



**HEMI**

HOPKINS EXTREME  
MATERIALS INSTITUTE

# **Student Research Internships and Apprenticeships**

**Summer 2019**



**JOHNS HOPKINS**  
UNIVERSITY

## From the HEMI Director



Each summer, the Hopkins Extreme Materials Institute (HEMI) at Johns Hopkins University offers a number of opportunities for high school, undergraduate, and graduate students to conduct research both within HEMI as well as at our partner institutions. These internships are very competitive, and I am impressed at the quality of applicants. These exciting internships provide the students experience in state-of-the-art research techniques, laboratory facilities and individual mentorship firsthand. Students gain valuable insights into university-led research, which will hopefully inspire them to pursue a future career in a STEM-related field.

This year we had a record 20 externally funded internships! I am extremely proud of the students and the research activities they conducted during this summer. I am also grateful to the faculty hosts, mentors, and administrative personnel who ensured the students had the resources and guidance for a rich and rewarding experience. HEMI would like to acknowledge the following organizations who made these opportunities possible: the Army Educational Outreach Program, the CDC Army Research Office, the CDC Army Research Laboratory, the National Endowment for the Arts, 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 hope this encourages students to apply in 2020!

Sincerely,

A handwritten signature in black ink, appearing to read 'K.T. Ramesh'.

KT Ramesh  
Director

Alonzo G. Decker Chair Jr. Professor of Science and Engineering

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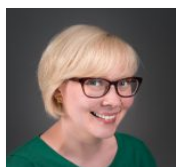
## HEMI Administration Supporting these Programs



Lori Graham-Brady  
Associate Director



Victor Nakano  
Executive Prog. Dir.



Bess Bieluczyk  
Sr. Admin. Coord.



Jess Ader  
Comm. Specialist

# Research and Engineering Apprenticeship Program (REAP)

REAP is a summer STEM program that places talented high school students, from groups historically under-represented and underserved in STEM, in research apprenticeships at JHU. REAP apprentices work under the direct supervision of a mentor on a hands-on research project. REAP apprentices are exposed to the real world of research, gain valuable mentorship, and learn about education and career opportunities in STEM. REAP apprenticeships are 5-8 weeks in length (minimum of 200 hours) and apprentices receive a stipend.

## Program Goals

- To provide high-school students from groups historically under-represented and underserved in STEM, including alumni of the AEOP's UNITE program, with an authentic science and engineering research experience;
- To introduce students to the Army's interest in science and engineering research and the associated opportunities offered through the AEOP;
- To provide participants with mentorship from a scientist or engineer for professional and academic development purposes; and
- To develop participants' skills to prepare them for competitive entry into science and engineering undergraduate programs.

## Funding Sponsor

Army Educational Outreach Program, administered by the Rochester Institute of Technology

## Website Information

<https://www.usaeop.com/program/reap/>



2019 REAP Students with U.S. Army Guests



## Nia Lowery

From the Heart Christian School, Suitland, Maryland

Mentor: Henry Herbol

Faculty Host: Professor Paulette Clancy

Department of Chemical and Biomedical Engineering

Johns Hopkins University

Project Title: Investigating the Nudged Elastic Band (NEB) Method with a Reaction Mechanisms Database

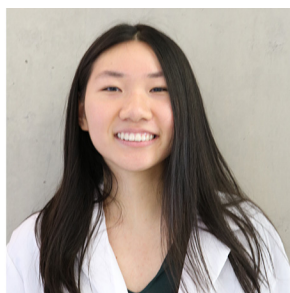
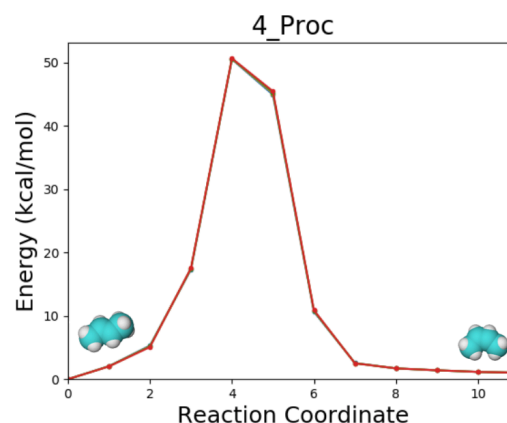
The Purpose of this project was to investigate the Nudged Elastic Band (NEB) Method in order to create a reaction mechanism database. The NEB method works by applying spring forces in order to balance the potential force and energy (of a predicted reaction mechanism) which helps find minimal energy

pathways (MEP). The database will be able to help scientists better understand how NEB works so that it can be used in future research. This project is important because understanding reaction mechanisms help improve industrial chemical processes while lowering experimental costs.

Research shows that NEB is an effective method for finding MEP and saddle points between known reactants and products. MEP is useful because reactions need a minimal amount of energy for the reaction to occur. The lower the activation energy, the faster the reaction takes place which helps to better scale processes for societal demands. Knowing the MEP allows us to study materials, such as catalysts. Catalysts lower the activation energy in chemical reactions and help to speed up the reaction process by increasing the rate of the reaction. Using NEB, we can discover novel catalysts to study.

The process used to find the MEP using NEB was to first generate the molecular reactants and products of a given reaction. Then, to generate the reaction mechanisms by linearly interpolation and visually assess them. Finally, NEB calculations were run using quantum mechanics (Density Functional Theory). My work was to study the isomerization of 34 different molecules to generate a database for future studies.

Results showed that a good reaction pathway must be given for NEB to get the lowest MEP. When given a good reaction mechanism pathway, NEB was able to get a transition state of 50 kcal/mol. When given a bad pathway prediction for the same reaction, NEB processed a transition state of 140 kcal/mol.



## Michelle Shen

Thomas S. Wooten High School, Rockville, Maryland

Mentor: Srivathsan Kalyan

Faculty Host: Professor Soojung Claire Hur

Department of Mechanical Engineering

Johns Hopkins University

Project Title: Centrifuge-less Layer-by-Layer Deposition on Particle

Recently, there has been an increased interest in the creation of layer-by-layer (LbL) drug delivery systems that would be both fast-acting and long-lasting. Such systems consist of a naturally charged microparticle alternatively layered with solutions of oppositely charged drug and polymer that would allow for mediated extended-release effects. However, current LbL deposition

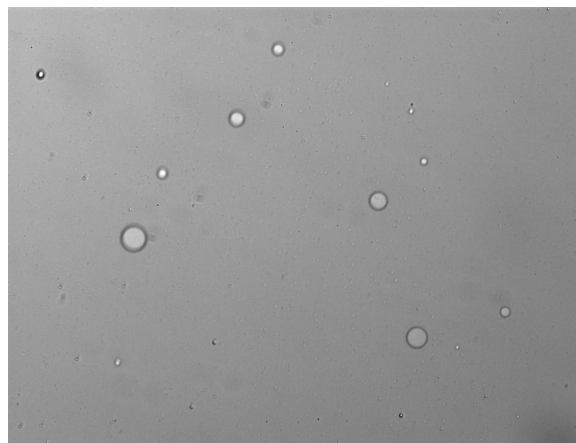
methods are time-consuming and inefficient, requiring multiple centrifugation steps.

We describe the use of microfluidic devices with vortices capable of trapping microparticles for automated, centrifuge-less LbL deposition. The integrated procedure allows for higher throughput and a lesser loss of microparticles. Sodium alginate was chosen as the central microparticle for its biodegradable and charge properties. These

particles were created with an emulsification/internal gelation method involving the use of  $\text{CaCl}_2$  as both a cross-linking and gelation agent. To trap these central microparticles, we used a vortex trap, further described in the project, to effectively trap microparticles that were 10-20  $\mu\text{m}$  in diameter.

Our results reveal that the use of sodium alginate microparticles with a  $\text{CaCl}_2$  washing and storing solution was a good candidate for this experiment. We also determined that a Reynolds number of 150 was sufficient at

trapping the sodium alginate microparticles to perform automated LBL process.



### Angela Torrejon

Connelly School of the Holy Child, Potomac, Maryland

Mentor: Lucas Pressley

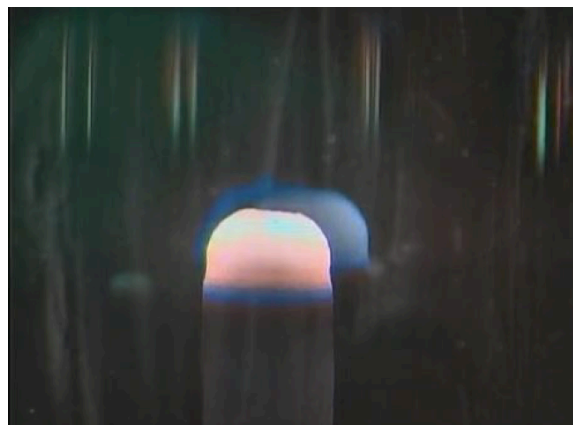
Faculty Host: Dr. William Adam Phelan  
Department of Chemistry  
Johns Hopkins University

Project Title: Synthesis, Characterization, and Crystal Growth of Defect Pyrochlores  $\text{Mg}_2\text{LnTaO}_6$

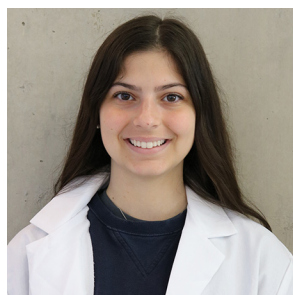
There has been an increasing interest in the preparation of new functional ceramic oxides whose basic properties can be altered for specific applications: one such oxide class is  $\text{Mg}_2\text{LnTaO}_6$ , which has been studied for its dielectric properties and flexible pyrochlore-type structure. For example, Ln can be many of the elements from the lanthanides family. However, the characterization of the defects in these structures has been limited in Powder X-Ray Diffraction (XRD): growth of single crystals will allow for a better understanding of the defect structures, and subsequently the physical properties, for this class of materials.  $\text{Mg}_2\text{LnTaO}_6$  was chosen for initial experiments. The initial reactants were dried out to eliminate any water, and grounded together to react at 1450 C. To check that the reaction had gone to completion, Powder XRD was performed to analyze the structure of the material. Rods of

the  $\text{Mg}_2\text{LnTaO}_6$  were pressed to melt in the Laser Diode Floating Zone. A melt test was done on the rod with the LDFZ to see if the material melted, and if it could retain the same chemical structure at a high temperature. Powder XRD of the melt confirmed that the structure did not change, showing the viability for the floating zone growth process to produce single crystals for further characterization. Within the lanthanide series, powders of all analogues have been synthesized through Gd. Since the ion size becomes smaller, the  $\text{Mg}_2\text{LnTaO}_6$  structure is less likely to accommodate the large difference in size. The  $\text{Mg}_2\text{LnTaO}_6$  placed in the LDFZ did melt while keeping the same structure and composition as the starting material. The next step would be attempting a floating zone growth and then characterizing the magnetic and structural properties of the obtained crystal. Further

single crystal growths should be done to better understand the magnetic properties and crystal structures for the rest of the lanthanides series.



Mg<sub>2</sub>LnTaO<sub>6</sub> melting



### Buena Zajmi

Quince Orchard High School, Gaithersburg, Maryland

Mentor: Arlene Chiu

Faculty Host: Professor Susanna Thon  
Department of Electrical and Computer Engineering  
Johns Hopkins University

Project Title: Enhancing Hole Mobility of Lead Sulfide Colloidal Quantum Dot Solar Cells Through Sulfur Doping

Colloidal quantum dots (CQDs) are materials which many researchers are exploring for use in solar cell devices due to their low cost and solution processability. Lead Sulfide (PbS) quantum dots are an ideal absorbing material for solar cells in combination with electron transport layers composed of wide bandgap semiconductors including TiO<sub>2</sub> and ZnO. However, the performance of these solar cells is significantly hindered by the low hole mobility of the ethanedithiol (EDT) PbS CQD hole transport layer (HTL). Thus, this project aims to improve hole mobility through doping the EDT-PbS layer with more sulfur.

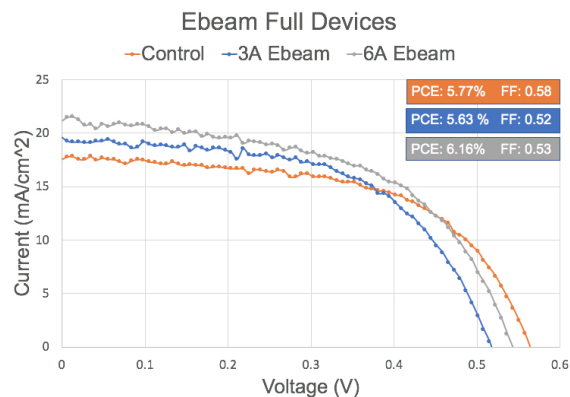
When p-type and n-type semiconductors are placed in contact with each other, the rearrangement of the charge distribution occurs and the maintenance of an electric field. In order to avoid recombination (when excited electrons and holes come into

contact with each other and relax to their respective band edges), the HTL is essential to blocking electrons and avoiding leaked currents. The HTL also facilitates the flow of holes and has higher charge transporting properties, allowing the charges to move quickly away from the active layer and thus reducing chances of recombination. So through doping this layer of the solar cell with sulfur, we hope to improve the efficiency of this material as a semiconductor.

We studied two methods of sulfur doping: chemical treatment and electron beam evaporation. In the chemical treatment, Na<sub>2</sub>S is dissolved in methanol at various concentrations (0.1 mM and 0.01 mM), deposited on the EDT layer by soaking for 30 s and spinning for 10 s at 1250 RPM before washing 4 times. In E-beam evaporation, an

electron beam heats the desired material to a point where it sublimates and coats onto the EDT layer of the substrate at varying thicknesses (3 Å or 6 Å). Once we've fabricated a batch of devices using both these methods, we then test their performance using a solar simulator as a broadband light source with a power density of 100 mW/cm<sup>2</sup>. The simulator will test current density and voltage, which enables us to determine figures of merit which tells us about device performance.

After testing many devices, we found that short-circuit current was enhanced, power conversion efficiency and fill factor was maintained, and Voc decreased. SILAR treatment had little impact on device performance, and e-beam evaporation showed improvements in efficiency. Overall, Sulfur doping is a promising route to improving device performance.



J/V Curve representing E-beam evaporation device performance

# Undergraduate Research and Apprenticeship Program (URAP)

URAP provides undergraduate students with an authentic science and engineering research experience alongside university researchers sponsored by the Army Research Office. Through this commuter program, students will develop skills in Army critical science and engineering research areas in a university lab setting to prepare them for the next steps of their educational and professional career.

The US Army established the Center for Materials in Extreme Dynamic Environments (CMEDE) to design, develop and test improved soldier protection materials. JHU leads the CMEDE collaborative research alliance, which includes university and research institutions across the United States, the United Kingdom, and Germany. Together these partners, in close collaboration with the Army Research Laboratory, serve a vital role as a materials-by-design capability for the US Army. URAP opportunities within CMEDE are available at universities performing research on this program.

Students receive an educational stipend and contribute to the Army's research in the laboratory while learning research methods, using advanced research equipment and becoming a part of an active research group. This authentic experience provides exposure to science and engineering research careers.

## Program Goals

- Provide authentic science and engineering research experience to undergraduate students pursuing science and engineering majors;
- Introduce students to the Army's interest and investment in science and engineering research and the associated educational opportunities available through the AEOP and DoD;
- Provide participants with experience in developing and presenting scientific research;
- Provide participants with experience to develop an independent research program in preparation for research fellowships, graduate school, and careers in science and engineering research;
- Benefit from the expertise of a scientist or engineer as a mentor for professional and academic development purposes; and
- Develop students' skills and background to prepare them for professional and academic development purposes.

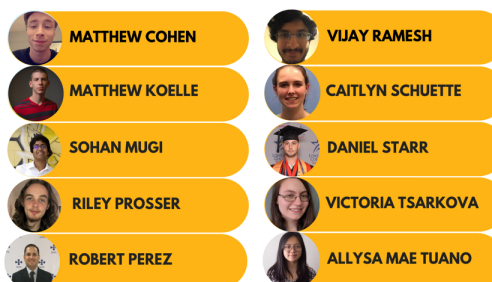
## Funding Sponsor

Army Research Office through the Army Educational Outreach Program and the Center for Materials in Extreme Dynamic Environments

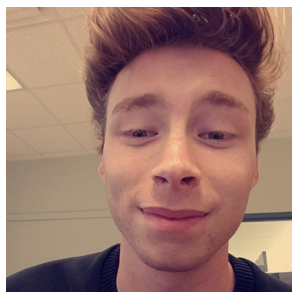
## Website Information

URAP - <https://www.usaeop.com/program/undergraduate-research-apprenticeship-program-urap/>

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



2019 URAP Participants



## Matthew Cohen

University of Delaware, Newark, Delaware

Mentor: Dr. Sanjib Chowdhury

Faculty Host: Professor Jack Gillespie

Department of Mechanical Engineering and

Center for Composite Materials

University of Delaware

Project Title: Developing Accelerated ReaxFF Framework for Epoxy Curing Reaction within LAMMPS

Generally, epoxide-amine curing reactions require minutes to hours to fully complete, which is infeasible to achieve with all-atom conventional molecular dynamics (MD) simulations. To overcome this issue, we are developing an accelerated reactive MD framework within the open source simulation tool LAMMPS using LAMMPS-Python interfacing. This method of reaction acceleration is superior to other cross-linking methods because it better captures the variability of bond formation and transformation states considering reaction energy barrier.

Our developed LAMMPS-Python interface tracks the position of each epoxide and amine group during the MD simulation. It identifies the potential Epoxide-Amine pairs based on the inter-atomic O-H, N-H, C-N and C-O distance and applies restraint energy to make the curing reaction happen as shown in Fig.1 below. Restraint energy is defined by  $E_{rest} = F_1(1 - e^{-F_2(R_{ij}-R_{12})^2})$ , where  $F_1$  and  $F_2$  are force constants and  $R_{ij}$  and  $R_{12}$  are instantaneous and equilibrium inter-atomic distance between the corresponding atoms. It is important to get these constants value correct to avoid unwanted reactions during the simulations.

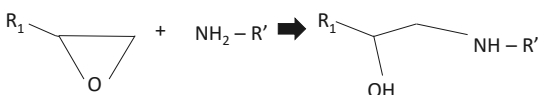


Fig. 1 Epoxide-Amine curing reaction

Using this framework, we have performed benchmark simulations considering small models (less than 200 atoms) and it works perfectly well capturing the curing reaction (Fig.2). We plan to increase the capability of this framework, so that it can work with systems made up of hundreds of molecules. This framework will reduce computational cost compared to the AMBER based cross-linking algorithm.

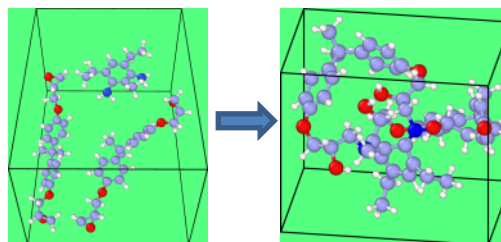


Fig. 2 Epon-Amine model before and after curing

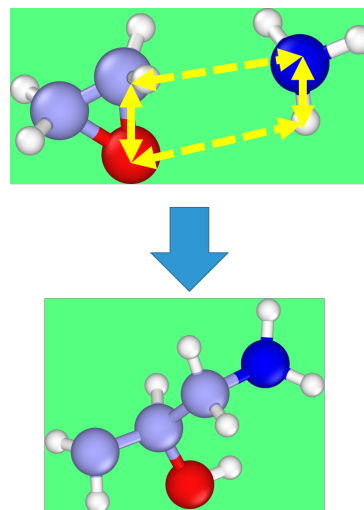


Fig. 3 Ammonia-dETDA-Final Transition



## Matthew Koelle

Rutgers University, Piscataway, New Jersey

Faculty Host & Mentor: Professor Richard Haber

Department of Materials Science & Engineering

Rutgers University

Project Title: Survey on Wetting of Boron Carbide

In this project the wetting of Boron Carbide by oxide compounds was observed. Materials that wet Boron Carbide may be useful for creating intergranular films. These films are commonly utilised in high strength ceramics to increase fracture toughness or wear resistance. Currently Boron Carbide has not exhibited the formation of intergranular films, but similar ceramics, like Silicon Carbide, have. All oxide compositions utilised in this project contained Aluminum Oxide. This oxide was selected as a base because of the solubility of aluminum within Boron Carbide, the high stability of the material even at elevated temperatures, and the ability to dissolve or incorporate other oxides. Pure Alumina was used as a control to compare the effect of various oxide additions. Different oxides were added to the Alumina bulk to observe the effects of eutectic compositions, lower surface energy oxides, and other properties on the wetting of Boron Carbide. Increased wettability of Boron Carbide by the oxide mixtures could help discover mechanisms to create

intergranular films. In addition, multiple compositions of Boron Carbide were used as substrate materials for testing in order to measure the effect this has on wetting behavior. Substrates include B<sub>4</sub>C, Boron rich Boron Carbide, Aluminum doped Boron Carbide, and Silicon doped Boron Carbide.



## Sohan Mugi

Georgia Institute of Technology, Atlanta, Georgia

Mentor: Dr. Svitlana Fialkova

Faculty Host: Professor Jagannathan Sankar

Department of Mechanical Engineering

North Carolina A&T State University

Project Title: Relationship between Rolling Process Parameters of Magnesium-Aluminum Alloys and Their Corresponding Vickers Hardness Levels

Magnesium-Aluminum alloys play an important role in the functionality of various types of structures and machinery. According to an article published in 2015, magnesium, along with its alloys, “have received significant attention in the fields of automobiles and electronics industries due to their low density.” (Guo,Zhang,Yang, Jiang,Pan, 2015) While there are several research studies on magnesium alloys, research on plastically deformed magnesium-aluminum(MgAl) alloys is limited. Particularly, the effect of the rolling processing parameters on hardness levels should be considered for a deeper understanding of a strengthening mechanism of MgAl alloys. For a proper analysis of the alloys, all samples were cut into appropriate sizes, and sorted by different processing parameters (i.e. Aluminum concentration, surface direction, processing speed ratio, etc.). After a total of 32 samples were polished and etched with 5%  $\text{HNO}_3$  concentrate, the surface was carefully indented at different regions (i.e. DRX region, grain boundary and inside the big grains). Using image processing through a microscope and software measurement tool, all indentations were measured to determine the Vickers Hardness of each indent. The study concluded that the DRX Region is the region with the highest hardness levels, with a few exceptions. Additionally, the lower concentration of the two Al concentrations (Al6 and Al9) had the same level of significant difference between the regional-comparisons (i.e. DRX Region vs. Big Grain, Big Grain vs. Grain Boundary). As a result, at

a 95% confidence level, we can further conclude that: a) increasing the concentration of Al from 6 to 9 % increases the hardness by ~ 20%, b) considering the rolling speed parameter, the DSR process shows a significant advantage in increasing hardness of MgAl alloys compared to the conventional rolling process and c) the thickness reduction per pass parameter does not have a significant effect on the hardness of MgAl . These conclusions can be used to provide a better understanding of the effect of rolling process parameters on mechanical properties of MgAl alloys, along with propelling future research on other types of plastically deformed alloys.



## Robert Perez

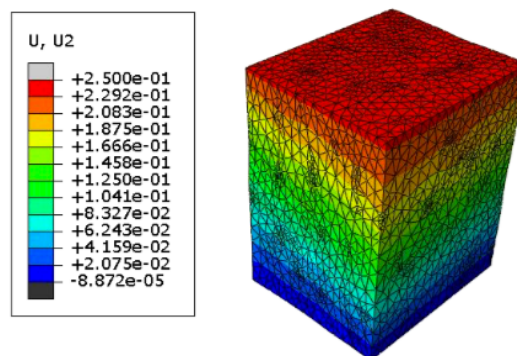
University of Houston, Houston, Texas

Faculty Host & Mentor: Professor Shailendra Joshi  
Department of Mechanical Engineering  
University of Houston

Project Title: Computer Simulations to Investigate the Texture and Intrinsic Plastic Anisotropy of Pure Magnesium

In my URAP internship, I worked with Dr. Shailendra Joshi at the University of Houston (UH). My task was to perform computer simulations to understand the mechanical behavior of magnesium (Mg) with a particular emphasis on quantifying the role of texture and anisotropy. This task was a subset of a bigger project at UH, funded by the US Army Research Laboratory under the Materials for Extreme Dynamic Environment (MEDE) Program with Johns Hopkins University (JHU) as the lead institution. Mg is particularly interesting as a structural material due to several attractive properties – it has a low mass density (nearly 2/3 of aluminum) and is truly bio-compatible. As a result, it has tremendous applications in industries ranging from aerospace, automotive, and biomedical field. In my research, the single crystal plasticity model implemented by Zhang and Joshi (2012) was adopted in performing large-scale polycrystal simulations under uniaxial tensile and compressive loading. I was guided by Dr. Joshi and his two graduate students: Mr. Padmeya Indurkar and Mr. Shahmeer Baweja. The valuable information that is expected to be obtained from the simulations is the macro and micro responses of Mg under different loading directions and with different textures. The computational simulations demand a powerful computing resource,

which was provided to me through the High-Performance Computing Clusters managed by the Core facility for Advanced Computing and Data Science (CACDS) at UH. I performed 60 simulations which included 5 textures, 6 loading directions and 2 loading modes. The 5 textures mimicked typical textural variations of a rolled Mg plate, 6 loading directions included 3 principal-axis and 3 off-axis orientations, and 2 loading modes included tension and compression. Notably, most of the simulations are completed and we anticipate data mining and analysis to be completed within the next two months. The outcome of this work is expected to provide insights into the coupling between texture and plastic anisotropy of Mg.



Displacement variation throughout the Mg specimen



## Riley Prosser

University of Delaware, Newark, Delaware

Mentor: Dr. Sanjib Chowdhury

Faculty Host: Professor Jack Gillespie  
Department of Mechanical Engineering and  
Center for Composite Materials  
University of Delaware

Project Title: Molecular Modeling of Silica-Epoxy Interphase with Monolayer Silane

In this project, molecular dynamics is used to study the interactions between epoxy-amine resin and silica surface in the presence of

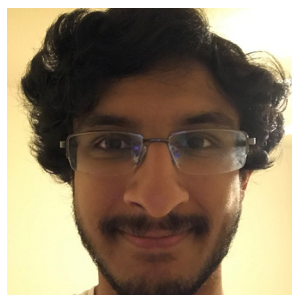
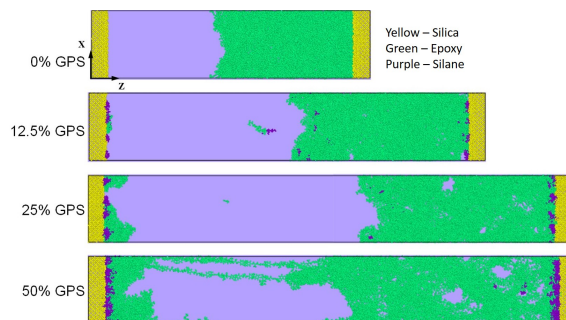
monolayer silane. In order to do so, multiple models involving various densities of silane (glycidoxypopyltrimethoxy silane or GPS) was

used) ranging from 0 to 100% were carefully created and the epoxy-amine resin was added to each model using the correct stoichiometric ratio. After the models were constructed, they were equilibrated using the general AMBER force field and the epoxide-amine curing reaction was simulated using a specialized cross-linking algorithm. Finally, the reactive force field, ReaxFF, was utilized in Mode-I and Mode-II loading simulations in order to predict the stress-strain responses and failure loci within the model's interphases.

Following the simulations, there was plenty of data to be analyzed. Graphs were utilized to determine the effect of silane number density on the stress-strain relationship of the models. Also, MATLAB code was used to analyse the bonding structures that occurred in the model interphases and how the bonding structures varied with the silane number densities. Visualization programs such as Ovito were utilized to better understand and display what was happening

in each simulation and to support the results and conclusions we were drawing.

In the end, simulation results indicated that increasing silane number density led to decreased contact of epoxy and amine molecules with the silica surface, increased covalent bonding interactions in the interphase, increased interphase strength, and transition from adhesive to cohesive damage mode. Moving forward we plan to continue working with more models and silane concentrations in an attempt to find an optimal silane density for the interphases' mechanical properties.



## Vijay Ramesh

University of Houston, Houston, Texas

Faculty Host & Mentor: Professor Shailendra Joshi  
Department of Mechanical Engineering  
University of Houston

Project Title: Behavior of Notched and Smooth Magnesium Alloys at High Strain Rates

Recently, Prof. Joshi and colleagues performed large-scale crystal plasticity simulations for notched bar geometries of polycrystalline alloyed magnesium at low tensile strain rates, on the order of 0.001/s, for different meshes and textures. As an extension of that work, the primary goal of this research internship is to determine the mechanical response of the same notched bars at dynamic strain rates ~1000 1/s. In doing so, the textural and finite

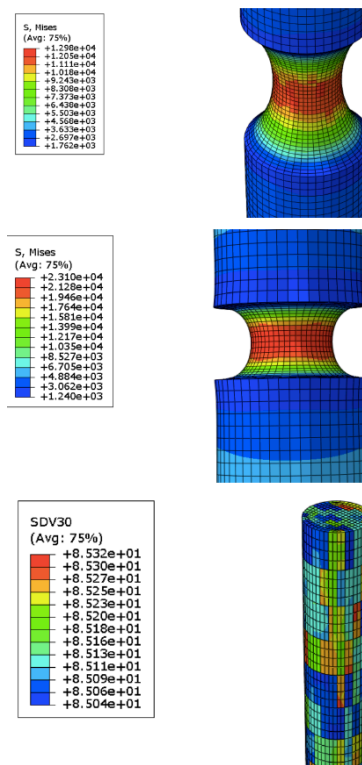
element meshing details are kept fixed as in the prior work to enable cleaner comparison of the results. Although the simulations do not consider damage, the understanding developed from the simulations could be useful in making projections of the manner in which damage may occur in Mg alloys through the evolution of porosity under dynamic conditions.

Notched round bar geometries have the advantage of allowing a reasonable control on a parameter called stress triaxiality, or triaxiality (T) - defined as the ratio of hydrostatic stress and von-Mises equivalent stress. In a smooth bar,  $T \sim 1/3$ , resulting in an acceptable basis to compare the triaxiality of the notched specimens where  $T > 1/3$ . Void growth is mainly affected by the mean stress component of the triaxiality, thus the greater the triaxiality, the easier it will be to induce crack propagation.

The texture of these specimens deals with orientations of the grains. Finite element methods are employed such that particular grains are grouped based on orientation to make up elements allowing for determination of the response of the material grain by grain, thus computing the true response of the material by amalgamating those of each grain.

Investigation using strain rate of 1000 1/s began for one mesh and three different textures for one smooth and two notched geometries. Finite element simulations results were collected for the stress and strain in the notch (and throughout the bar in the smooth specimen) in addition to several

state variables, the details of which will be pursued further in the future. In particular the stress, along with measurements of the notch radius can help us determine the triaxiality of the geometry, thus allowing us to predict failure mechanisms.



## Caitlyn Schuette

Bucknell University, Lewisburg, Pennsylvania

Mentor: Suhas Eswarappa Prameela

Faculty Host: Professor Timothy Weihs

Department of Materials Science and Engineering

Johns Hopkins University

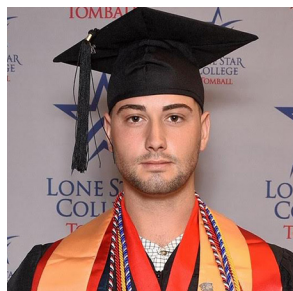
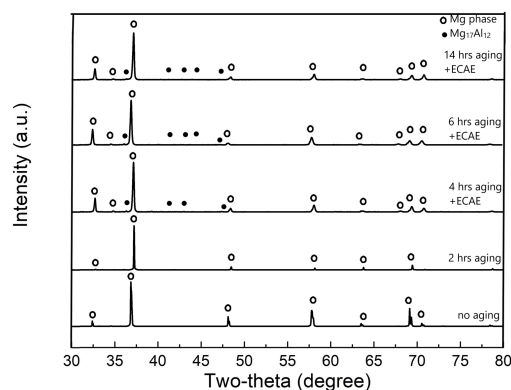
Project Title: X-ray Diffraction Characterization of Mg Alloys: Tracking Influence of Solute Clusters on Dynamic Precipitation of Nanoprecipitates During ECAE

Army protection materials are increasing in complexity to accommodate better battlefield performance. For this reason, the MEDE (Materials in Extreme Dynamic Environments) project has been developing

lightweight Magnesium (Mg) alloys with improved spall and dynamic strength. It is known that large particles within the microstructure often serve as sites for void nucleated failure. Thus, it is critical to design

clean alloys with fine precipitates. A combination of conventional aging (CA) and dynamic aging (via Equal Channel Angular Extrusion- ECAE) were used to generate microstructures with high number density of nanoprecipitates in Mg-9Al (wt%). The idea is to exploit the formation of solute clusters and segregates near dislocations to produce fine precipitates. In our study we performed CA for 0, 2, 4, 6 and 14 hours followed by one pass of ECAE, and one pass of ECAE followed by CA for same times, all at 150oC. Optical microscopy showed the shearing of large grains by ECAE. X-ray diffraction was used to track shift in precipitate and matrix peaks. Further analysis of the shift showed that with increase in solute concentration, lattice parameters (a, b, and c) decreased but the c/a ratio increased. Initial Transmission Electron Microscopy and nanoindentation results show a greater number of precipitates and higher hardness for samples that underwent ECAE first followed by CA. This is

likely because dislocations introduced during ECAE produced more solute segregates which then formed nanoprecipitates during CA. In the other route, it is likely the solute clusters produced during CA were less and contributed very little during ECAE. The microstructures produced by ECAE followed by CA show promise in improving spall and dynamic strength which will be verified via collaboration with another research group at JHU.



## Daniel Starr

Lone Star College, Tomball, Texas

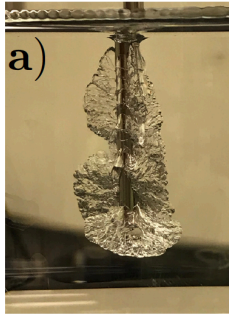
Mentor: Yuan Ji

Faculty Host: Professor Justin Wilkerson  
Department of Mechanical Engineering  
Texas A&M University

Project Title: Experimental Analysis of Quasistatic and Dynamic Void Growth in PMMA-PnBA-PMMA Hydrogel

This research examined cavitation and fracture “wound” patterns inflicted on different concentrations of poly methylmethacrylate-poly n-butylacrylate-poly methylmethacrylate (PMMA-PnBA-PMMA) hydrogel. These wound patterns were inflicted by injecting air into the hydrogel samples using two methods. In order to observe wound patterns inflicted in a quasistatic environment, one method utilized a slow and controlled flow of air provided by a test tube pump. The other method utilized an custom apparatus designed by the URAP intern, which affixed

to a modified paintball marker that injected air into the hydrogel at a significantly higher rate. After comparing observations from the 2 groups of experiments it seems that in the dynamic group fracturing is more spherically symmetric than the quasistatic group, which has implications on damage modeling assumptions under high rates.



Cavitation formation in a hydrogel resulting in (a) asymmetrical void growth under quasi-static loading and (b) nearly spherically-symmetric void growth under dynamic loading.



## Victoria Tsarkova

Rutgers University, Piscataway, New Jersey

Mentor: Mustafa Alazzawi

Faculty Host: Professor Richard Haber

Department of Materials Science and Engineering  
Rutgers University

Project Title: Developing Improved Stereolithography Suspensions

### Additive

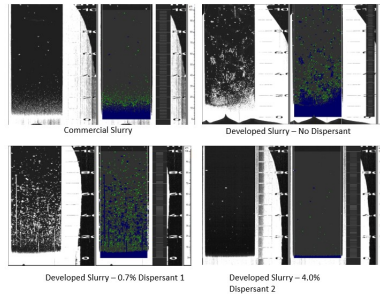
manufacturing (AM) is one of the fabrication processes that is used as a novel approach for complex and developed product manufacturing. Stereolithography (SLA) is one of AM's technologies. SLA provides high surface resolution, accuracy, high fabrication rate, and utilizes diverse materials when compared to other technologies. The suspensions consist of photocurable resin and ceramics. In the SLA process, objects are solidified by photopolymerization where the ceramics are trapped in crosslinked polymer network. SLA industry lacks basic understanding of providing day to day unique formulations for varying applications. The overall goal of this project is to develop an improved stereolithography filled material systems. The slurries that we tested consist of a solid and a liquid phase. The solid phase includes ceramics and dispersants, while the liquid phase consists of oligomers, monomers, photo-initiator (PI), diluents, solvents and additives. Several unfilled resins were developed by mixing varying proportions of oligomer to monomer, with the primary focus being on developing

unfilled resins for alumina. The bad resins were eliminated based on the high shrinkage as well as a low depth of cure.

Varying dispersants were tested to determine compatibility with the developed unfilled resins. The mixing methodology and the optimal content of dispersants was studied. The optimal content was determined by using viscosity and fineness of grind measurements.

Each slurry had its viscosity measured using a viscometer. The optimal percentage was chosen once the viscosity started increasing from the previous percentage. The fineness of grind measurement was applied to examine the agglomeration level. One of the formulations was printed. Further study is necessary to determine the shrinkage level of printed objects. We believe that dark powder can be mixed with these filled resins with higher degree of dispersion.

- 0.7% Dispersant 1 formulation did not show significant improvement in the degree of dispersion compared to the rest.
- Lower degree of dispersion was associated with 0.7% Dispersant 1.
- 4% Dispersant 2 formulation showed highest degree of dispersion compared to the rest of slurries.



## Allysa Tuano

University of Delaware, Newark, Delaware

Mentor: Dr. Bazle Z. (Gama) Haque

Faculty Host: Professor Jack Gillespie

Department of Mechanical Engineering and

Center for Composite Materials

University of Delaware

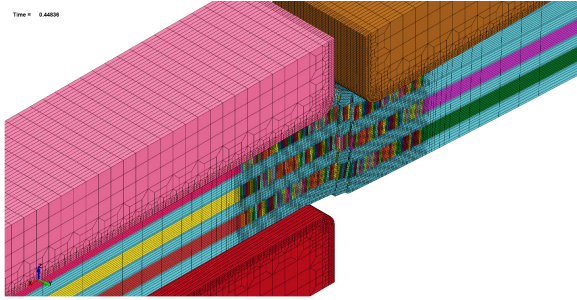
**Project Title: Progress on Stochastic Micromechanical Modeling of Progressive Punch-Shear Behavior of Unidirectional Composites**

Understanding punch-shear behavior in composites is important for improving their impact response. A microscale, finite element model (FEM) of unidirectional (UD) glass fiber-epoxy composites can be used to study the micromechanics of punch-shear behavior. These micromechanics model shall include fiber-matrix debonding, rate-dependent matrix damage, and mixed-mode fiber fracture. Different fiber volume fractions (FVF) are being modeled in this project. The goal is to study the dependence of the micromechanical responses to the FVF.

We created a parametric, hexagonally close packed (HCP) unit cell, shell model of a unidirectional composite. The model is designed such that the FVF can be parametrically changed in LS Dyna. To observe the effects of different FVFs, we kept the diameter of the fiber constant while adjusting the nodes of the matrix. Each node was defined through parametric calculations, with FVF as the parameter. The unit cells were then replicated across the YZ-Plane to create a rectangular cross-sectional shell of a

composite with 7 rows of 4 fibers. The fibers of the shell model were extruded in X-direction to create solid segments in uniform length distributions. To create a fiber of uniform fiber segment length distribution, the shell was extruded to a 150 um long fiber with 2um segments to create the central region of the model. Graded larger segments are used for the left and right sides of the ribbon.

In these 3D micromechanical models of UD composites with different FVF, the stochastic Weibull distribution of tensile and shear tractions between adjacent fiber segments have been defined using a random number distribution routine. Stochastic computational simulations of punch shear will predict stochastic punch shear strength of UD composites as a function of FVF. Finally, with the choice of rate dependent non-linear matrix behavior and fiber-matrix traction laws, one shall be able to design a system of materials with varying energy dissipation capacities.



The 3D unidirectional (UD) composite finite element model (FEM) undergoing punch shear damage.

## 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). ESI are STEM-focused with a particular emphasis on providing research opportunities related to MEDE, a basic research program focused on designing, developing and testing improved soldier protection materials.

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. External ESI are 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 the Center for Materials in Extreme Dynamic Environments

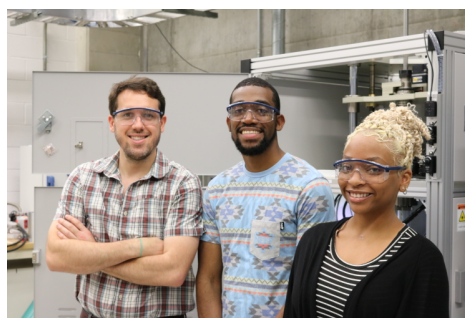
### Website Information

Morgan State University ESI

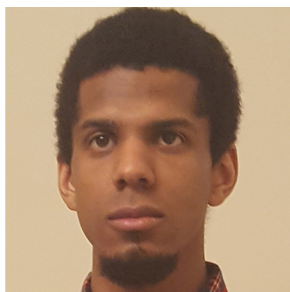
[https://www.morgan.edu/school\\_of\\_computer\\_mathematical\\_and\\_natural\\_sciences/student\\_programs/internships\\_and\\_fellowships/extreme\\_science\\_internships.html](https://www.morgan.edu/school_of_computer_mathematical_and_natural_sciences/student_programs/internships_and_fellowships/extreme_science_internships.html)

CMEDE

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



2019 JHU ESI Students with faculty advisor Dr. Adam Phelan



## Tyler Amory-Moody

Morgan State University, Baltimore, Maryland

Mentor: Professor Dereje Seifu, Morgan State University

Faculty Host: Dr. Shashi Karna

U.S. Army Research Laboratory at Aberdeen Proving Ground, MD

Project Title: Magnetostriction, VSM, TMM, and Magneto Optic-Kerr

Effect Measurements

Summer 2019 project included theory and application of Magnetostriction and the Magneto Optic-Kerr Effect. Magnetostriction is a property some materials exhibit when their physical dimensions change in response to the application of an external magnetic field. In this project, the magnetostrictive strain  $\lambda$  is measured and is defined by  $\lambda = \Delta l / l$  (the ratio describing the change in length of a material to the original unaffected length). The ability to control the dimensions of a material through the application of a magnetic field makes magnetostrictive materials useful in actuators, motors, sensors, and transducers. There are four different types of strain that are measured with a strain gauge: axial, bending, shear, and torsional.

Vibrating Sample Magnetometer, Torque Magnetometer, and Magneto Optic-Kerr Effect measurements were taken of a thin TFD tri-layer. The results of which include information regarding squareness ratio, saturation values, reversal mechanism, and symmetries. These were identified in thin layers as well as in bulk layers. The software used to take the measurements are Labview and Python.

Topics further discussed include spectroscopy, Raman scattering, etching and spin coating as well as floating techniques, Chemical Vapor Deposition (CVD), microwave sintering, and SEM operation.

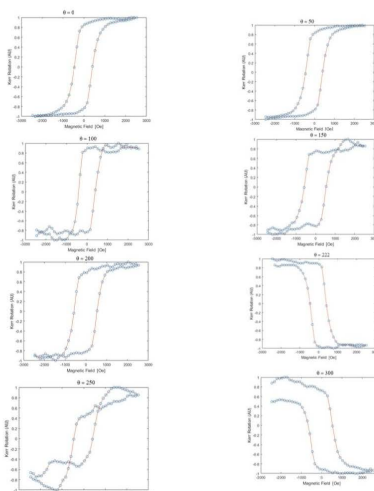


Figure 10- Longitudinal MOKE measurements for a 5 by 5 mm square TFD film.



## Atiyya Davis

Morgan State University, Baltimore, Maryland

Faculty Host: Dr. Adam Phelan

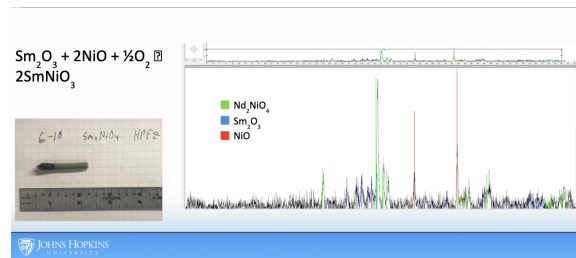
Department of Chemistry

Johns Hopkins University

## Project Title: Further Explorations of the Ln-Ni-O Phase Space Using High Pressure Optical Floating Zone Methods

An initial study of the single crystal growth of  $\text{Sm}_2\text{NiO}_4$  using a high-pressure optical floating zone furnace is presented. Extreme fluid pressures ranging from 50 - 250 bar are used to produce samples of  $\text{Sm}_2\text{NiO}_4$ . Powder x-ray diffraction is used to identify the phases present in the crystal boules. Precise targeted stoichiometries and low level purities appear to play a large role in the stabilization of the material. Future work such as elemental analysis will be a useful to investigate how purity plays a role in the stabilization of  $\text{Sm}_2\text{NiO}_4$ . The purity of the starting materials may give insight into why

certain phases are not present between crystal growths. Magnetic and thermodynamic data will also be collected.



### Michael Straker

Morgan State University, Baltimore, Maryland

Faculty Host & Mentor: Dr. Adam Phelan & Professor Tyrel McQueen  
Department of Chemistry  
Johns Hopkins University

Project Title: Floating Zone Crystal Growth and Characterization of Boron Carbide

Boron carbide is an inexpensive, light weight ceramic with potential for applications in body armor, high temperature thermoelectrical conduction, ionizing radiation shielding, and neutron detection. The rhombohedral crystal structure of the material means that mechanical, electrical, and physical properties may vary along differing crystallographic orientations. Thus, measuring such anisotropic properties requires the use of single crystals. Single crystals of boron carbide are non-trivial to grow; thus, few studies have been conducted measuring the properties of this material across its varying orientations. Single crystals of boron carbide were grown via the floating zone method utilizing PARADIM's laser diode floating zone furnace. From Laue diffraction, we identified several distinct rhombohedral

crystal directions, which has allowed and will continue to allow us to measure orientation dependent physical properties. We were also able to characterize the quality of the material, verifying its purity and that the samples were indeed single crystalline. Initial mechanical property measurements show results comparable to the literature. Larger diameter crystal samples have been produced to allow for more robust mechanical and ballistic impact studies.



## 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

National Endowment for the Arts,  
The Whiting School of Engineering at JHU,  
and MICA

### Website Information

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



Laila Milevski

Yi Zheng

Mae Rowland



### Laila Milevski

Focus Area: Illustration

MICA Advisor: Kimberley Ellen Hall, Illustration Practice

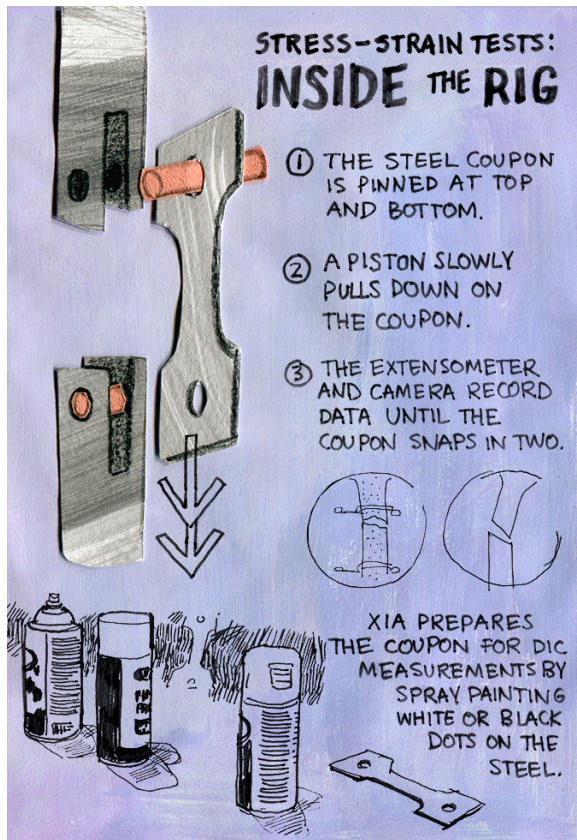
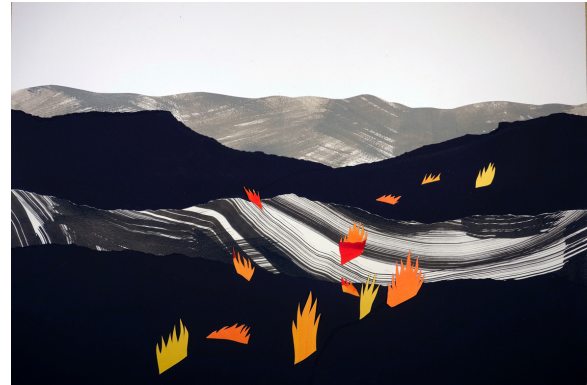
HEMI Advisor: Professor Thomas Gernay  
Department of Civil Engineering  
Johns Hopkins University

Project Title: Famous Fires pamphlet series / Sparks Fly animation

This two-part project responds to what I have learned about fire engineering in two ways: one linear, seeking to explain Gernay's

research and the field of fire engineering in general, and the other expressive, responding to the subject matter

emotionally. In my pamphlet series I plan to explore different aspects of fire engineering (stress-strain tests, SAFIR, community resilience, uncertainty and idealization in research and modelling) and link each to a well-known fire event from recent or more distant history. In the stop-motion animation “Sparks Fly,” I allowed myself to make a narrative based on resonant images and moods centered on the experience of wildfire and losing one’s home.



## Mae Rowland

Focus Area: Interdisciplinary Sculpture

MICA Advisor: Ryan Hoover, Interdisciplinary Sculpture

HEMI Advisor: Professor Natalia Drichko

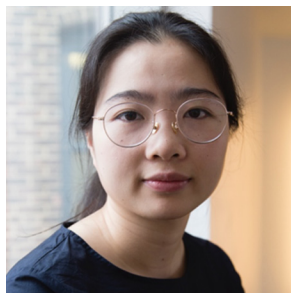
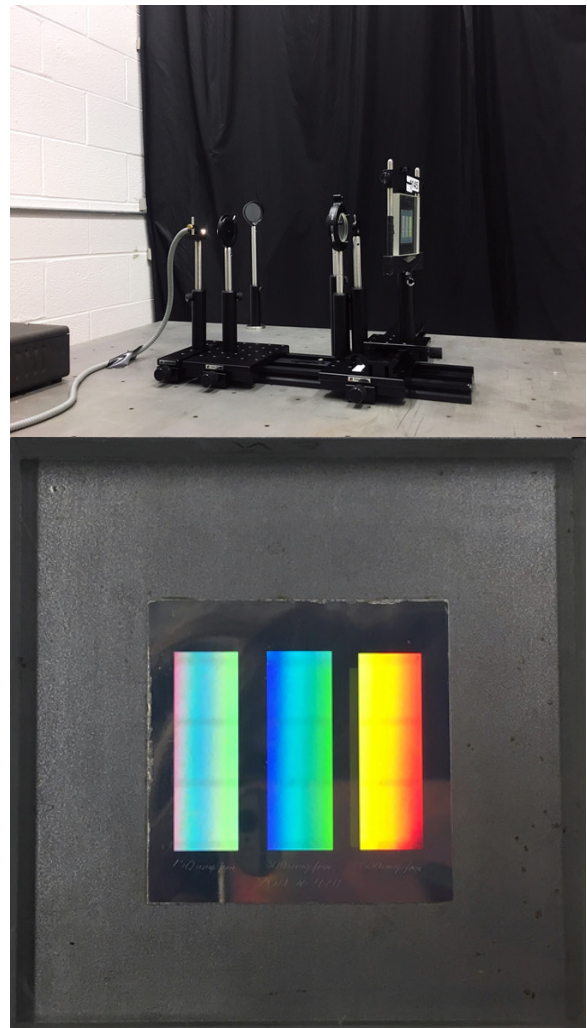
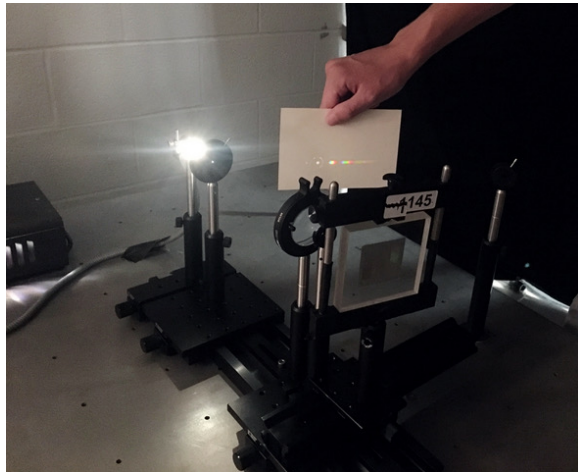
Department of Physics and Astronomy  
Johns Hopkins University  
and

Professor Susanna Thon

Department of Electrical and Computer Engineering  
Johns Hopkins University

Project Title: Optics: Towards Better Animation Through A Deeper Understanding of Physics and Computational Modeling

In this project, physically-based, digital 3D rendering is reinforced by optics lab experience. Being able to observe the physical principles of how light behaves in person has strengthened my ability to use 3D animating software, which simulates light behavior digitally. These dual practices of researching and making in the physical and digital mutually inform each other. As a result, I am able to achieve higher quality rendered images and a deeper knowledge and appreciation of optics and human perception.



## Yi Zheng

Focus Area: Illustration

MICA Advisor: Rebecca Bradley, Illustration

HEMI Advisor: Professor Sabine Stanley

Department of Earth and Planetary Sciences  
Johns Hopkins University

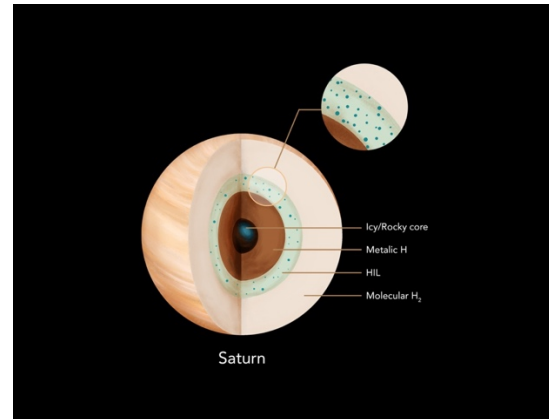
It is always my interest to explore the interdisciplinary area of science and art, and I am currently working on how to transfer dry science knowledge into interesting and clear visual information using illustrations and more dynamic animations. Because I feel that there

should be a bridge to deliver scientists' research to the general audience.

During HEMI project, I was working in Professor Sabine Stanley's group. Professor Stanley's research projects are on planetary magnetic fields, dynamo theory, and

planetary interior structure models. During the time I spend in Prof. Sabine Stanley's group, I talked with each lab member in order to have a better understanding to their researches. Basically, they are applying computer-assisted calculations and simulations to show the appearance of the planetary magnetic field of each planet in our solar system, and to explain why they look like certain shapes and their change through time.

I made a few illustrations and gifs for researchers' posters, such as the helium rain inside the Saturn, and I illustrate its helium rain process and the inner structure of Saturn with a gif. This can help researcher better interpret their hypothesizes during presentation. And I also make an animation to explain the magnetic field of the solar system. The researchers provided me the animation script and then we worked together to visualize in a novel visual manner, in this animation we try to explain those science facts in a understandable way, such as how did the planet's dynamo generate of magnetic fields and what does these planets' magnetic fields look like.



## Poster Symposium

In addition to providing a summary of their research during one of the weekly intern cohort meetings, students were encouraged to present a poster during the first Internship Poster Symposium. Below is a listing of participants, their home institution, the title of their poster and their HEMI Fellow mentor(s).

Jack Albin  
Johns Hopkins University  
*Rapid Prototyping to Improve Efficacy of HyFIRE Experiments*  
KT Ramesh

Aayush Anurag  
Indian Institute of Technology Bombay  
*Predicting strength of Dyneema*  
KT Ramesh

Alexander Betancourt  
Johns Hopkins University  
*Uncovering the Role of Solvents During Dissolution of Lead-Halide Salts*  
Paulette Clancy

Curtis Cooper  
Mount Saint Joseph High School  
*EASGC Function Evaluation*  
Lori Graham-Brady

Atiyya Davis  
Morgan State University  
*Further Explorations of the Ln-Ni-O Phase Space using High Pressure Optical Floating Zone Methods*  
Adam Phelan

Michelle Feng  
The Bryn Mawr School  
*Characterization of Porous Ceramic for Catalytic Convertors*  
Lori Graham-Brady

Angela Groznos  
Johns Hopkins University  
KT Ramesh

Nia Lowery  
From the Heart Christian School

*Investigating NEB with a reaction mechanisms database*  
Paulette Clancy

Elaine Nagahara  
Johns Hopkins University  
*Piezoelectric Biodegradable Bone Scaffold*  
Sung Hoon Kang

Jonah Offman  
Johns Hopkins University  
*High Strain Rate Multi-Axial Loading Behavior of Granular Boron Carbide*  
KT Ramesh

Mae Rowland  
MICA  
*Optics*  
Natalia Drichko/ Susanna Thon

Caitlyn Schuette  
Bucknell University  
*Characterization of Magnesium-Aluminium Alloys*  
Tim Weihs

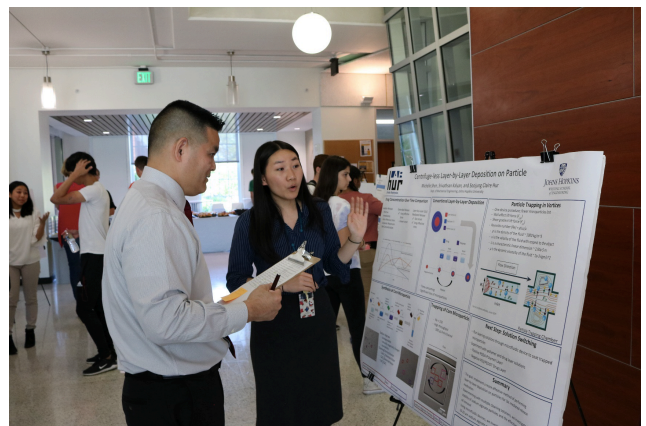
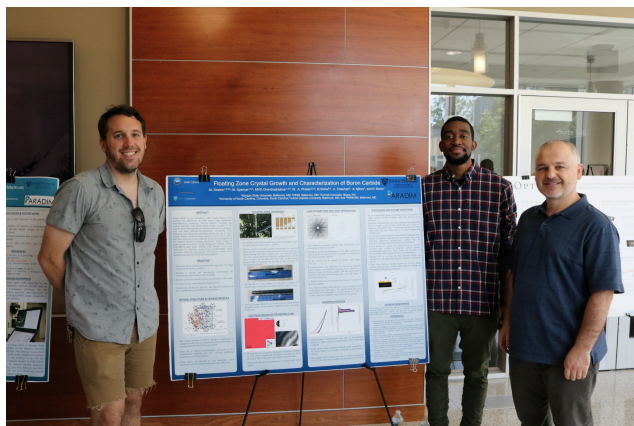
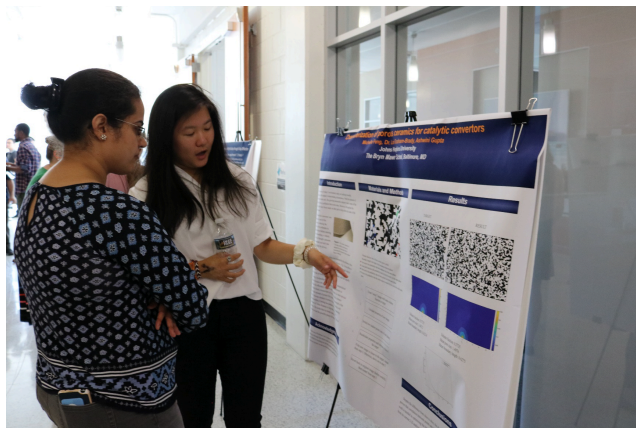
Michelle Shen  
Thomas S Wootton High School  
*Use of microfluidic devices in creation of extended release medication*  
Claire Hur

Michael Straker  
Morgan State University  
*Mechanical and Electrical Transport Property Characterization of Single Crystal Boron Carbide*  
Adam Phelan

Angela Torrejon  
Connelly School of the Holy Child  
*Synthesis, Characterization and Crystal  
Growth of Defect Pyrochlores  $Mg_2LnTaO_6$   
( $Ln=La, Pr, Nd, Sm, E$ )*  
Adam Phelan

Buena Zajmi  
Quince Orchard High School  
*Lead Sulfide Quantum Dot Solar Cells*  
Susanna Thon

Skyler Van Cruyningen  
Saratoga High School  
*Effects of Hydroxyapatite and PCL Coatings  
on the Mechanical Properties of Weaves*  
Tim Weihs



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:

