
HEMI
HOPKINS EXTREME
MATERIALS INSTITUTE
Student Research Internships and Apprenticeships
Summer 2021
JOHNS HOPKINS
UNIVERSITY

From the HEMI Director

Since its establishment in 2012, the Hopkins Extreme Materials Institute (HEMI) at Johns Hopkins University has provided opportunities for high school, undergraduate, and graduate students to conduct research both within HEMI as well as at our partner institutions. With COVID-19 precautions in place for the second consecutive summer, I am sincerely grateful that we had the ability to offer these programs. The apprenticeships and internships have grown to be very competitive, and I continue to be impressed by the quality of the students' research. It is my hope that their research experiences inspire these students to pursue a future career in a STEM-related field.

This year, we are honored to add the undergraduate research awards program managed by the Materials Science in Extreme Environments University Research Alliance (MSEE URA). The addition of the MSEE URA has significantly expanded the number of opportunities HEMI can offer.

Due to restrictions on our in-person research capabilities, the student opportunities were often conducted remotely this year. I am extremely proud of the students and the research activities they accomplished under these constrained circumstances! I also am continuously grateful to the faculty hosts, mentors, and administrative personnel who ensure that the students have the resources and receive the guidance needed for a rich and rewarding experience.

HEMI would like to acknowledge the following organizations for their support of these opportunities: the Army Educational Outreach Program, Rochester Institute of Technology, DEVCOM Army Research Laboratory and Army Research Office, the Defense Threat Reduction Agency, the Maryland Institute College of Art, and The Whiting School of Engineering at Johns Hopkins University. The summaries included herein (written entirely by the students) provide a glimpse of the hard work they accomplished within a short period of time. I am optimistic that we can return to 100% in-person apprenticeships and internships next summer and I hope this encourages students to apply in 2022!

Sincerely,

KT Ramesh
Alonzo G. Decker, Jr. Chair in Science and Engineering

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Contents

AEOP High School Apprenticeships

These apprenticeships provide high school students the opportunity to work one-on-one with a university faculty member and mentor in a STEM field. Students will experience firsthand the innovation and research that is driving the future of our country. These apprenticeships are conducted during the summer and the students earn a stipend. Apprentices are exposed to real world research, gain valuable mentorship, and learn about education and career opportunities in STEM.

AEOP Apprenticeship Benefits

- Stand out from your peers
- Be in the room where it happens
- Mentorship is the special sauce
- Research that matters
- Ongoing support
- Earn a stipend

Funding Sponsor

U.S. Army, administered by the Rochester Institute of Technology

Website Information

https://www.usaeop.com/program/high-school-apprenticeships/

Adesola Adelegan

Charles Herbert Flowers High School, Springdale, Maryland
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Faculty Host: Professor Lori Graham-Brady
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Johns Hopkins University

Project Title: Microstructure Reconstruction

Experimentalists often collect data from their experiments using a microscope to prepare the sample.
This process takes a lot of time, energy, and equipment. Creating more similar images with the same properties to conduct data experiments take up even more time and more materials. Recreating microstructure images with the same properties but still have differences in size is a long process to achieve. Using python to program a code and applying machine learning and deep learning to create style transfer. Style transfer consists of obtaining a content image and a style image to create another similar image combining all of this to create microstructure reconstruction.

To make data analysis more efficient, microstructure reconstruction speeds up the process of collecting multiple samples. It allows you to generate a large number of microstructure samples from limited experimental data. An image obtained from a microstructure reconstruction is not copied and pasted from the original sample but is a reconstructed image with the same properties but different sizes. It takes roughly an hour and a half to create 100 similar copies of a material microstructure slice, whereas if someone tries to recreate these pieces, it will take days to make the same amount of similar copies.

In this study, microstructure reconstruct generates multiple microstructure samples. The algorithm used for the python code ensures precise and clear

images contingent on the number of times the code is set to run. It compares the statistical properties of the original 2D slice of a material microstructure sample and the reconstructed microstructure. The output data shows the statistical properties of point probability, lineal path function, pore-size density, and the cumulative distribution function of pore-size.

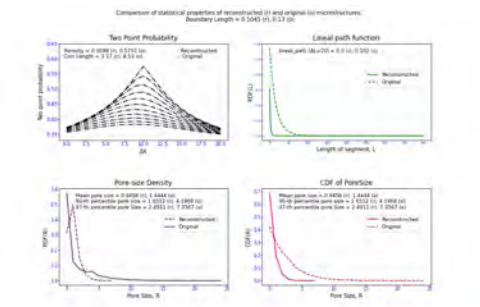


Image: Comparison Statistical Properties

Nahuel Albayrak

Chesapeake Science Point High School, Hanover, Maryland
Mentor: Adyota Gupta
Faculty Host: Professor Ryan Hurley
Department of Mechanical Engineering
Johns Hopkins University

Project Title: Investigating Granular Flow Through Network Analysis

In order to better gauge performance in armor ceramics we can study the granular flow of particles as a projectile makes impact. Granular flow can affect a projectile's depth and final placement. As impact is made within the material a comminuted zone is created. This zone is the area in which we analyze force networks at different time steps. When studying temporal changes in force networks we are dealing with different nodes and edges carrying information such as location(x,y,z), contact forces, radi etc. We are able to label assortments of these nodes and edges based on the information they carry. Through the contact force magnitude found in edges and angles created between triplets of nodes, we label them as either kinks (when the angle found between triplets is less than 135 degrees), extensions (when the angle found between triplets is greater than or equal to 135 degrees), merges (a new edge is found between 2 nodes), or disappearance (edge or node is no longer present). With this information we hope to find correlations between the labels to better understand particle rearrangement.

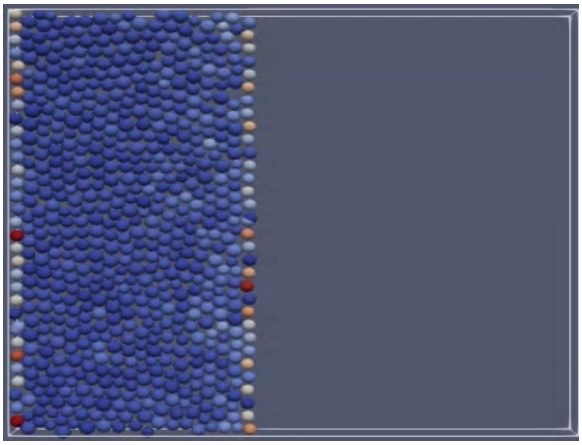


Image: Particles enduring stress

Kathy Ho

Atholton High School, Columbia, Maryland
Mentor: Dylan Madisetti
Faculty Hosts: Professor Jaafar El-Awady
Department of Mechanical Engineering
Johns Hopkins University

Dr. Christopher Stiles
Johns Hopkins Applied Physics Laboratory

Project Title: Exploring the Depths of Hyperparameter Tuning and Graph Embedding (Link Prediction) using Benchmark Frameworks

With all machine learning problems, from classifying whether a tumor is benign or malignant to classification in the material sciences, hyperparameter tuning is crucial to control the behavior of a machine learning model. What hyperparameter tuning does is that it finds the optimal combination of hyperparameters to minimize the loss and maximize a metric such as accuracy or precision. It is much more efficient than manually changing hyperparameters, and its importance is frequently overlooked.

What this first project aims to do is to explore the intricacies of hyperparameter tuning using a benchmark dataset: CIFAR-10, which includes 60000 images in 10 classes (50000 training and 10000 testing), with 6000 images per class. Using this, techniques to deal with overfitting such as Max/Mean

Pooling, Batch Norm, and Dropout were explored, in addition to optimization techniques such as Grid Search and Bayesian Optimization. After training, the model was able to reach 86% accuracy in the test set.

Following this 1st project, graph-embedding (a new, cutting-edge research used to transform nodes, edges, and their features into a vector space while maximally preserving properties like graph structure and information) was also explored. Like the previous project, to avoid getting bogged down by more technical data, an International E-road network (Topografisch Verbond Elbruz), which shows a network of all the major roads and water crossings in Europe was used. After preprocessing the data (including geoencoding), and creating a sub-dataframe/set with just the nodes, the data was determined to have 895 nodes, and 1295 edges. Using networkx and basemap, a graph was drawn to get a general sense of the data, and after converting the dataframe into a dataset (json structure), basic link prediction (using an adjacency matrix) was done. Finally, to tie in these 2 projects, basic hyperparameter tuning was done.

Ultimately, these frameworks that were built were generalized to be used on almost any other dataset. Following this research, teams such as the material science group at JHU can briefly reformat the framework as needed for their data, and utilize it in a more useful way.

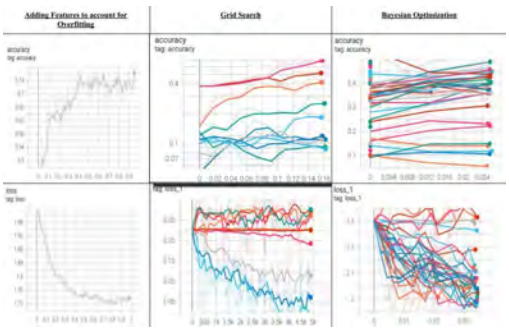


Image: HP Tuning

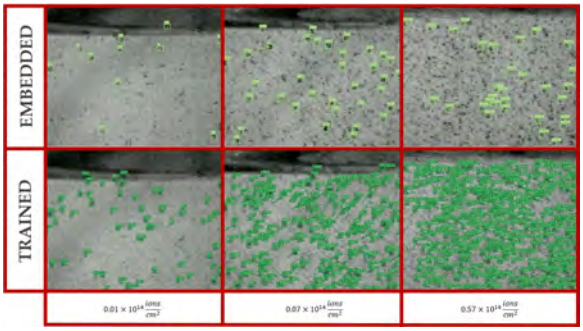
Emma Liu

Urbana High School, Ijamsville, Maryland
Mentors: Emily Hopkins and Cassandra Pate
Faculty Host: Professor Mitra Taheri
Department of Materials Science and Engineering
Johns Hopkins University

Project Title: Utilizing Deep Learning to Visualize Defect Evolution at the Grain Boundary

Light water reactors, key contributors in the generation of global electricity, experience degradation due to radiation damage as they age. Under radiation, atomic displacement leads to the formation of point defects and defect clusters in metals, These defects can be absorbed by grain boundaries, the interface between crystals of different orientations. Grain boundary engineering of more radiation-tolerant materials can help to mitigate the effects of aging on the efficacy of light water nuclear reactors, but in order to pursue the development of these materials, we must first understand the behavior of defects at grain boundaries.

A traditional method for analyzing the density and diffusion of defects is for researchers to count and label the defects by hand. However, this is not only time- and labor-intensive, but also inconsistent, as the perception of what is considered a defect is subjective, especially in relatively low-resolution microscopy images. To tackle this problem, we plan to utilize deep learning methods, particularly the You Only Look Once (YOLO) object detection model. This model, being a single-stage detector which directly applies a single neural network to an image, is much faster than other existent object detection models and thus, better suited to the problem. In this study, we use image frames from in situ transmission electron microscopy experiments, annotate them to create training data for our model, train the model on those annotations, and finally use the model to identify defects in test frames. Ultimately, the development of this model will allow us to count, track, and analyze defects and defect motion more efficiently, further developing our understanding of grain boundary sink behavior in metals.



AEOP Undergraduate Apprenticeships

In these apprenticeships, undergraduate students have the unique opportunity to conduct real-world, Army-sponsored research alongside scientist and engineer mentors in world-class facilities at university labs. Through this commuter program, students will develop skills in Army critical science and engineering research areas which prepare them for the next steps of their educational and professional career.

Students perform research activities associated with the Center for Materials in Extreme Dynamic Environments which is focused on designing, developing, and testing improved soldier protection materials. Students gain experience in working in a university lab and being a part of a faculty member's research group while earning a stipend.

AEOP Apprenticeship Benefits Goals

- Stand out from your peers
- Be in the room where it happens
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Funding Sponsor

U.S. Army, administered through the Army Research Office and Center for Materials in Extreme Dynamic Environments

Website Information

AEOP - https://www.usaeop.com/program/undergraduate-apprenticeships/

CMEDE - https://hemi.jhu.edu/cmede

Christopher Alevrontas

University of Delaware, Newark, Delaware
Mentor: Dr. Sanjib Chowdhury
Faculty Host: Professor John Gillespie
Department of Materials Science and Engineering
and Center for Composite Materials
University of Delaware

Project Title: Studying the Structure-Property Relationships of Glass Systems Using Molecular Dynamics Simulations

The purpose of my project I conducted with the guidance of Dr. Sanjib Chowdhury was to study the structure-property relationships of multi-oxide glass systems using molecular dynamics simulations. The interactions between atoms within aluminum oxide and magnesium oxide are critical to understand for the studying of the systems, as these compounds make up a large portion of the compounds within the glass systems. Using Molecular Dynamics simulations, we were able to develop composition mapping of the multi-oxide glass systems we were working with. Molecular Dynamics simulations were used because we were working with these systems on an atomistic scale, and the simulations are carried out using Matsui and ReaxFF force field to model the inter-atomic interactions of the compounds. By simulating with models of these compounds, it saves a lot of time, money, and effort which would have been spent in physical testing. The models were also used to predict the structure of these compounds, and the MD

predictions would then be validated when compared with experimental data available to us. The first step of this project was to model aluminum oxide and magnesium oxide in Packmol, which generated a specific number of atoms based on the size of the compound we used in the next step of the project, which was to use the number of atoms generated in a Matsui script which I edited and revised for our new, specific purpose of modeling the compounds on their own. After this step, the required data was then used in a ReaxFF force field script to demonstrate the physical properties of the compounds which would be applied to the multi-oxide glass systems. Using the simulations described in this summary, critical information about aluminum oxide and magnesium oxide can be determined and applied to identify and design optimal glass structures that can later be manufactured, in addition to guiding manufacturing processes.

Eli Bogetti

University of Delaware, Newark, Delaware
Mentor: Dr. Bazle Z. (Gama) Haque
Faculty Host: Professor John Gillespie
Department of Materials Science and Engineering and
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Project Title: Stochastic Continuum Damage Modeling of Composites and Automated Data Processing

Stochastic ballistic impact perforation in thin-section composite panels made from plain-weave S-2 glass fabric SC-15 is being modeled to predict perforation damage mechanisms. Composite damages have been modeled using the rate-dependent progressive continuum damage model MAT162 in LS-DYNA. Research this summer sought to include stochastic variability in the FE model and to reduce time needed for data collection, reduction, and visualization. The FE model of composite is a 178mm-by-178mm panel with a thickness of 1.2 mm, meshed with three elements in the through-thickness direction, for every two layers. To improve the realism of the FE model's damage response, a stochastic distribution has been applied to the model's material properties. The model elements were grouped in the through-thickness direction, and the stochastic material properties were randomly assigned to the groups of elements. Many stochastic simulations have been run per MAT162 properties to accurately predict the stochastic behavior of perforation. For each simulation, time dependent data and damage contour images of each layer were extracted from LS-PrePost. Originally, the time dependent data and a few selected images were gotten manually, and the data was reduced and visualized manually. A Python script has been written to automate the data collection process of extracting the data and all images for each simulation. The data reduction process and visualization process has also been automated using Python. The time dependent data is reduced, summarized, and plotted to understand the deformation dynamics and perforation. The damage images are processed to collect max damage area for certain damage modes and area of element erosion. With the applied stochastic material properties, the simulation results better predict the stochastic perforation behavior, and through the use of Python, the data collection, reduction, and visualization processing times have been reduced to a few minutes.

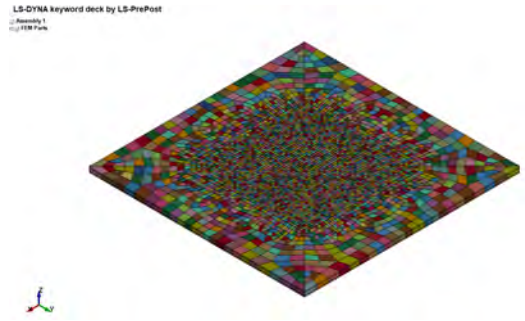
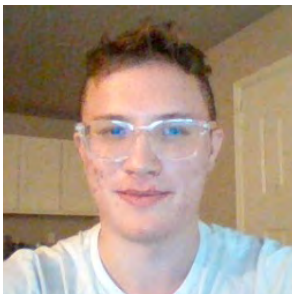


Image: Two-layer finite element model with stochastic material properties applied. Model elements were grouped in the through-thickness direction for the stochastic distribution of the material properties.



Scott Brame

University of Houston, Houston, Texas
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Department of Mechanical Engineering
University of Houston

Project Title: Discrete Element Modeling of Granular Assemblies

The discrete element method (DEM) is a numerical method used to model the behavior of individual granular particles. Parametric tests were conducted using discrete element models to investigate sand heap formation, shape and behavior with varying particle sizes, friction coefficients and clumping percentages. Statistical studies were then performed to analyze the results of each test and identify the effects and trends of each parameter that was tested.

The open-source DEM software, LIGGGHTS, was used to perform particle simulations using the cluster computing power available at the University of Houston. Paraview, an open-source visualization software, was used to in conjunction with Blender, a common 3D computer graphics software, to analyze the results of the simulations and record the relevant data. Microsoft Excel was utilized to plot data in a concise and presentable format.

The effects of particle size, friction coefficients and clump percentage on the formation heap were analyzed. The results of the three parametric studies show clear trends in the effects of the tested parameters on the variables that define heap formation: heap angle and height-to-base ratio. With an increase in particle size, heap angle and height-to-base ratio decrease due to the change in particle interaction forces. The heap angle and height-to-base ratio increase with increasing friction coefficients and clump percentage. Additional friction between particles generates more resistance to motion and prevents more particles from sliding or rolling down the heap during formation. Increasing clump percentage causes particles to interlock, applying further resistance to motion.

Figure 2: Angle of Repose as a Function of Sliding Friction

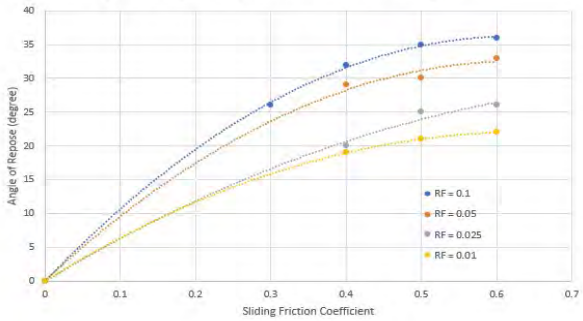

Image: Results of some of the particle simulations performed.

Nicholas Henson

Rutgers University, Piscataway, New Jersey
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Department of Materials Science and Engineering and
Ceramic, Composite & Optical Materials Center
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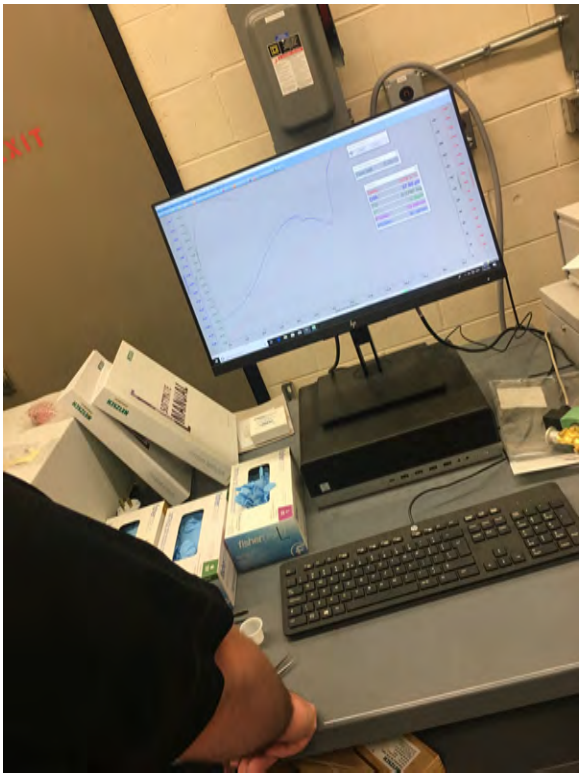
Project Title: Ultra-High Temperature Ceramics for Hypersonic Applications

Ultra-high temperature ceramics (UHTC's) are a promising materials branch for applications in hypersonic (> Mach 4) vehicles where surface temperatures can exceed 2000 °C. ZrB2/SiC composite is a promising UHTC with a high melting point (~3250 °C), high strength (> 500 MPa) and good oxidation resistance. Mixing of ZrB2 and SiC can be done using arc-melting which due high temperature gradients results in better mixing than traditional synthesis methods like reactive hot pressing. However due to rapid cooling rates the final structure may not be at equilibrium, so heat treatment was investigated as a method to relieve this.

Arc-melted ZrB2/SiC composites were annealed in a graphite furnace at temperatures up to 2000 °C for two hours under argon. XRD, SEM, and EDS analysis was performed before and after heat treatment to determine phase change, microstructure, and chemistry, respectively. In addition, DTA-TGA was employed to capture potential reactions during annealing.

XRD showed that the same ZrB2 and SiC phases were present in the pre, and post heat treated samples. SEM showed the SiC and ZrB2 forming lamellar and eutectic structures and EDS confirmed the composition of these phases. DTA analysis displayed little to no change in the samples.

Based on the post heat treatment analysis, ZrB2/SiC composites showed little phase change or reaction occurring for samples up to 2000 °C. This concurs with the phase diagram found in the literature in which only a ZrB2+SiC phase is present at all mole percentages up to ~2200 °C. The analysis showed little change between heat treated and purely arc-melted samples, meaning they are already at equilibrium and heat treatment will not affect the structure. In the future, work will be done to characterize the thermal properties of different ZrB2/SiC composites.



Christopher Karber

Texas A&M University, College Station, Texas
Mentors: Mr. Joshua VanCura and Mr. Yuan Ji
Faculty Host: Professor Justin Wilkerson
Department of Mechanical Engineering
Texas A&M University

Project Title: Micromechanics and Failure Mechanics

The projects I was assigned while participating in research activities with Texas A&M University's Laboratory for Nonequilibrium Phenomena largely fell under the scientific "umbrella" of micromechanics and failure mechanics. Two of research activities of the laboratory involve developing models for soil-tire interactions of vehicles and characterizing the behavior of ballistic gel in extreme environments. Currently, there are few mathematical or phenomenological models that can be used to predict these interactions with enough precision to maintain scientific validity. Many defense sciences and applications, e.g., armor protection, vehicle mobility, traumatic brain injury, etc., involve the non-linear behavior of materials at large deformation and high strain rate. To foster the participation, education, and training of undergraduate students in the defense sciences, there is significant value in the development of simple benchtop experiments to probe the non-linear, large deformation response of various materials under various types of high-rate loading. Such experiments enable undergraduate students to take full ownership of small experimental studies and begin to develop into independent researchers. This goal has been the primary focus of this summer apprenticeship. This report details the various projects I supported as an apprentice with the Laboratory for Nonequilibrium Phenomena.

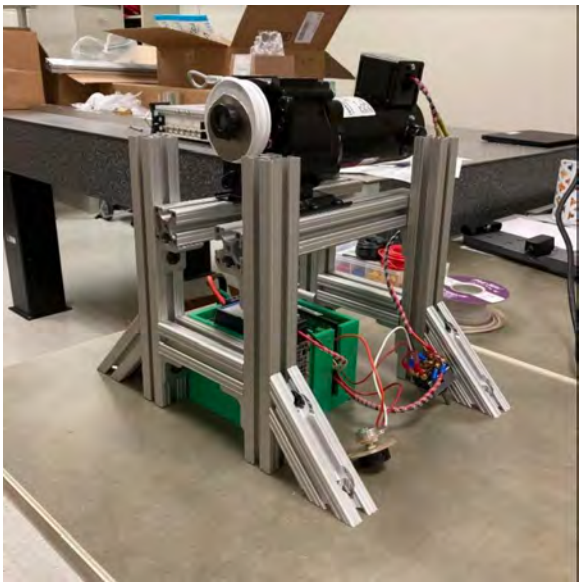


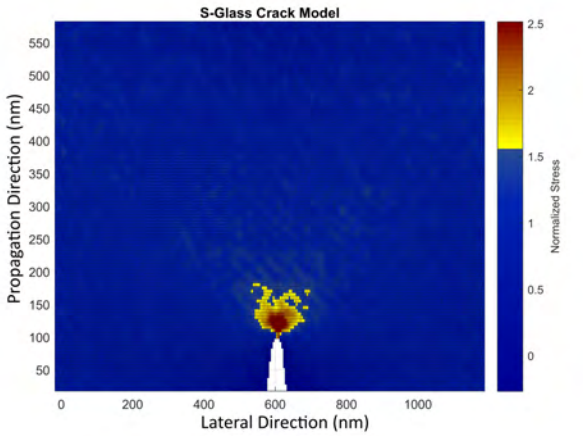
Image: Completed motor and mount for a project.

Tim Longoria

University of Delaware, Newark, Delaware
Mentor: Dr. Sanjib Chowdhury
Faculty Host: Professor John Gillespie
Department of Materials Science and Engineering and
Center for Composite Materials
University of Delaware

Project Title: Atomic Level Stress Analysis in Glass Fibers

Glass fibers are used in optical fibers and in structural composite materials. Surface cracks can appear during spinning and handling. These cracks are on a nanometer length scale which makes it difficult to study the effects of the cracks experimentally. Therefore, molecular dynamics (MD) simulations with reactive force field ReaxFF are used to study the effects of surface cracks on the mechanical properties of glass fiber at this small length scale. Atomistic J-integral approach is used to determine fracture toughness. Over the internship, various Matlab scripts are developed to speed up the post-processing analysis. The simulation results showed that surface cracks significantly reduce the glass fiber's strength without affecting fiber modulus.

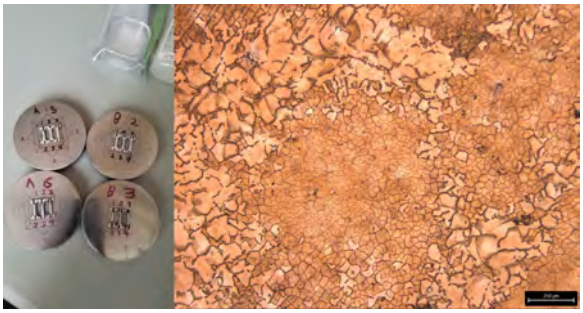


Fanuel Mammo

Johns Hopkins University, Baltimore, Maryland
Mentor: Mr. Suhas Eswarappa Prameela
Faculty Host: Professor Tim Weihs
Department of Materials Science and Engineering
Johns Hopkins University

Project Title: Thermo-mechanical Processing and Characterization of Magnesium-Zinc Alloys

Light metallic alloys of Magnesium (Mg) are extremely useful for applications such as body and vehicle armor. They are lightweight and help in reducing the overall weight of protection materials. However, they demonstrate very poor strength when subjected to high loads or strain rates. To overcome this, we have thermo-mechanically processed binary alloys of Mg-Zn (Zinc). Mg-5 Zn (wt%) alloy of two conditions were considered in this study: solutionized and peak aged. The peak aging was done at 150oC for nearly 99 hours. Both these alloys were then cut using EDM (electrical discharge machining) into small rectangular dog bone pieces (as seen in the image on the left) for mechanical polishing for light microscopy characterization and into dog bone shaped samples for micro-tensile testing. Light microscopy was useful for observing grain sizes and their distribution in both the samples. The tension experiments revealed that the peak aged sample showed much higher yield strength than solutionized sample. This shows that by picking the right processing path, it is possible to alter the microstructure of the material and hence it's properties.



Images: (left) dog bone shaped samples on a polishing chuck, (right) Bright Field micrograph of solutionized Mg-5Zn(wt%) alloy

Alex Pasara

Rutgers University, Piscataway, New Jersey
Mentor: Dr. Chawon Hwang
Faculty Host: Professor Richard Haber
Department of Materials Science and Engineering and
Ceramic, Composite & Optical Materials Center
Rutgers University

Project Title: High-Temperature Analysis of Ultra-high Temperature Ceramics (UHTCs) for Hypersonic Applications

Ultra-high temperature ceramics (UHTCs) with melting points above 2500-3000°C are promising for use in hypersonic vehicles as this class of vehicles must withstand temperatures in excess of 1600-2000°C. One material system of interest is zirconium boride (ZrB_2) as ZrB_2 has a melting point of >3000°C and a yield stress of >400MPa. However, ZrB_2 has low oxidation resistance and is difficult to fully sinter. Thus, silicon carbide (SiC) is used as an additive to aid in the sintering process and increase the oxidation resistance of ZrB_2 without compromising the desired qualities of the bulk ZrB_2.

The current prevailing method of forming ZrB_2-SiC is to use Reactive Hot Pressing (RHP), which involves the reaction of Zr, B, Si, and C containing precursors at temperatures below 2000°C. However, this process results in the formation of secondary phases as well as large grains, which result in poor strength and high oxygen content. We chose instead to use arc melting as it can efficiently melt ZrB_2, thus allowing us to avoid using alternative precursors, and create a fine microstructure, which preserves the strength of the UHTCs.

The target composition of ZrB_2-SiC is the eutectic composition, 58.5mol% SiC, for which ZrB_2 powder and SiC powder were used. Pellets (20g, 25mm diameter) of the powder mix, prepared through wet ball milling (isopropanol; SiC media, 5 mm) and subsequent uniaxial pressing (5MPa), were arc melted using an arc melter in a Cu crucible under Ar gas at 400 Amps. Thus arc melted ingots were imaged through SEM to examine the resulting microstructure.

From the SEM results, we found that upon arc melting, the ingots formed large regions of very fine lamellar structure, <10µm in length, which indicates that this is the eutectic composition and that phase segregation did not occur. We also found that in the ingot's midsection, a region of long, oriented grains had formed, which we believe to be a result of the large temperature differential between the arc and the crucible. Densification study of the arc melted ZrB_2-SiC eutectic is planned and underway.

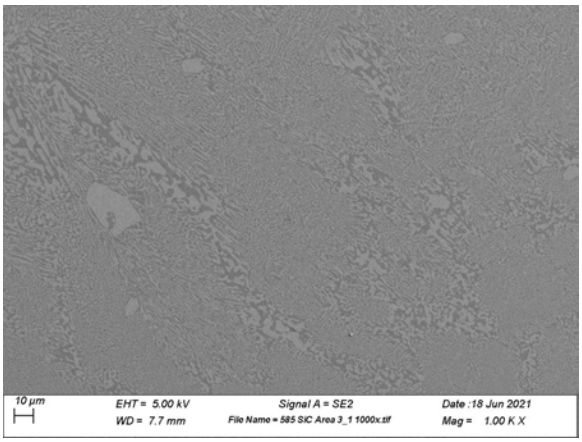


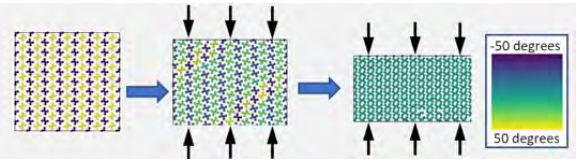
Image: Cross sectional SEM image of arc melted ZrB_2 - 58.5mol%SiC

Paul Zaloga, Jr.

University of Delaware, Newark, Delaware
Mentor: Dr. Sanjib Chowdhury
Faculty Host: Professor John Gillespie
Department of Materials Science and Engineering and
Center for Composite Materials
University of Delaware

Project Title: Atomistic Analysis of Interphase and Polyethylene Fibers

The goal of my project was to develop pre- and post-processing tools to create and analyze composite interphase as well as assessing change in the structure of polyethylene fibers under transverse compression. This included the use of molecular dynamics simulations to capture the phase transformation of polyethylene crystal under transverse pressure, and the use of Matlab to take the positions/angles of particles and color code them to show the change in morphology of them under the same pressure (shown below). As of right now, we believe that a silane number density of about 1-2 nm^2 is an optimal density for a silane-epoxy composite system regarding for both high strength and energy. However, more research needs to be done to understand the load transfer mechanism within the polyethylene fiber at different length scales.



Extreme Science Internships (ESI)

ESI provides opportunities for Morgan State University (MSU) students to participate in both internal and external internships associated with the Center for Materials in Extreme Dynamic Environments (CMEDE) and the Materials Science in Extreme Environments University Research Alliance (MSEE URA). ESI are STEM-focused with a particular emphasis on providing research opportunities related to CMEDE and the MSEE URA.

ESI is open to undergraduate and graduate students in MSU's School of Computer, Mathematical, and Natural Sciences and the School of Engineering.

Internal ESI are hosted by MSU faculty on the campus of Morgan State University. During the summer of 2021, external ESI were conducted at one of the CMEDE university and research institutions located across the United States, the United Kingdom and Germany. ESI are paid internships in accordance with MSU policies and regulations.

Program Benefits

- Opportunities for undergraduate/graduate students to gain a research experience, and to present the findings of their research;
- Opportunities for students to meet colleagues at majority institutions to develop research collaborations;
- Engage representatives from majority academic institutions to explore opportunities to pursue graduate degrees; and
- Expand their professional networks and further position students for future job opportunities.

Funding Sponsor

Army Research Laboratory through CMEDE and the Defense Threat Reduction Agency through the MSEE URA

Website Information

Morgan State University ESI

https://www2.morgan.edu/school_of_computer_mathematical_and_natural_sciences/information_for_students/research_and_internship_opportunities/extreme_science_internships.html

CMEDE

https://hemi.jhu.edu/cmede/

Aalliyeh Clinton

Morgan State University, Baltimore, Maryland
Mentor: Mr. Christopher Hale
Faulty Host: Prof. Jag Sankar
Department of Mechanical Engineering
North Carolina Agricultural and Technical State University

Project Title: Magnesium Alloy Effectiveness in Mechanical Engineering

My experience this summer involved interesting virtual presentations, reading materials, and video calls with my mentor Christopher Hale. With his mentorship, I was able to develop an understanding of magnesium alloys' effectiveness in mechanical engineering. Each week was a different introduction to the processes used in the laboratory to develop the specimens.

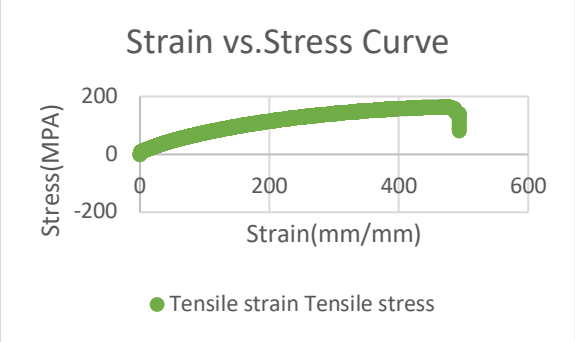
We begin by observing the magnesium processing lab in which everything takes place. Preparation is one of the first things taught to know how the procedure is completed.

1. The material must be cast (heated over its boiling pointed). To do so it is put in the crucible and poured into the ingot to complete casting.
2. Then the casting is cut into a small sample for the polishing process. After that analyze material under an optical microscope (OM) and Scanning electron microscope (SEM).
3. Microstructure mechanical properties of the alloy can determine if the deformation is high or low. One method to seek plastic deformation would be to perform rolling which reduces the specimens' thickness.
4. Next, to further evaluate the materials strength and ductility include tensile and hardness test.

After walking through the preparation process, we had a visual section of how polishing is completed. This was a wonderful site to see this process included the sample moving in a circular motion to fully polish the sample in its entirety at a set speed. Each sample took a different time, rolling reduction, and speed to complete its process due to its differences in the microstructure. Another visual representation was done using the SEM which scans the sample with electronic beams. A imagine is produced containing information regarding the composition and surface topography of the specimen. Electron Backscatter diffraction (EBSD) was a test unable to see performed but it was explained in depth that it assesses grain size in high and low magnitude.

Moreover, with this understanding, we were able to move forward to analyzing a sample with the OM. Under the microscope, we were able to get a good look at the grain size which affects hardness availability. To evaluate the material's strength a visual tensile test was performed. This test determines the point where the material will elongate. While testing data is being gathered: tensile strain, tensile stress, elongation percent, load, extension, and the time used to later evaluate the sample.

We were able to use the information from the test to gather a stress-strain curve to evaluate the materials' tensile strength. I evaluated the data and designed a graph to compare the analyzed data visually. Overall, I was able to learn, understand, and evaluate data relating to testing magnesium alloys mechanical properties.



Francis De-graft Johnson

Morgan State University, Baltimore, Maryland
Mentor: Dr. Brandon Zimmerman
Faculty Host: Prof. Vicky Nguyen
Department of Mechanical Engineering
Johns Hopkins University

Project Title: OCT Image Segmentation with Deep Learning

My summer research experience started off with me gaining contact with Dr. Vicky Nguyen and having a zoom meeting in order to decide what project to work on. The Johns Hopkins Extreme Science Internship team ran multiple projects in the same summer session divided between their members. However, after meeting with Dr. Nguyen explained that I could possibly work with imaging with optical images. Shortly after I met with Dr. Nguyen I met with her associate professor in the same program working under her Dr. Brandon Zimmerman. He explained that he was working in a clinic with a renowned optics doctor to identify traces of glaucoma in the eye of the patients that would come to the clinic for a screening. Dr. Zimmerman gets digital imaging of the eye, scans and segments parts of the eye such as the choroid, ALC, PLC, PLNT, retina, and sclera. However, even on his fastest day it takes about an hour to segment all parts of the eye he needs. This manual segmentation is extremely tedious, slow, and difficult. We were looking for a way to make the process either faster or more efficient and we found a solution with the use of Machine and Deep Learning. Machine Learning is the study of computer algorithms that improve through experience and use of data. Deep learning is a subset of machine learning concerned with algorithms inspired by a neural network to learn the data fed to it. Our goal was to use deep learning to automate this process of segmenting these optical images by creating a code to identify and segment several parts of an optical image. Throughout the summer Dr. Zimmerman and I had to teach ourselves about Machine and Deep Learning through various articles, a Coursera course and a student class from Stanford. We also learned the language of the code used for Deep learning, the parameters of forming the code such as optimizations and loss, weights and structure of codes and we encountered and ran several example codes that would identify parts of an image.

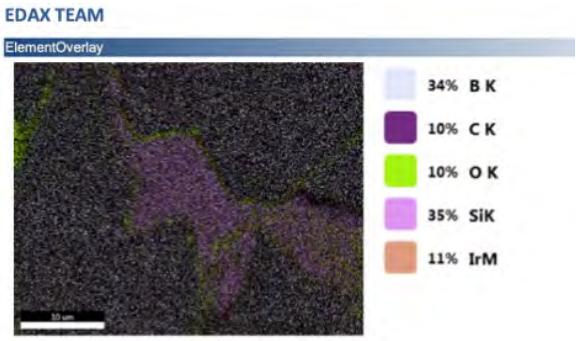
Deidre Grogan

Morgan State University, Baltimore, Maryland
Faculty Host: Dr. Chris Marvel
Department of Materials Science and Engineering
Lehigh University

Project Title: Microanalysis of Si-doped Boron Carbide

This summer I worked on how to use a Scanning Electron Microscope, SEM, to image Si-doped boron carbide. Boron carbide is a super-hard material. Its hardness can be improved by

incorporating silicon into its stoichiometry. After taking images of different percentages of Si-doped boron carbide I was able to analysis it further using energy dispersive x-ray spectroscopy or EDS. EDS is an analytical technique that is used to study chemical characteristics of a sample. Given the elemental breakdown of an image, how much silicon was integrated into the boron carbide could be determined.



HEMI/MICA Extreme Arts Summer Projects/Internships

Extreme Arts is a joint program between HEMI at Johns Hopkins University and the Maryland Institute College of Art (MICA). The program brings faculty and students from both institutions together to explore unique perspectives on extreme events. The program aims to encourage collaboration among artists and researchers to examine data, interpret outcomes, and translate results from extreme events in new ways. It is our hope that this dialog will create a stronger community through a shared sense of curiosity and exploration.

The Extreme Arts summer projects/internships provides an opportunity for MICA students to spend a summer within HEMI. Students receive a stipend during the internship, which is co-advised by MICA and HEMI faculty members.

Program Goals

- To provide an opportunity for meaningful engagement among engineers, scientists, artists and designers that sparks a creative dialog and leads to new outcomes;
- To explore systems of communication that translate ideas and provide platforms for engineers, scientists, artists and designers to discuss concepts and develop a common understanding;
- To create programming between JHU researchers and MICA faculty/students that examines new approaches to HEMI-related materials research and data visualization; and
- To design a framework that serves as a model for sustained, long-term partnership between JHU and MICA.

Funding Sponsors

The Whiting School of Engineering at JHU, and MICA

Website Information

https://hemi.jhu.edu/academic-programs/hemimica-extreme-arts-program/hemi-micasummerinternship/

Sarah Black-Sadler

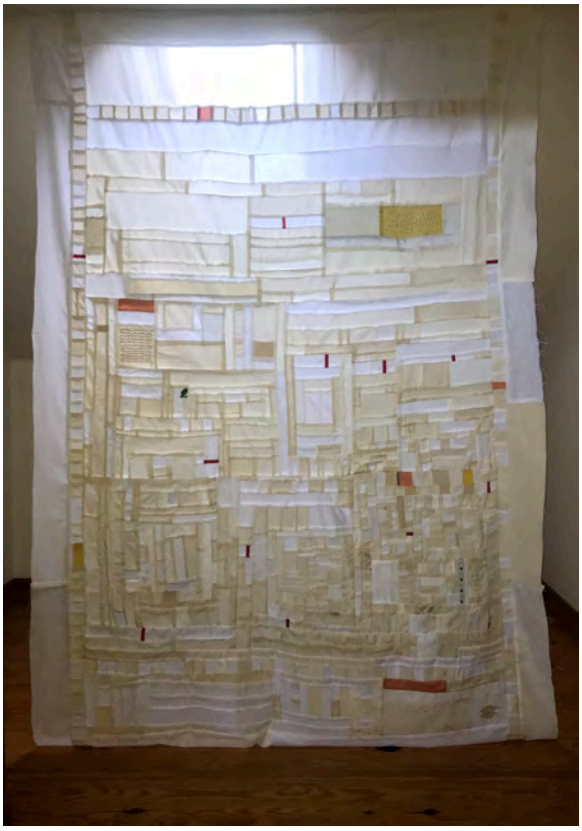
Focus Area: Interdisciplinary Art
MICA Advisor: Liz Ensz, Fiber
HEMI Advisor: Prof. Paulette Clancy
Department of Chemical and Biomedical Engineering
Johns Hopkins University

Project Title: The Third

For this project, I will use biochemical data models, microscopic images, and research to metaphorically visualize the psychotherapeutic theory of Intersubjectivity. Essentially, this concept, written about by Dr. Jessica Benjamin, posits when two or more people come together in a mutual act of recognition they create a separate entity. They make a new third thing that

is their relationship, or a "transformational space of thirdness" in which radical healing can take place.

Scientific images of matter undergoing physical or chemical transformations (emulsion, combustion, decomposition, etc.) will inspire a series of three to five large scale quilted assemblages. I choose to explore these concepts through quilting as it is by nature a generative practice. Though often created from tiny scraps, quilts simultaneously acknowledge the unique histories of individual parts while containing them within a new whole. By adopting models of cellular transformation, each assemblage will poetically create its own third space in which alternative modes of relating may be considered.



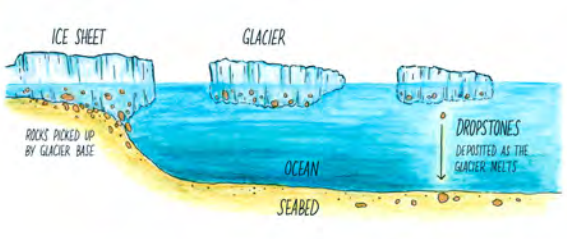
Yifan Luo

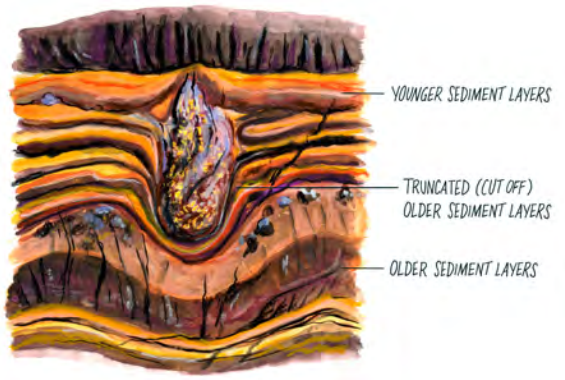
Focus Area: Illustration
MICA Advisor: Whitney Sherman, Illustration
HEMI Advisor: Prof. Emmy Smith
Department of Earth and Planetary Sciences
Johns Hopkins University

Project Title: Snowball Earth: A Tale Told by Ancient Rocks

Geological records suggest that our planet goes through ice ages, or extended periods of cold and glaciation, once every 100,000 years. But scientists posit that beginning about 720 million years ago, the earth became completely encased in ice—at least twice—turning the planet into a giant snowball and threatening all life on it.

A once-controversial theory, Snowball Earth has many implications on the co-evolution of life and is an extreme product of Earth's long-term climate cycle. I worked with Dr. Emmy Smith in the Department of Earth and Planetary Sciences to create an informational illustrated booklet providing a brief introduction to this global phenomenon and some of the people who are working to further uncover its mysteries. I hope it sparks interest amongst the general public and encourages collaborative geological field research like that conducted by Dr. Smith and her colleagues, which can piece together the puzzle of what the world might have once looked like.





DR. EMMY SMITH
ASSISTANT PROFESSOR,
DEPT. EARTH AND PLANETARY SCIENCES
JOHNS HOPKINS UNIVERSITY

MSEE URA Undergraduate Research Awards

The Materials Science in Extreme Environments University Research Alliance (MSEE URA) provides opportunities for undergraduate students to participate in research through these awards. Students work under the mentorship of an MSEE URA principal investigator within the technical areas of chemical and biological agent defeat, and nuclear blast. These are conducted during the semester and the summer, and the students earn a stipend. Through this program, undergraduates develop research skills and gain professional experience to prepare them for the next steps in their career development.

Internship Goals

- To provide a hands-on research experience at an MSEE URA institution.
- Develop communications skills by presenting research project results.
- Motivate students to pursue a graduate degree in a STEM related field.
- Develop the future workforce who will seek employment in DoD/National laboratories, academia, and industry.

Funding Sponsor

Defense Threat Reduction Agency

Website Information on the MSEE URA

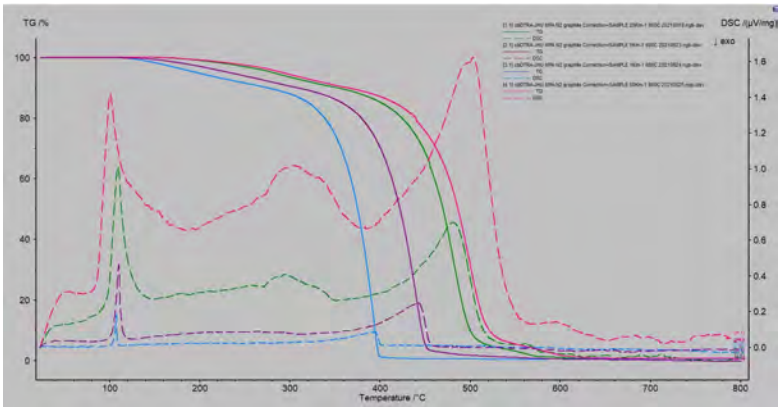
https://hemi.jhu.edu/mseeura

Catherine Bodinger

Western Washington University, Bellingham, Washington
Mentor: Ms. Natalie Gese
Faculty Host: Prof. Hergen Eilers
Institute of Shock Physics
Washington State University

Project Title: Decomposition of Methylphosphonic Acid (MPA) Under Slow Heating Conditions

This research project aimed to analyze the decomposition chemistry of methylphosphonic acid (MPA) in inert gas atmospheres, such as nitrogen, and oxygen rich atmospheres, such as dry air. An attenuated total reflection (ATR) technique was used with a Fourier-transform infrared (FTIR) spectrometer to collect spectra of solid MPA at room temperature. A platinum coil Pyroprobe was used with the same spectrometer and spectra measurements were made at set temperatures for both rapid kinetics (250°C, 375°C, 425°C, 600°C, and 800°C) and non-kinetics (400°C, 600°C, 800°C, and 1000°C)



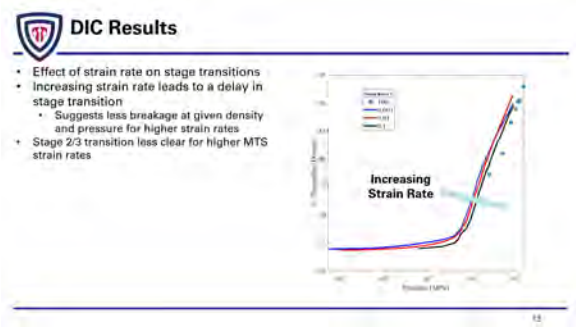
runs, all after the application of various heating rates (10°C/sec., 100°C/sec., 1000°C/sec.). A simultaneous thermal analysis (STA) instrument was used with graphite crucibles to record differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) measurements with heating rates of 1K/min., 5K/min., 20K/min., and 50K/min., in an atmosphere of nitrogen.

Maximilian Garcia

Johns Hopkins University, Baltimore, Maryland
Faculty Host: Prof. Ryan Hurley
Department of Mechanical Engineering
Johns Hopkins University

Project Title: Strain Rate Effect on Granular Mechanics

The main research goals coming into the summer were to study the effect strain rate and saturation had on experimental compaction of sand particles. Although the latter was not achieved during the summer period, the former was studied in great extent. An MTS machine was used for quasi-static loading while a Instron Drop Tower was used for dynamic loading. Using a high speed camera, a load cell, and a strain gauge, sufficient data was collected and able to analyzed for comparison between tests. Using MATLAB, I was able to visualize many important features of the sample under loading such as its density vs pressure and stress vs strain. We were able to determine at which pressures a sample would experience different stages of sand compaction in which the sample exhibits different granular mechanics. When tests at different strain rates were compared, it is evident that there is a delay in stage transition with increasing strain rates. This suggests that there is less breakage at a given density and pressure for higher strain rates. We were also able to quantify breakage within each stage using a Morphology particle scanner. The effects of strain rate on breakage are still to be determined.



Lauren Gotshall

Gonzaga University, Spokane, Washington
Faculty Host: Prof. Hergen Eilers
Institute of Shock Physics
Washington State University

Project Title: Decomposition of Diisopropyl Methylphosphonate Under Slow Heating Conditions

Although there has been initial research regarding the decomposition pathways and products of diisopropyl methylphosphonate (DIMP) under fast heating conditions, there is a lack of basic data for slower heating conditions. To get more information surrounding this subject, a variety of techniques were used to analyze diisopropyl methylphosphonate as it is

heated slowly, from about 1 K/min to 50 K/min. To get this information, the techniques of thermogravimetric analysis (TGA) in parallel with differential scanning calorimetry as well as Fourier Transform Infrared Spectroscopy (FTIR) using a temperature controlled demountable liquid cell were used. A small amount of data was also gathered using the Pyroprobe within the FTIR, but this did not yield many results. The TGA data was used to determine the onset, ending, and peak rate of evaporation of DIMP. Additionally, activation energy was calculated as a function of conversion for the evaporation of DIMP. The FTIR data gathered from the liquid cell was used to analyze relationships between peak location and temperature. This was done using subsequent spectra of the same sample as it is being heated to compare peak locations. A few peaks were found to have linear relationships between wavenumber and temperature, which could be used in future processes to determine the temperature of a sample. Overall, this project determined that DIMP does not undergo decomposition in the liquid phase when being heated slowly.

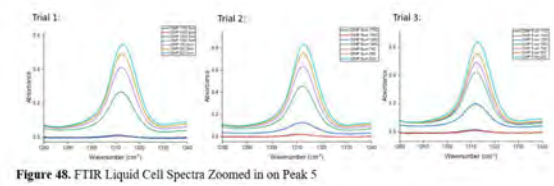


Figure 48. FTIR Liquid Cell Spectra Zoomed in on Peak 5

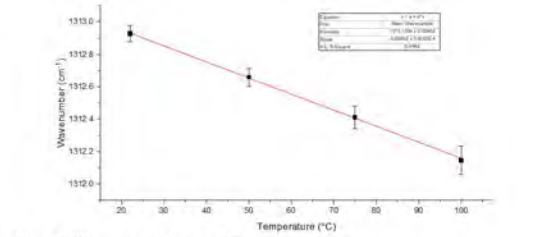


Figure 49. Wavenumber as a Function of Temperature for Peak 5

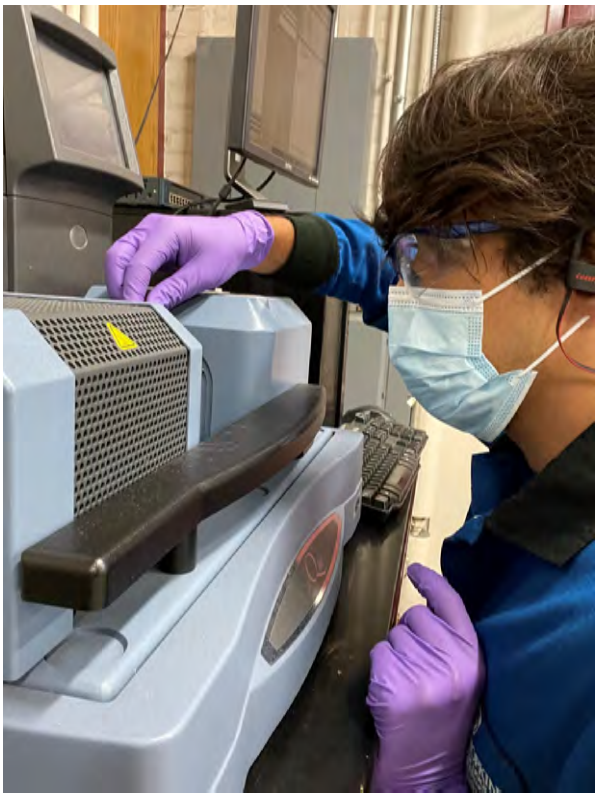
Omar Khan

Johns Hopkins University, Baltimore, Maryland
Faculty Host: Prof. Tim Weihs
Department of Materials Science and Engineering
Johns Hopkins University

Project Title: Exploration of Aluminum Binary Composites for Ignition

Chemical weapons have been used throughout history to kill countless innocents and inflict great harm on the environments. As such, there has been increased interest in the exploration and design of material systems that can be used to degrade chemical toxins and to mitigate the threat of chemical warfare agents. Past work has demonstrated that by creating bi-metallic composite powders such as Al-Zr, their ignition and combustion rates can be independently tuned to favor biological agent defeat with Al-Zr composites effectively defeating harmful biological agents such as Anthrax. In this study, low temperature reaction mechanisms and tuning the microstructure of bi-metallic composites containing Al were explored in an effort to determine potential bi-metallic chemistries and their feasibility to be utilized as reactive feedstock for generating high temperature environments and oxides for chemical agent defeat. Nine (9) varying chemistries, each under three (3) different milling conditions (0,1 and 3 vol% acetonitrile), giving a total of twenty-seven (27) samples were prepared by high energy ball milling. Commercial Al, Ti, Hf, and Zr powders with atomic ratios of 3Al:X, Al:X, and Al:3X where X is Ti, Hf, or Zr were prepared in a shaker mill in an inert environment for 1 hour with a total of 10 mL of process control agents: hexane and acetonitrile. The samples were recovered and sieved below 75 microns in diameter. Thermogravimetric experiments were performed on the samples in an inert argon environment up to 1000C. The density of the powders was determined using a helium pycnometer and particle size distribution

analyses was completed by low-angle laser scattering. Preliminary data showed that introducing acetonitrile as a process control agent lowers the density, reduces particle size, and lowers ignition temperatures across all chemistries. We are continuing to conduct research on these samples through SEM, XRD, and annealing studies, along with more wire ignition and thermogravimetric experiments in different environments such as Argon + Nitrogen and Argon + Oxygen. These tests will be used to characterize all the chemistries, and will allow us to determine the most effective bi-metallic chemistries for defeating chemical weapons.



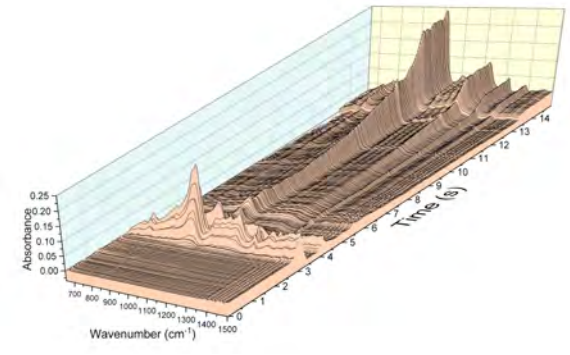
Brynn Scheckenbach

Gonzaga University, Spokane, Washington
Mentor: Ms. Natalie Gese
Faculty Host: Prof. Hergen Eilers
Institute of Shock Physics
Washington State University

Project Title: Decomposition of Isopropyl Methylphosphonate (IMP) under slow heating conditions

Isopropyl Methylphosphonate (IMP) is a simulant molecule for (RS)-propan-2-yl methylphosphonofloridate or Sarin, a dangerous chemical warfare agent. IMP was used for this project because of its similar structure to Sarin and less toxic nature. In order to gain knowledge and eventually simulate the decomposition of Sarin, all of the possible pathways of thermal decomposition must be studied. IMP was analyzed under slow heating conditions in both inert gas (nitrogen gas) and oxygen rich (dry air) atmospheres. A Simultaneous Thermal Analysis instrument was used for Thermogravimetric analysis (TGA) and Differential Scanning Calorimetry (DSC). Heating rates of 1, 5, 20, and 50 K/min in alumina crucibles were used for both a dry air and a nitrogen series, graphite crucibles were used for another series in nitrogen. The graphite crucibles were used due to phosphoric acid, a decomposition product of the IMP, reacting with the alumina and leaving behind solid residue. Samples of the residue were analyzed with an Electron Scanning Microscope to view the crystalline structure and perform elemental analysis. 1H NMR data was obtained for IMP in a CDCl3 solvent in order to verify its purity, no significant impurities were

found. A Liquid Cell-Fourier Transform Infrared spectrometer (FTIR) was used to obtain IMP spectra at multiple temperatures up to 175°C. Decomposition of the IMP was not significant before 200°C, so only slight changes in the spectra progression were observed. Initial platinum coil Pyroprobe FTIR measurements were taken at heating rates of 10°C/s to 200, 400 and 600°C to obtain gas phase FTIR spectra. Kinetic FTIR measurements were run with a platinum ribbon Pyroprobe at heating rates of 10, 100, and 1000°C/s. Kinetic measurements analyze IMP in the gas phase and produce 3D figures that show wavenumber as a function of temperature and time. The data obtained through these experiments was used to verify the predicted thermal decomposition pathways for IMP and hopefully provide helpful information to the study of Sarin for the Defense Threat Reduction Agency (DTRA).



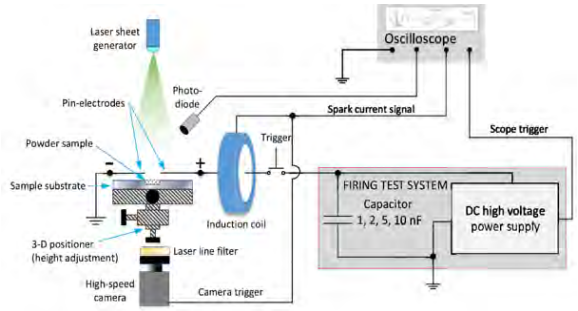
Rostyslav Shkromiuk

New Jersey Institute of Technology, Newark, New Jersey
Mentor: Mr. Shomik Mukhopadhyay
Faculty Host: Prof. Edward Dreizin
Department of Chemical & Materials Engineering
New Jersey Institute of Technology

Project Title: Effect of morphology of reactive materials on their interaction with shock and plasma generated from electrostatic discharge

Explosives can be used to remotely target chemical warfare agent (CWA) stockpiles stored in regions with limited on-ground access. Agents stored in inaccessible facilities need to be destroyed rapidly without dispersing the compounds to surrounding areas. High temperatures generated inside a fireball created from explosives can rapidly decompose CWA; however, part of the stockpile may be outside of the fireball, which could lead to its spread and contamination of surroundings.. Reactive materials (RMs), often added to explosives and fuel mixtures to enhance combustion characteristics, could be exploited for this application. The subsequent experimental efforts focused on preparing and characterizing selected RM powders. Both spherical and irregularly shaped composite RM powders were prepared. They were exposed to shock and plasma produced by electrostatic discharge (ESD). ESD initiation served in these experiments to obtain a small-scale, laboratory analog of stimuli generated by an explosive. Experiments focused on nanocomposite titanium boron powders prepared using arrested reactive milling. The effect of powder morphology on its interaction with the shock and plasma generated by the ESD was studied. The combustion process was recorded using a high-speed video camera and the images were analyzed. The spherical and irregular powders were compared to each other using several metrics, such as lifting efficiency, emitted light intensity, and particle velocity. The effects of the ESD voltage and distance between the substrate holding the powder and ESD electrodes on the above metrics were characterized. It is found that spherical powders were lifted and removed from surface more readily than irregular powders. Spherical powders also responded more strongly to

changes in the ESD voltage and distance to the substrate. At higher ESD voltages, some particles were lifted off with the plasma plume and moved with the speed approaching Mach 3. Other particles were lifted later and moved slower forming, in some cases, a combustion cloud. Processing of images of such clouds informed an estimate of the respective particle burn time. The burn times were in the order of 100 μs, much shorter than observed in reported earlier single particle combustion experiments.

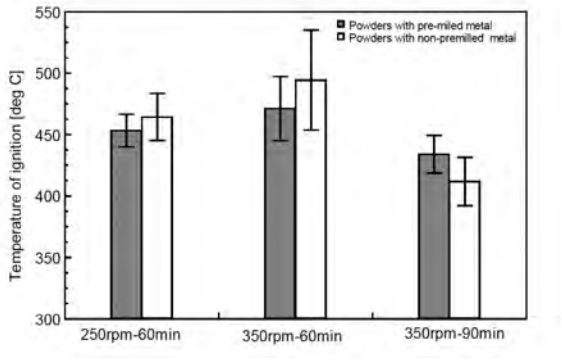


Agata Skura

New Jersey Institute of Technology, Newark, New Jersey
Faculty Host: Prof. Edward Dreizin
Department of Chemical & Materials Engineering
New Jersey Institute of Technology

Project Title: The spherical powders from mixed oxidizers and aluminum

The research objectives were to synthesize spherical reactive powders from mixed oxidizers (i.e. potassium nitrate, molybdenum oxide) and metal fuels (i.e. aluminum, magnesium). The spherical shapes as well as changes in a surface morphology were achieved using mechanical milling. Two immiscible liquids (i.e. hexane, acetonitrile) were used in order to create a droplet phase. Upon milling, the fragments of the powders became trapped into the droplets, where they were eventually compacted into composite spheres. The morphology of the obtained spherical powders was described and thermal characterization (i.e. DSC, TG, ignition temperature) was reported. Furthermore, the analog reactive powders were prepared by using the same mechanical milling parameters. However, in this case, two immiscible liquids were not used while mechanical milling but powders were prepared either with hexane or acetonitrile as process control agents. In the future, the powders prepared this way will be subjected to the same experiments as spherical powders in order to establish the effect of the morphology in the ignition process.



On behalf the Hopkins Extreme Materials Institute at Johns Hopkins University, we would like to thank the support from the sponsors and organizations that made these student opportunities possible: