared spectroscopy and EMPA on selected samples to assess the reliability of field-based Vis/NIR measurements in providing first-order quantitative information regarding the P-T conditions in collisional tectonic settings.
**ABSTRACT**

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Multiphoton microscopy allows deep, three-dimensional imaging of the structural and chemical properties of materials, we have introduced a transmission grating into the multiphoton microscope to spectrally-resolve the non-linear optical response consisting two photon induced fluorescence and second harmonic generation. Experiments on characterizing the photopolymerization of non-invasive natural vascular scaffolds (NVS), target for the treatment of peripheral artery disease were provided by Alumend, LLC. We spectrally resolved the signals from drug-eluted arterial cross-section and compare these to similar samples after “light activation” (photo-polymerization). From the spectrum, we conclude that there is a shift toward the longer wavelength after light activation, confirming with our hypothesizes that “light activation” aids in cross linking the collagen fibers with the eluted drug in the artery forming the NVS scaffold. We also imaged a paclitaxel (Abraxane). This is a chemotherapy medication, which is insoluble in water. When suspended in water it forms a crystals, which are optically active due to the non-centrosymmetric material, generating SHG. Due to its crystalline properties, SHG imaging can characterize the drug formulation which is currently in clinical use.

*Figure 1: (a) Second harmonic, two photon induced fluorescence images and spectrum of drug-eluted after light activation sample. (b) Second harmonic image (SHG), Scanning Electron image (SEM) and spectrum of Paclitaxel (Abraxane).*
Development of the CellWell™ - a novel micropatterned biphasic nanocomposite platform for chondrocyte cell culture.

Ram Saraswat; Nanoscience and Nanoengineering Department (NANO)

Mentor/Advisor: Dr. Scott Wood; Nanoscience and Nanoengineering Department (NANO)

ABSTRACT

We are developing a unique micropatterned nanocomposite cell culture platform to model the articular cartilage. This platform, dubbed the CellWell™, is designed to combine the physiological advantages of 3D culture systems with the practical advantages of 2D. To combine those advantages, we constructed CellWell™ platforms out of a mechanically tunable substrate micropatterned with a network of wells, with geometries designed to reinforce a physiological morphology. The CellWell™ material was constructed of an agarose hydrogel (modeling the cartilage proteoglycans), and with embedded electrospun polyvinyl alcohol nanofibers (modeling collagen II fibers).

Methods: 5% (wt.) agarose hydrogel samples were prepared in PBS-1x. PVA nanofibers were electrospun and aldehyde crosslinked. Primary human articular chondrocytes were isolated from normal human articular cartilage (8,375 cells from 18 donors), and the diameters of the chondrocytes were obtained to inform the CellWell™ design parameters. Standard contact photolithography techniques were used to pattern and shape wells in 5% agarose. Feature sizes for these proof-of-principle studies were chosen to be larger than those found for chondrocytes for ease of manufacturability. Swelling studies were performed on agarose hydrogel samples to confirm agarose hydrogel stability. Nanoindentation tests were performed on 5% agarose hydrogel samples using an Asylum MFP 3D atomic force microscope with 5µm diameter spherical tips at an indentation rate of 500 nm/seconds and the compressive modulus of the hydrogels was estimated using Hertz’s Contact Model. Optical transmittance measurements were obtained on a video spectral comparator (VSC).

Results: The compressive moduli of 5% agarose hydrogels at 0.1% compressive strain was found to be 119.6 ± 1.7(SEM) kPa, which is within the compressive modulus range of 0.1-1 MPa widely reported for articular cartilage.

Figure 1. (A) Chondrocyte diameters were found to average 14.6± 0.48(SEM) µm, which will ultimately be the size of the lithographically generated wells in the CellWell™(B) Agarose Hydrogel Stability tests showed a ~98% maintenance of wet weight over 28 days, confirming their stability for use in long term cell culture studies. (C) DIC Images and Height maps (in 2D and 3D) of both a 50 µm by 50 µm photolithographic pattern(top) and agarose patterned using lithographic features(bottom) confirming our ability to micropattern agarose samples.

Conclusions: We have demonstrated our ability to generate and characterize optically transparent nanocomposite materials compatible for use with high-resolution fluorescence microscopy, as well as to pattern agarose hydrogels with wells of approximately the shape and sizes within one order of magnitude of single chondrocytes. Future work will include optimization of our photolithographic technique to refine the size and shape of the wells to more precisely match chondrocyte morphology and verification of CellWell™ cytocompatibility, morphology, and phenotype maintenance capabilities in long-term cultures of primary human articular chondrocytes using standard fluorescence imaging and immunoblotting techniques.
Correlative Fluorescence and Atomic Force Microscopy of Unroofed SKMEL-2 Cells

Lin Kang; Nanoscience and Nanoengineering Department (NANO)
Mentor/Advisor: Dr. Steve Smith; Nanoscience and Nanoengineering Department (NANO)

ABSTRACT

Atomic force microscopy (AFM) provides nanometer resolution maps of topographic and mechanical properties of materials, but lacks chemical specificity. Combining AFM with fluorescence microscopy allows us to assign topographic and mechanical properties to specific chemical structures. We examine the inner membrane of SKMEL-2 cells, one of a series of melanoma (skin cancer) cell lines, using correlated AFM and fluorescence imaging to reveal intracellular details of the cytoskeleton, and correlate the mechanical properties with protein-specific fluorescence labels, mainly focusing on clathrin mediated endocytosis (CME). Endocytosis is the process of admitting foreign materials through the cell membrane, clathrin mediated endocytosis involves the assembly of triskelion clathrin lattices, which facilitate the membrane bending during endocytosis. We use an ultrasonic cell unroofing method to reveal the inner membrane of these cells, keeping intact the cell membrane and cytoskeleton. Fluorescence imaging localized the clathrin vesicles (labelled with TQ2) and actin filaments (labelled by ActinGreen488), and AFM reveals high resolution topography and mechanical properties of select regions using force spectroscopy, which gives mechanical data like stiffness and modulus distribution for the clathrin vesicles. These data are compared to topographic information (height distributions) also acquired from AFM. The connection between height and elastic modulus are then shown. These results may help in understanding the mechanism by which cancer cells grow and multiply, which could be important in finding effective therapeutic drugs which can prevent or cure skin cancer and possibly other forms of cancer.

Fig. AFM 2D and 3D data in Height channel for clathrin vesicles and actin filaments respectively from unroofed SKMEL-2 cells.
**Deletion of (GAA)\textsubscript{n} Repeats in Friedreich Ataxia Using an Escherichia Coli Model System**

**Erica Everson**; Biomedical Engineering Program

Mentor/Advisor: Dr. Richard Sinden; Biomedical Engineering Program

**ABSTRACT**

Friedreich Ataxia (FRDA) is an autosomal recessive neurodegenerative disease caused by a (GAA)\textsubscript{n} trinucleotide repeat expansion mutation. This mutation occurs in intron 1 of the frataxin gene located on chromosome 9. The vast majority of patients with this disease have obtained one recessive allele from each parent; although there are cases when this disease affects people with heterozygous alleles. This is an anticipation disease in which subsequent generations of affected families usually have an earlier onset and more severe symptoms. Currently there is no treatment or cure for this terminal disease. Biochemically people with FRDA do not produce enough of the protein frataxin. Frataxin is a mitochondrial protein found throughout the body, but the highest in the heart, spinal cord, liver, pancreas, and voluntary skeletal muscles which also happen to be the tissues affected the worst by FRDA. The (GAA)\textsubscript{n} trinucleotide repeat can range from carriers having 50’s to low hundreds of repeats, to thousands in severe cases. The exact mechanism of this mutation is not defined. We are investigating the mechanism of this repeat expansion mutation using an *E. coli* bacterial model measuring mutation rates of three different sequence lengths in two different orientations cloned into the chloramphenicol gene of plasmid pBR325 and pBR235. The goal is to establish whether the rate of repeat deletion is dependent on the (GAA)\textsubscript{n} or (CTT)\textsubscript{n} sequence being in the template strand and likewise if the rate of repeat deletion is dependent on which sequence is in the leading or lagging strand of the replication fork. Future work for this research includes performing a Luria Delbruck assay to study the rate at which (GAA)\textsubscript{n}•(TTC)\textsubscript{n} repeat deletions occur and statistical analysis of the mutation rates. This information will eventually be applied to a human cell line which may lead to a therapeutic approach for preventing or delaying the onset of Friedreich Ataxia.
Investigation of the Role of Cilia in Cystic Kidney Diseases by Transmission Electron Microscopy

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Mentor/Advisor: Dr. Phil Ahrenkiel; Nanoscience and Nanoengineering Department (NANO)

ABSTRACT

Transmission electron microscopy (TEM) of samples prepared by ultramicrotomy provides detailed structural information for interrogation of processes at the cellular level. In this work, we are using mouse models and cell culture systems to understand how Notch signaling suppresses renal tubular cyst formation and microadenoma (a tumor) formation. These studies are likely to reveal how Notch signaling is linked to primary cilia and the cell cycle and will provide insights into the mechanisms by which Notch functions as a tumor suppressor in epithelial cancers. By performing electron microscopy, we are investigating the structure of cilia to understand their role in Notch signaling deficient kidney cells. By analyzing TEM images, we are able to detect normal 9+0 microtubule doublets within the axoneme of primary cilia in both wild type and mutant type cells. After analyzing mutant kidney cells, we detected cilia which have unusual arrangements of microtubules. These abnormal structures may be due to alterations in “posttranslational modifications”. We believe that the Notch signaling deficiency may alter the posttranslational modifications of the microtubules in mutant cells. In the future, we plan to determine the posttranslational modifications in Notch signaling deficient cells by performing a quantitative analysis by western blotting. Also, by performing TEM tomography, we can confirm that the abnormal structures are real and not artifacts.

Fig. 1. TEM images of the cilia in mutant kidney cells. (A) The axoneme of primary cilium shows normal 9+0 microtubule doublets. (B) An unusual arrangement of microtubules.
Effects of Aeration on the Metabolism of Furfural and 5-Hydroxymethylfurfural Using Saccharomyces Cerevisiae

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ABSTRACT

Lignocellulose is a common waste product of agricultural processes with little or no commercial uses. It is possible to use lignocellulose as a feedstock for fermentation because it is rich in carbohydrates, but it must be pretreated beforehand. In the dilute acid pretreatment process cellulose and hemicellulose are hydrolyzed to create fermentable sugars, but inhibitory compounds such as furfural, 5-hydroxymethylfurfural (HMF), and acetic acid are also produced. The goal of this study was to determine how furfural and HMF affect the growth of the Saccharomyces cerevisiae strain D5A under both anaerobic and aerobic conditions. The yeast was exposed to the inhibitors both with and without glucose, then with or without oxygen in the presence of glucose; metabolite concentrations were measured using HPLC and cell concentrations using optical density. It was determined that the yeast was able to tolerate and metabolize both inhibitors much more quickly in the presence of glucose and oxygen. Using HPLC, it was also determined that the aldehydes were being metabolized to both alcohol products in anaerobic conditions and carboxylic acid products when oxygen was present. These additional aerobic pathways may partially explain why furfural and HMF are metabolized faster under microaeration (-150 mV redox potential) conditions (0.25 g furfural/L/OD/hr vs 0.13 g furfural/OD/hr for anaerobic fermentation). Faster furfural and HMF metabolism ultimately leads to greater ethanol productivity with microaeration (1.32 g ethanol/L/hr vs. 0.51 g ethanol/L/hr for anaerobic fermentation).
Study on Ordered/disordered Structures in GaInP Semiconductor Alloys by Using Transmission Electron Microscopy (TEM)

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ABSTRACT

The spontaneous ordering in III-V ternary semiconductor alloys comes with drawbacks of optical anisotropy, shift in the band gap energy, crystal growth defects such as antiphase boundaries (APBs) and electronic properties. But, the combination of ordered/disordered heterostructures of GaInP can have potential applications in electronic devices such as amber/red LED’s. GaInP exhibits ordering in CuPt-like structures grown on GaAs substrates. Several samples of GaInP were grown using MOCVD in order to look of strong ordering by altering the growth parameters. Ordering in GaInP is optically indicated by the additional spots observed in the diffraction pattern taken using Transmission electron microscopy (TEM). Conventional TEM diffraction patterns could not detect the superlattice ordered reflection spots, whereas the application of Buerger precission diffraction in TEM could increase ordered spots profile. Calculating the ordered parameter of these extra spots will differentiate between weak to strong ordering from 0 to 1. Dark field images of APB’s in GaInP displays image contrast by tilting away from Bragg condition. The structure factor calculated from the difference in the tilt angles, is one possible way to determine the order parameter. High resolution TEM images were also taken to display the single-variant and double variant lattice structures.
Upconverting Nanoparticles for Latent Fingerprint Development on Fluorescing Surfaces

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ABSTRACT

A wide variety of fingerprinting methods are currently in use, with powder-based methods being most common. However, substrates that exhibit fluorescence (e.g. printed surfaces) present challenges with most powder methods because the print may be overpowered by the background fluorescence.

To mitigate the effects of patterned or fluorescent backgrounds, an imaging method utilizing NaYF₄:Yb,Er upconverting nanoparticles (UCNPs) that are excited under 980 nm NIR light and emit 800 nm light through NIR (near-infrared)-to-NIR upconversion has been explored. When imaging with only NIR light, background patterns are suppressed, while the UCNP-covered fingerprint ridges are easily visible.

Aerosolization of particles, and nanoparticles in particular, is of concern from a toxicology perspective. Hence, this research has focused upon use of liquid deposition methods of UCNPs for detection of latent fingerprints.

First, an oil-in-water microemulsion was created, where the UCNP payload was contained within the oil phase. It was found that an oily film was left over the whole fingerprint. Imaging with this method showed no discernible fingerprint details.

Next, an aqueous-based method was used. In this portion of the research a surfactant (sodium dodecyl sulfonate (SDS)) was added to help stabilize the UCNPs. This suspension is unstable for but can be successfully used to develop latent fingerprints.

In the future, a toluene-in-water microemulsion, with UCNPs contained in the toluene phase, will be explored for use as a fingerprint development method. This could be a better alternative to the oil-in-water microemulsion, as UCNPs are easily suspended in toluene, and previous UCNP-in-toluene suspensions have been used to successfully develop latent fingerprints.

Application of Unmanned Aerial Vehicles (UAVs) for Underground Atmospheric Monitoring

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ABSTRACT

In underground mines, toxic and explosive gases such as Carbon Monoxide (CO), Oxides of Nitrogen (NOx), Oxides of Sulphur (SOx), and Methane (CH₄) are regularly monitored to make sure working conditions for the miners are safe. Traditional methods for measuring these gas concentrations include hand-held devices and laboratory gas testing instruments. These methods are time-consuming, labor-intensive, and not available when access to the desired area is limited. With the recent developments in unmanned aerial vehicles (UAVs) and sensing technologies, UAV-based sensors have high potential to collect, analyze, and provide critical safety information to the management and the miners in real-time. It is anticipated that the UAV based atmospheric monitoring system will be safer, cheaper, and faster than traditional systems. In this proposed study, the first step is selecting suitable UAV and sensors, second, the selected sensors will be mounted on the UAV, and, third, sensor performance will be tested under laboratory settings to select the best sensors for atmospheric monitoring. The developed UAV system will be tested in the underground environment to determine its viability. This research is aimed to demonstrate whether a UAV based atmospheric monitoring system could be developed and utilized in underground mines in a cost-effective manner.

References:
Underwater Navigation Using Geomagnetic Field Variations

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Mentor/Advisor: Dr. Shankarachary Ragi; Electrical and Computer Engineering Department (EE, CENG)

ABSTRACT

Underwater positioning and navigation for autonomous vehicles is challenging because of the GPS-denied environments. We present a novel positioning and navigation method for underwater vehicles using the Earth's magnetic field properties including field intensity, declination, and inclination. In other words, we assume that the underwater vehicle is equipped with magnetometers that can sense the magnetic field properties at the sampling location. Based on the sensor readings, we estimate the geographical location of the vehicle. Specifically, we develop a feed-forward neural network model to estimate the geographical location of the vehicle by mapping magnetometer sensor readings to a unique location on the Earth's surface. To train the neural network, we generate data using the International Geomagnetic Reference Field (IGRF) model [1].

We consider several case studies with varying parameter sets in the neural network. To assess the impact of the neural network parameters on the error performance, we consider a scenario (5 cases in total) where we evaluate the magnetic field properties at certain known locations. Figure 1 shows the actual locations given by the green colored crosses, the green colored curve represents the fitted curve for these locations, and the circles represents the estimated locations for different scenarios.

Figure 2 Multi neural network mapping.

Development of a Wireless Body Area Network

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Mentor/Advisor: Dr. Sayan Roy; Electrical and Computer Engineering Department (EE, CENG)

ABSTRACT

The objective of this project is to create a wireless body area network which includes flexible, wearable biomedical and strain sensors that will help to track astronaut’s health in outer space in real time. The space environment is dangerous and unfriendly which affects the astronaut’s health and mental status dramatically. We need to create a robust efficient and secure wireless body area network with a variety of conformable, lightweight sensors for monitoring sweat (glucose/sodium/potassium), heart rate, temperature & blood pressure and motion. As NASA’s next goal is to send astronauts into deep space for exploration, NASA is trying to ensure astronaut’s health and safety by minimizing the negative effects of space travel. Findings from the received data, will give insight into bio-psychosocial changes, and indicate potential solutions to mitigate the negative health effects. Their target is to enhance holistic well-being of astronauts.
Decentralized Formation Shape Control of UAV Swarm

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Mentor/Advisor: Dr. Shankarachary Ragi; Electrical and Computer Engineering Department (EE, CENG)

ABSTRACT

Swarm intelligence is one of the emerging fields of study capable of changing many industries including infrastructure inspection, precision agriculture, underground mining, target tracking, and so on. Swarm intelligence is inspired from nature such as cooperative behavior in ant colonies, school of fishes, group of birds working together. Formation control is one of the most important aspects of a swarm. In this paper, we study formation control of unmanned aerial vehicles UAV swarm.

Formation control of (UAVs) has many applications including target tracking, surveillance, terrain mapping, precision agriculture, etc. Although many centralized control methods (single command center/computer controlling the UAVs) exist, there are no standard decentralized control frameworks in the literature. In this paper, we present a novel UAV swarm formation control approach based on a decision-theoretic approach. Specifically, we pose the decentralized swarm motion control problem as a Decentralized Markov Decision Process (Dec-MDP). Here, the objective is to drive the swarm from an initial geographical region to another geographical region where the swarm must lie on a certain geometrical surface (e.g., surface of a sphere). As most decision theoretic formulations suffer from the curse of dimensionality, we adopt an approximate dynamic programming method called nominal belief-state optimization (NBO) to solve the formation control problem approximately. We perform simulation studies in MATLAB to validate the performance of the algorithms. Figure illustrates a group of UAVs is converging in a region of interest from a certain initial location.

Figure: UAVs converging to the rectangular formation shape

Swarm formation is required in many applications where a collection of UAVs are required to collect sensor data (e.g., images) from a certain geographical region where it may be optimal for the UAVs to lie on a geometrical surface. We develop our methods in 2-D in this study, which will be extended to 3-D in our future studies. Our formation control problem can be extended to include even formation to make the swarm evenly distributed inside formation shape which is useful in many sensing applications. Moreover, we plan to extend our algorithm to make the UAV swarm robust to addition and deletion of a UAV.

Reference:
Decentralized Sensor Network Optimization for Target Tracking

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Mentor/Advisor: Dr. Shankarachary Ragi; Electrical and Computer Engineering Department (EE, CENG)

ABSTRACT

We develop a decentralized sensor network optimization method to track a moving target. Given the increasing number of sensor and surveillance systems in public places, there is a need for decentralized methods to track moving targets (e.g., humans, vehicles) with a distributed network of sensors. The objective is to optimize the sensing decisions including the decisions on sensing direction and information sharing (between sensing nodes) while maximizing the target tracking performance and minimizing the energy consumption in the network. The target tracking performance is measure by the error between the target’s actual location and the location estimate.

The goal is to optimize the sensing directions and the information sharing decisions at each sensor in a decentralized manner to maximize tracking performance. We assume that the sensors have limited battery power, which limits the sensor to minimize frequency of sharing local sensor information with its peers. This make the optimization problem challenging as the objectives are conflicting – more information sharing benefits tracking performance but consumes more energy. We formulate the above problem as a dynamic program (DP) with decentralized decision makers (sensor nodes). As most DP problems suffer from high computational issues, we develop a heuristic approach to solve the problem approximately.

Figure: Target tracking on a distributed sensor network

Though, several studies have been conducted on this optimization problem, where the objective function is non-convex, we are currently implementing two techniques to solve the above optimization problem: 1) ant colony optimization (ACO), 2) particle swarm optimization (PSO).

In ACO, artificial ants (notional entities) can potentially find the globally optimum solution by moving on the problem graph by emulating the behavior of real ants. They leave artificial pheromones to generate trails which can help future artificial ants to find the best solution. Here artificial ants use reinforcement learning to discover the best solution.

In PSO, which is inspired by natural life like bird flocking, predefined size of particle can give a complete solution of multidimensional optimization problem. Here, to reach up the global best position, each particle follows its own best and global best to update its own velocity and position.

Reference:

On the Design of an Improved Model of Additively Manufactured Microstrip Transmission Lines for Radio Frequency Applications

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Mentor/Advisor: Dr. Sayan Roy; Electrical and Computer Engineering Department (EE, CENG)

ABSTRACT

Additive Manufacturing Technology is very popular among researchers and engineers. Demands of communication speed and bandwidth for catering versatile applications is increasing. Over 1.5 billion parts of mobile devices were shipped all over the world in 2017 and in the forthcoming years, the numbers are trending to go upward [1]. As a result, RF circuits are becoming more complex and this also leads to higher manufacturing costs. But Modern-day wireless devices thus require to be integrated with such systems that are of high-bandwidth and efficient including antennas that has the ability to cover multiple frequency bands [2]-[3]. Additive Manufacturing (AM) technology helps us to manufacture next generation RF circuits. In order for this process to be a success, materials with far lower melting points than the conventional metals are a necessity. Here, we tested an improved version of industrially available conductive material with low melting point to design high frequency circuits for applications from 100 MHz up to 5 GHz. The research also presents the data measured along with the verification.

Fig: Printed 50Ω Microstrip Transmission Line using an improved version of Electrifi filament on TMM4 substrate

References


Beam Monitoring Using 3DST System in DUNE Near Detector

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Mentor/Advisor: Dr. David Martinez; Physics Department (PHYS)

ABSTRACT

The Deep Underground Neutrino Experiment (DUNE) is an international project with primary physics objectives to measurement the CP violation in the neutrino sector, proton decay and supernova neutrino bursts. DUNE will use the liquid argon time projection chamber technology (LArTPC).

DUNE will be composed of two neutrino detectors exposed to the world’s most intense neutrino beam. The near detector will be placed ~ 574 meters from the neutrino source at Fermilab. The far detector will be located ~1300 km away and ~1.4 kilometres underground at the Sanford Underground Research Facility (SURF) in South Dakota.

In this poster, we will focus on one of the DUNE near detector, a three-dimensional detector tracker called 3DST, which is a highly segmented plastic scintillator detector. With 3DST we expect to have a 4pi angle coverage for charged particles, as well as good energy and angular resolutions. Due to a fine granularity, 3DST is suitable for monitoring the beam profile and due to fast timing, it has great potential to measure neutron energy.
Assessing Impacts of Salinization on Water and Rangeland in Northwest South Dakota

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Co-Mentor/Advisor: Dr. Dan Heglund; Chemistry and Applied Biological Sciences (CABS)

Co-Mentor/Advisor: Dr. Kurt Chowanski; Chemistry and Applied Biological Sciences (CABS)

ABSTRACT

Salinization of rangeland and water resources are a major concern for ranchers and other land managers. With over 12,000 identified impoundments in Butte and Harding Counties of South Dakota, there is concern for increased salinization of managed water sources and potential impacts to rangeland health. We examined baseline soil and water conditions in the study area to identify areas of concern and provide direction for future research and management. We selected impoundments and creek locations to collect both water and soil samples on public land and surrounding areas in Harding and Butte Counties. We measured electrical conductivity at 44 impoundments and 15 creeks in July and August 2018 to evaluate spatial variability in salinity. Initial analysis indicated spatial variability of conductivity in impoundments (28-7,720 µS cm⁻¹) and creeks (359-4865 µS cm⁻¹), and mean conductivity was lower in impoundments (829 µS cm⁻¹) than in creeks (1632 µS cm⁻¹). In addition these preliminary samples, we will include BLM soil samples and terrestrial AIM (Assessment, Inventory, and Monitoring) database information to develop a baseline for water and soil quality for the study area. We will also look at leveraging remotely sensed imagery (Landsat and National Agriculture Imagery Program) to develop a temporal series of soil salinity maps. Our intent is to create a geospatial regional database as a baseline for rangeland and impoundment salinity to identify potential salinity sources and evaluate their effects on water quality, soil health, and plant communities over time.
Examining the Potential Influence of Climate Change in Stream Temperatures in the Black Hills

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Co-Mentor/Advisor: Dr. William Capehart; Atmospheric and Environmental Sciences Department (AES)

ABSTRACT

Water resources in the Black Hills provide multiple recreational and economic benefits to the surrounding area. Biodiversity and water quality can be significantly affected by increases in stream temperature. Rapid Creek is a heavily regulated stream with headwaters in the central Black Hills. Spring Creek is a smaller less regulated stream that is 10 miles south of Rapid Creek and Battle Creek is a completely unregulated stream 10 miles south of Spring Creek. USGS gauge station stream temperature observations on Rapid Creek throughout the year range from -2.0º C to 29.5º C with a large increase in stream temperature in the immediate tailwaters of Pactola Dam with temperatures gradually increasing downstream as it converges with the Cheyenne River. Spring Creek also increases in stream temperatures as the creek descends from the higher elevations of the Black Hills to the surrounding plains, with observed USGS gauge station stream temperatures ranging from 0.0º C to 25.5º C. Battle Creek experiences the same increase in stream temperature as Rapid and Spring Creek with observed USGS gauge station stream temperatures ranging from -0.3º C to 28º C. The goal of this project is to model stream temperature changes in response to projected climate change, and then discern if the modeled stream temperature changes are different or similar in the unregulated, less regulated and regulated streams. Data from Global Climate Models (GCM) will be used in SWAT (Soil and Water Assessment Tool) to model stream temperatures. Two emission scenarios will be used, Representative Concentration Pathways (RCP) 4.5 and 8.5. Unregulated or regulated streams may be more resilient to climate change.
**Assessment of Tight Oil in Pierre Shale of South Dakota**

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Mentor/Advisor: Dr. Daniel Soeder; Geology and Geological Engineering Department (GEOE, GEOL)

**ABSTRACT**

The Pierre Shale is the division of Upper Cretaceous rocks in the United States that occurs in South Dakota, Montana, Colorado, Minnesota, New Mexico, Wyoming, and Nebraska. The Pierre consists of about 600 m of dark gray shale, sandstone and layers of bentonite. In some regions the Pierre Shale may be as little as 200 m thick. This study aims to assess tight oil in Pierre shale of South Dakota. Tight oil is light crude oil contained in petroleum-bearing formations of low permeability. The focus of the study is two-fold. The first objective is to assess existing rock eval data for the Pierre Shale in South Dakota. The second objective is to determine if the oil in the Pierre could be self-sourced and if not, then attempt to determine where it originated.

The study takes into consideration the samples from Presho area and from outcrops along the Bad River in South Dakota. The source rock analysis of the samples from the Presho area shows that the Pierre Shale in South Dakota has optimum carbon content for the generation of petroleum. It also has appropriate kerogen type. Also during the Presho core drilling, oil was found from the lower part of Pierre Shale whereas the underlying Niobrara formation has only gas. But the ROCK-EVAL data does not show it to be in oil window which remains a mystery. The approach of the study will be to find organic matter concentrations in the Pierre Shale, finding its organic content type i.e. kerogen and finally its thermal maturity for which methods like source rock analysis and vitrinite reflectance will be used. All the previous literature concludes that Pierre Shale has correct organic matter and suitable kerogen types for the generation of oil. The Niobrara Formation below it produces only gas and does not normally contain oil. Thus it is expected that there is some error in the source rock analysis results and oil found in Pierre Shale is self-sourced.

**References**

Accuracy of Measurements Collected from 3D Digital Models of Fossils

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Co-Mentor/Advisor: Dr. Maribeth Price; Geology and Geological Engineering Department (GEOE, GEOL)

ABSTRACT

Fossil and model measurements are to be compared to test the accuracy of measurements collected from 3D digital models and to investigate the effects of user experience. The models were created by capturing multiple images of each fossil, editing them using Adobe Lightroom, then masking and building in Agisoft PhotoScan Professional. Volunteers of varying experience will be recruited to collect measurements, first collecting measurements from the seven fossils, then collecting the same measurements from the seven corresponding models. The measurements are broken up into three difficulty categories, based on ease of identifying landmarks, and are identified as “easy”, “moderate”, and “difficult”. Preliminary results from one measurement session indicate that the average difference between physical and model measurements increases based on measurement difficulty. A t-test showed that 17 of the 21 measurements are statistically indistinguishable and four are not, with all volunteers identifying as having no experience in collecting morphometric measurements.
Streamflow Losses From the White River Along the Whiteclay Fault Zone Near Oglala, South Dakota

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Mentor/Advisor: Dr. Liangping Li; Geology and Geological Engineering Department (GEOE, GEOL)

ABSTRACT

The White River is located within the Great Plains physiographic province, transecting a terrain consisting of variable geologic units and structure. Annually, the region receives about 420 mm of precipitation, yet it has a potential evaporation of 1500 mm/yr. The Whiteclay Fault zone occupies the northern portion of the study area, underlying weathered and alluvial sediments.

U.S. Geological Survey streamflow gages on the White River in Oglala Lakota County, South Dakota, indicate net streamflow losses between a gage located near the South Dakota-Nebraska state line and another gage located approximately 20 km downstream near Oglala, South Dakota. The average annual streamflow loss between the gages is about 9%, or 5,000,000 m³. The apparent discharge deficit is the result of the transferal of water out of the channel, either to groundwater storage or evaporation to the atmosphere. A comparison of hydrologic and climatic data shows a relationship between the degree of streamflow loss to average annual precipitation and discharge. Groundwater well data measured in the White River alluvial aquifer indicate a water table elevation approximately 1 – 5 m below the riverbed elevation, which supports the potential for streamflow loss. The relationship between the White River and alluvial aquifer is represented by a 2 dimensional, steady-state, river-groundwater model. By combining climate, surface water, and groundwater data, the segment of the White River is interpreted as a losing reach. Overall, this study provides a basis for future hydrogeological investigations in the vicinity of the Whiteclay Fault.
Enhanced Heavy Metal Removal from Urban Stormwater Runoff Using Nanoscale Zerovalent Iron Modified Biochar

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Mentor/Advisor: Dr. Mengistu Geza; Civil and Environmental Engineering Department (CEE)

ABSTRACT

Urbanization has degraded the quality of urban water resources, and effective stormwater treatment is necessary to lowered concentration of pollutants. Ideally, conventional Best Management Practices (BMPs) such as bioretention cells and infiltration basins should attenuate contaminants in stormwater. However, contaminants like heavy metals ions, pass through these systems. Heavy metals (Cu, Cd, and Zn) were used as model species to evaluate the sorption capacity of biochar (BC) and biochar modified with nanoscale zerovalent iron (BC-nZVI). Batch experiments were carried out for synthetic stormwater solution containing a single metal ion and a mixed metal ion with varying initial concentrations (2.5 to 60 mg/l). Surface morphology and properties of BC and BC-nZVI were characterized using Scanning Electron Microscope (SEM), Fourier-Transform Infrared Spectroscopy (FTIR) and Brunauer–Emmett–Teller (BET) techniques elucidate the mechanism of metal removal. Metal removal efficiencies were higher for BC-nZVI compared to BC. The equilibrium data of metal adsorption to BC-nZVI followed Pseudo-second-order kinetics and Langmuir adsorption isotherm. Higher metal removal by BC-nZVI is attributed to enhanced sorption due to chemical reduction, and adsorption. The study demonstrated that BC-nZVI composite enhances removal of heavy metals in urban stormwater compared to biochar. Future studies may focus on this composite preparation cost-benefit ratio and large-scale testing on actual stormwater treatment.

Keywords: Heavy Metal, Adsorption, modified biochar, Stormwater treatment, nanoscale zerovalent iron-biochar composite.
Testing for Congruence Between Molecular and Morphologic Evolutionary Trees in the Bivalve Family Lucinidae

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Mentor/Advisor: Dr. Laurie Anderson; Geology and Geological Engineering Department (GEOE, GEOL)

ABSTRACT

Lucinidae are the most speciose family of chemosymbiotic bivalves with a fossil record dating back to the Silurian (~420 million years ago). The most recent lucinid phylogenies (evolutionary trees) have been produced using molecular sequence data, therefore limiting these phylogenies to living species. To fully understand a family’s evolutionary history, fossil species must be integrated into the phylogeny, which requires the incorporation of morphologic character data. The incorporation of fossil taxa in molecular phylogenies often results in recognition of morphological synapomorphies (characters that are shared and derived from a common ancestor). In fact, published lucinid molecular phylogenetic studies note shell characters with a potential phylogenetic signal that could be applicable to the fossil record. In this study, we test the congruence of published molecular data and a suite of morphologic characters on fossil and extant species, and the potential use of morphology to reconstruct evolutionary history. In this analysis, 52 lucinid species and a morphologic matrix of 58 characters was developed to describe interior and exterior shell features including ornamentation, the hinge and teeth, muscle scars, pallial line, and the inhalant channel (a region assumed to be associated with chemosymbiosis). Published molecular data for two nuclear ribosomal genes (18S and 28S rRNA) and the mitochondrial gene cytochrome b (cytb) were used for 21 extant species. Both parsimony and Bayesian analyses of morphology produced poorly resolved phylogenies that show considerable non-congruence with molecular phylogenies. Further, in the combined dataset of morphologic and molecular characters, cladograms contain many polytomies and were not congruent with molecular phylogenies. Therefore, this study indicates that morphologic characters seem to have a low phylogenetic signal and may be highly homoplastic. Instead, morphology may instead be a more reliable proxy for environmental factors.
Non-Equilibrium MOCVD Growth with Plasma Enhancement

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Mentor/Advisor: Dr. Phil Ahrenkiel; Nanoscience and Nanoengineering Department (NANO)

ABSTRACT

The use of plasma enhancement for non-equilibrium growth of III-V compound semiconductor materials by metal-organic chemical vapor deposition (MOCVD) is being examined, to aid in establishing greater control and understanding of the underlying growth mechanisms for their uses in photovoltaic and solid-state lighting devices. While plasma is commonly used with group-IV materials, such as silicon, few studies have examined the impact of plasma enhancement on III-V material growth. A plasma-enhanced MOCVD (PE-MOCVD) method using radio-frequency coupling was developed for the deposition of elemental Al from trimethylaluminum, which is not generally possible by conventional methods. PE-MOCVD provides improved decomposition of metalorganic precursors driven by hydrogen plasma excitation, rather than either hydride reactions or thermal pyrolysis. The PE-MOCVD approach can also enable lower temperature growth, the uses of alternative precursors, improvements in interface abruptness, and lower production costs. Textured, elemental Al films grown by PE-MOCVD show distinct crystallographic texturing, offering a step towards epitaxial Al layers, which have potential roles as buffer layers for III-Vs and in ultraviolet plasmonics. We have demonstrated PE-MOCVD of GaAs at temperatures as low as 300 °C, and the use of plasma as a handle to control spontaneous atomic ordering in GaInP. The latter is the basis for our investigations into forming order/disorder AlInP unicompositional heterostructures, which are appealing candidates for red/amber light-emitting diodes. Growth for this work is performed with a home-built PE-MOCVD system, with supporting characterization by transmission electron microscopy, transmission electron diffraction, energy-dispersive X-ray spectrometry, and X-ray diffraction. In its current implementation, films grown by PE-MOCVD are subject to plasma damage during growth, resulting in microstructural degradation. Improvements in the system design and growth sequences are at the focus of on-going efforts.
A Fault Identification and Risk Management (FIRM) Method for Structural Integrity Assessment Using Multi-Point Guided-Waves and Deep Neural Networks

Yun Seok Gwon; Mechanical Engineering Department (ME)

Mentor/Advisor: Dr. Hadi Fekrmandi; Mechanical Engineering Department (ME)

ABSTRACT

In this study, a new data-driven approach is investigated using ultrasonic guided waves and recurrent neural networks method to identify location of damage on an aluminum plate structure. An active structural health monitoring technique, Surface Response to Excitation Method, was implemented to actively obtain the health status of the host structure. Several diagnostic and structural health monitoring applications were found to be effective by this method\(^1,2\). In this method, surface guided waves propagate and interfere with internal and external conditions of the structure. By spectral analysis of the frequencies of the propagated waves, the health condition of the structure can be evaluated.

In this paper, the effectiveness of Long-Short Term Memory model (LSTM) is studied for identification and localization of damage on an aluminum plate. As in Figure 1, the stress concentration caused by damage was simulated through applying a static load. Four piezoelectric sensors were attached on the aluminum plate. Sweep sinusoidal waves were generated on a plate and captured by three different sensors. The design of experiment included 16 different locations of artificial cracks simulated by placing applied loads and measuring the transferred guided waves as the response. The frequency range for sweep excitation was selected between 150 – 250 kHz and sensory measurements were used to generate the features by extracting local peaks. Two different sets of features were utilized, one was compared with the baseline signal when no load wasn’t present and, in another scenario, baseline was not used. The LSTM was trained after adequate parameter calibration and its performance was compared to that of a conventional neural networks that was also trained with same input data.

![Figure 1. Experimental Setup Schematics. Signal generator is exciting the plate in a ranged frequency, and the data acquisition device is collecting the response. The computer takes the data from the scope and process them.](image)

References


**Mixing Height: Effects on Wildfire Growth and Establishing a Climatology**

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**ABSTRACT**

In this observational study, we explore the connection between wildfire growth and the observed mixing layer height in the Central Plains and Rocky Mountain region. Understanding if extreme fire behavior is linked to abnormally high mixing heights has many implications for fire weather forecasting and may lead to better preparedness and response times of suppression resources during periods with conditions conducive to wildfire growth. Field observations suggest a correlation between the rate of spread and an abnormally high mixing height. Higher mixing heights are known to impact low-level vertical transport of smoke above a fire; however, the relationship between mixing height and fire behavior is not well understood. This study establishes a method for generating a climatology for mixing heights using a modified Stull method. A selection of wildfire cases is studied, using the nearest National Weather Service radiosonde site data. On days of reported large-scale fire growth, the observed mixing height is compared to the climatological average. Future areas of research could include expanding the scope of the study to explore how different climates, elevations, fuel types, and/or other fire behavior factors affect the mixing height-wildfire behavior relationship.
Investigation of Particle Interfacial Energy Using a Drop Test Apparatus

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ABSTRACT

Measurement of the adhesive force between solids is of great interest for the future of mining and mineral processing, and particulate processing in general. The mineral industry uses tremendous amounts of water every year in the processing of ores to metals. In the United States, much of this water use is in the desert Southwest. Thus, the sustainability practices associated with the production of metals from ores is of critical importance. The purpose of this investigation is to evaluate a dry separation and concentration process based upon adhesive forces. Glass spheres were chosen as model particles representative of silicate minerals, the most abundant type of minerals found in mineral deposits. A drop test method was used to calculate the adhesion force between the glass spheres and a flat substrate. Particles that are adhered to a substrate (glass disks) are dropped from a set height and subjected to a tensile force. The tensile detachment force and adhesive force are equal for a critical particle size, particles with higher size are detached and particles with smaller size remain on the substrate. The specific interfacial energy is calculated for this critical size. The Johnson-Kendall-Roberts theory was used to estimate the adhesive force between the particles and the surface. A direct correlation between the velocity of impact and interfacial energy was obtained, as the velocity increased, the interfacial energy also increased. Similar values of the critical particle size were obtained by varying the velocity of impact.

References

Microwave Materials Characterization of Geopolymer Precursor Powders in the X-Band and S-Band Frequencies of the Electromagnetic Spectrum

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ABSTRACT

Geopolymers are the amorphous alkali aluminosilicate end products of the chemical reactions between alumina/silica-rich base constituents and alkaline solutions. The application of geopolymers as viable alternative construction materials to ordinary Portland cement concrete is hindered by limited knowledge regarding the fundamental reaction mechanisms that produced the geopolymers. Microwave materials characterization to measure dielectric properties of Geopolymer Precursor Powders (GPPs) over the S-Band and X-Band frequency ranges (i.e, 2.0 – 4.0 GHz and 8.2 – 12.4 GHz, respectively) is considered a viable method that permits percipience of these polycondensation reaction mechanisms in geopolymer synthesis. In this study, we investigated the dielectric properties of 9 common GPPs – Ordinary Portland Cement Type I/II (OPC I/II), Class C Fly Ash with high calcium content (CCFA), Class F Fly Ash with medium calcium content (CFFA I), Class F Fly Ash with low calcium content (CFFA II), Lime (L), Metakaolin (M), Zeolite (Z), Silica Fume (SF), and Blast Furnace Slag (BFS) – through detailed physical, elemental, mineralogical and phase characterizations. Emphasis was placed on identifying physical (PSD, D50, Gs), elemental composition (XRF), mineralogical and phase characterization (XRD, QRXD) factors contributing to the dielectric properties of individual GPPs. The results indicated that the crystalline form of silica (SiO2) played an important role in the measurements of both the permittivity and conductivity components of the complex dielectric properties attained for the GPPs. The impact of crystalline silica contents on dielectric properties irrespective of the pozzolanic potential of each GPP, was observed for both the S-Band and X-Band frequencies of the electromagnetic spectrum.
Field Testing of Microbial Bio-Cement Soil Erosion Stabilization

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ABSTRACT

Microbial-induced carbonate precipitation (MICP) results in biocementation initiated by the urease enzyme which is secreted by a ureolytic bacterium. This process occurs naturally and also can be engineered to change soil properties. Soil surface treatment or volumetric mixing of an aqueous solution containing: urea-broth, a calcium source and S. pasteurii with soils has been proven to increase unconfined compressive strength, decrease permeability and increase wind erosion resistance. The potential increase in calcite content in soil horizon A could also result in an increase of plant available water (PAW). Regular concentration MICP contains 61 g/L of TDS of which 12 g/L is free, amino, bound and ionized Nitrogen, 25 g/L is ionic-bound chlorine and 10 g/L is ionic-bound calcium. Percent by mass of the ionic solids used in MICP is: 46% CaCl$_2$, 33% CH$_4$N$_2$O, 16% NH$_4$Cl and 5% nutrient broth. MICP surface application rates used in the study were in the range of 5.25 to 21 lb N/1000 ft$^2$ which compare to 2.5 to 5 lb N/1000 ft$^2$ as would be used for typical fertilizer application rates. MICP as classified for the industry standard for fertilizers would be labeled as a 36-0-0 fertilizer. When compared to existing calcium dust suppression technology, MICP application rates for this study use only 8% of the calcium dihydrate and provide comparable or better dust suspension prevention.

During summer and fall of 2018 three field trials were conducted in western South Dakota. The first site at the Rapid City Solid Waste Facility consisted of highly acidic soils in which vegetation is difficult to grow and soil erosion is noticeable by the deep gullies. The second site at Custer State Park was in an area burned by the Legion Lake Fire in December 2017 and again during a slash pile burn in early spring 2018. The third site was along I-90 as it passes through Rapid City, SD. These soils are easily eroded by wind and water and very little vegetation persists in the area. Sixteen control plots and treatment plots were tested for unconfined compressive strength, shear strength, pH, vegetation and erosion resistance. Results varied by site and were difficult to analyze due to the conditions and challenges of field experimentation, however, some erosion resistance was observed on plots with half, regular and double concentration MICP treatments. Strength measurements showed limited consistency amongst sites and plots. Vegetation was difficult to grow at sites 1 and 3 but grew well in all plots that were seeded on site 2, burned soils. Analysis continues on the field data collected to determine more trends.
**Mining Metagenomes for Bioplastics and Other Useful Bioproducts**

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**ABSTRACT**

Enrichment of microorganisms with special traits and the construction of metagenomic libraries by direct cloning of environmental DNA have great potential for identifying genes and gene products for biotechnological purposes. This research aimed to expand the diversity of known PHA synthases, catalyzing the polymerization of hydroxyacyl-CoA molecules, to the corresponding Polyhydroxyalkanoate (PHA), a bioplastic, via functional metagenomics. A metagenomic library consisting of 750 clones was constructed from the biofilm sample collected over the course of an expedition to SURF in Lead, South Dakota (USA) in September 2017, from the Ross Campus (4850 feet deep level). Because, Deep mine biofilm sample contained high amount of mucoid exopolysaccharide, an improved MINES method, developed and optimized in our lab was used for optimal biofilm DNA recovery suitable for all types of high-resolution downstream applications. Metagenomic Plasmid and Fosmid Library was constructed using pBR322 and pCCFOS1 vectors respectively, and five positive E. coli clones conferring a stable PHA producing phenotype were obtained during the initial screen. These clones expressed Class I, Class III, and Class IV PHA synthases. with an open reading frame of 1100-1400 bp. The clone P-4 was found to accumulate 35-40% of a medium chain length PHA (mcl-PHA) semi-crystalline PHA composed of 3-hydroxybutyrate 3-hydroxyvalerate in glucose containing medium. Data demonstrated paved a path from metagenomics to bioplastics and its use for the production of a variety of PHA polymer and copolymer mixtures.

**Keywords:** Biofilm, Fosmid, Metagenome, Polyhydroxyalkanoate.
Plasmon-enhanced Near-infrared to Visible Upconversion Luminescence from Single β-NaYF₄:Yb³⁺: Tm³⁺ Nanoparticles on Silver Nanowire Composites

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ABSTRACT

We use spectroscopic imaging, and statistical analysis to assess the plasmonic enhancement of NIR-to-visible upconversion luminescence (UCL) from single β-NaYF₄:Yb³⁺: Tm³⁺ upconverting nanoparticles (UCNPs) supported on substrates consisting of random silver nanowire composites (NWCs). We measure both apparent luminescence enhancement, which is power dependent due to the nonlinear kinetics of energy transfer upconversion (ETU), and the excitation enhancement, defined as the ratio of the excitation intensity needed to produce a given UCL emission, divided by the equivalent power needed to produce the same emission on the plasmonic substrate, which we showed recently is power-independent over 5 orders of magnitude for Er³⁺ doped UCNPs on Au nano-cavity arrays. By examining the effects at the single particle level, and accumulating a statistical sampling of single particle emitters, both on and off the plasmonic substrates studied, we eliminate the effects of particle fluctuations on the apparent UCL emission enhancement, and observe a significantly larger excitation enhancement on the Ag NW substrate than previously reported (up to 12.25X, compared to 4.6X for Er³⁺ doped UCNPs on Au Nano-cavity arrays). We compare these results to our frequency domain life time measurements, FDTD simulations, and statistical analysis of ensemble measurements made of Er³⁺ doped UCNPs supported on random Ag NWCs.

Figure 4. a) FDTD simulation of |E|² for a random NWC. b) power dependence of UCL from different UCNPs on NWCs.
Epitaxial Recrystallization of Al Deposited by Plasma-Enhanced MOCVD On GaAs Substrates

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ABSTRACT

We report epitaxial Al film on GaAs (001) substrates using plasma-enhanced metalorganic chemical vapor deposition. Growth was conducted at low temperatures (<300 °C) to eliminate carbide incorporation that occurs through thermal cracking of metalorganic precursors. The as-deposited films were strongly textured, with a tendency to orient an Al-film <110> parallel to a <110> in-plane direction of the substrate. After deposition, the films were thermal annealed at 640°C, near the melting point of Al, resulting in significant recrystallization. The recrystallized Al structures on axis (001) GaAs substrate and substrates with offcuts 2°<101> and 6°<111>B were (011)R oriented. In addition, the epitaxially recrystallized film showed reduced surface roughness compared to companion films. This method presents a simple route to form epitaxial metal/semiconductor heterostructures using conventional metalorganic precursors.

Fig 1. Plan view selected area diffraction pattern of {011}Al (red) on (001)GaAs (green).
Evaluation of LLDPE/EVOH Geomembrane Barrier for EPS Geofoam Protection

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ABSTRACT

Schematic of EPS geofoam fill project with potential geomembrane candidates for fluid protection

Construction grade expanded polystyrene (EPS), or geofoam, is dimensionally sensitive to hydrocarbons and is typically covered with a protective polyolefin geomembrane when used as a foundation material. Data has been generated showing that the geomembranes currently used in construction applications provide less protection than initially assumed, with liquid fuels diffusing through some in as little as 4 hours. Enhanced protection for EPS geofoam foundations can be achieved using barrier geomembrane products, which utilize multilayer polymer geomembrane technology for increased protective performance. Fuel spill experiments using a variety of geomembranes (composed primarily of either linear low-density polyethylene (LLDPE), high density polyethylene (HDPE), ethylene interpolymer alloy (EIA), polyvinyl chloride (PVC), or chlorosulfonated polyethylene (CSPE-R)) show these geomembranes to have poor permeation resistance to gasoline, resulting in rapid degradation to encased blocks of EPS geofoam in a matter of hours. In contrast, a multilayer barrier geomembrane was shown to provide considerable advantage in protecting the EPS foam by preventing gasoline permeation for over 1000 hours of continuous exposure. Additional testing has further demonstrated complete protection of the geofoam can be achieved even after 160 days (3840 hours) of continuous exposure to gasoline.