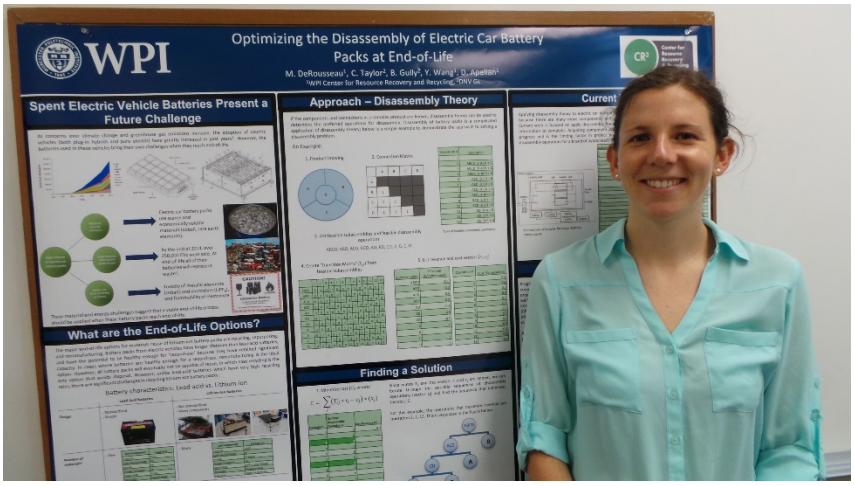
GRIE Poster Presentations 2016

MS Graduate Students

Title: Optimizing Disassembly of Electric Car Battery Packs at End-of-Life

Student: Mikaela DeRousseau
Advisors: Yan Wang, Diran Apelian



Abstract:
In the United States, millions of electric and hybrid vehicles have cumulatively been sold. Although the batteries in these vehicles are expected to last many years, considering what do with all of these battery packs at end-of-life should be a priority. There are several possible options for battery packs from electric vehicles when they reach end-of-life; these include remanufacturing, repurposing for a different application, and recycling. In all of these cases, accessing and extracting battery modules in an efficient and low-cost manner will be essential if any of these strategies are to be economically viable. Thus, the purpose of this research is to compare the likely sequence of operations needed to disassemble several models of battery packs. Furthermore, the goals are to determine what designs of battery packs are best for disassembly and what, if any, design features impede disassembly and extraction of battery modules. This is completed by constructing component-connection charts, listing disassembly operations, and constructing a disassembly priority matrix. This research is ongoing, but will lead to design recommendations to improve end-of-life prospects.

Title: A Closed-Loop Process For Recycling Spent Lithium-Ion Batteries

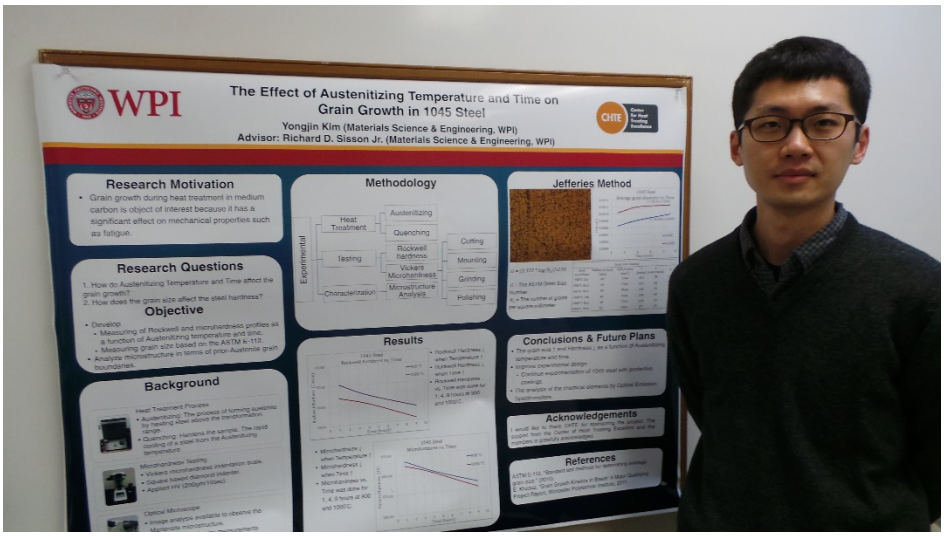
Finalist

Student: Joseph Heelan
Advisors: Yan Wang

Abstract:
Lithium-ion batteries dominate the energy storage market, powering everything from laptops and cell phones to electric and hybrid-electric vehicles. Of all these batteries, greater than 95% of them are landfilled instead of recycled upon reaching end of life. As applications for Li-ion batteries increase, recycling must become less of an after-thought to recover valuable finite elements like Li, Ni, and Co. There is a need for a flexible recycling system that can accommodate
any type of lithium-ion battery using a technology that is economically viable now and in the future. A novel, hydrometallurgical recycling process has been developed at WPI that offers an efficient, closed-loop system for synthesizing new NMC (Ni,Mn,Co) cathode powders as well as other valuable materials like copper, steel, aluminum and lithium carbonate from a spent Liion battery source. My poster will focus on the steps necessary to enhance the quality and electrochemical performance of the recovered cathode and lithium carbonate product by optimizing processing parameters. Properties and metrics of the cathode analyzed include the tapped density, average particle size, cycle life, and discharge capacity.

Title: The Effect of Austenitizing Temperature and Time on Grain Growth in 1045 Steel

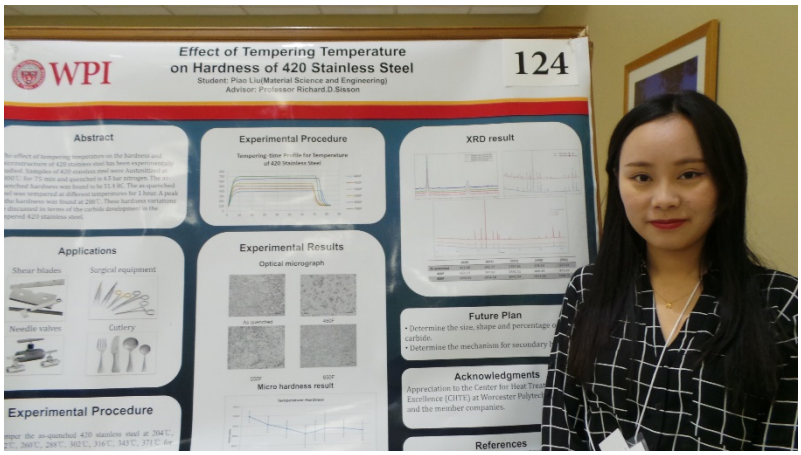
Student: Yongjin Kim
Advisors: Richard D Sisson, Jr.



Abstract:
Grain growth during heat treatment in medium carbon is object of interest because it has a significant effect on mechanical properties such as fatigue. In this work, the effect of Austenitizing temperatures and holding times on Austenite grain size, microstructure and hardness was experimentally investigated. Samples of 1045 steel were Austenitized at 900 °C and 1000 °C held for 1, 4 and 9 hours. After Austenitizing, samples were cooled down in the furnace to 850 °C followed by quenching in agitated water. Rockwell and Vickers hardness measurements were taken to each sample. The microstructures of all heat-treated samples was investigated with optical microscopy. Measurements for the Austenite grain size were performed according to ASTM E112-10. It was found that the Austenite average grain size increased with an increase in Austenitizing temperature and time. It was also found that the as-quenched hardness decreased with increasing grain size.

Title: The Effect Of Tempering Temperature OnHardness Of 420 Stainless Steel

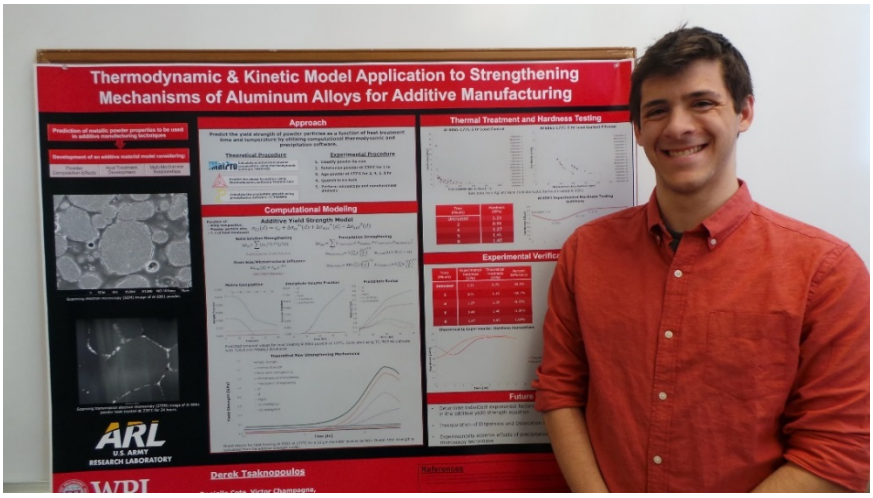
Student: Piao Liu
Advisors: Richard D Sisson, Jr.



Abstract:
The effect of tempering temperature on the hardness and microstructure of 420 stainless steel has been experimentally studied. Samples of 420 stainless steel were Austenitized at 1000□ for 75 min and quenched in 4.5 bar nitrogen. The asquenched hardness was found to be 51.4 RC. The as-quenched steel was tempered at 204□, 232□, 260□, 288□, 302□, 316□, 343□, 371□ for 1 hour. A peak in the hardness was found at 288□. These hardness variations are discussed in terms of the carbide development in the tempered 420 stainless steel.

Title: Thermodynamic & Kinetic Model Application to Strengthening Mechanisms of Aluminum Alloys for Additive Manufacturing

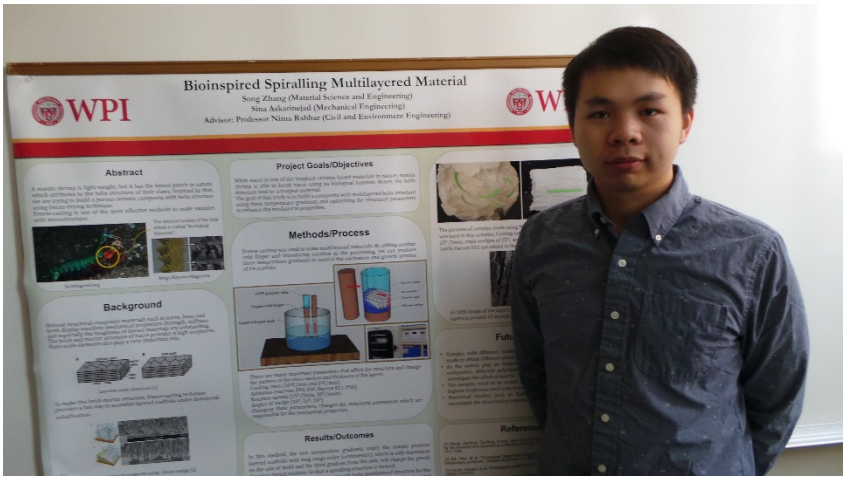
Student: Derek Tsaknopoulos
Advisors: Danielle Cote, Richard D Sisson, Jr., Victor Champagne



Abstract:
While gas-atomized powder has become a staple feedstock material for additive manufacturing, detailed understanding regarding the mechanical properties of the raw material is needed for superior process modeling. Focusing primarily on the yield strength of the feedstock powder, various strengthening mechanisms are considered for the contributions from solid solution strengthening, grain size strengthening, precipitation, and dispersion mechanisms. These equations utilize the quantified kinetic and thermodynamic outputs from modeling software Thermo-Calc, JMatPro®, and TC-PRISMA. The data from these models coupled with the strengthening contributions progress into a strengthening model that represents the overall strengthening influence of each mechanism for specified gas-atomized powders. The effectiveness of this strengthening model is determined using thermal, optical, and mechanical characterization methods.

Title: Bioinspired Spiraling Multilayered Ceramic Material

Student: Song Zhang
Co-Author: Sina Askarinejad
Advisors: Rahbar Nima



Abstract:
Natural porous materials, like nacre, bones and teeth display excellent mechanical properties, both high strength and fracture toughness. And a lot of efforts had been devoted to the techniques of building layered scaffolds with long-range order of porosity. In which freeze casting is commonly used as a simple and fast way to create highly porous materials with complex, hierarchical architectures during directional solidification. Inspired by the spiraling structure of mantis shrimp's claws, we are using freeze casting technique to assemble ceramic particles and produce a porous, lamellar, spiraling structure. By adjusting two cold fingers and using a silicone wedge, we could produce three temperature gradients in the nucleation and growth process of ice crystals. This method is promising to have a good control of developing a novel bioinspired polymer-ceramic composite with good mechanical properties at high porosity.

PhD Graduates

Title: Aluminum Composites for Automotive Applications

Finalist

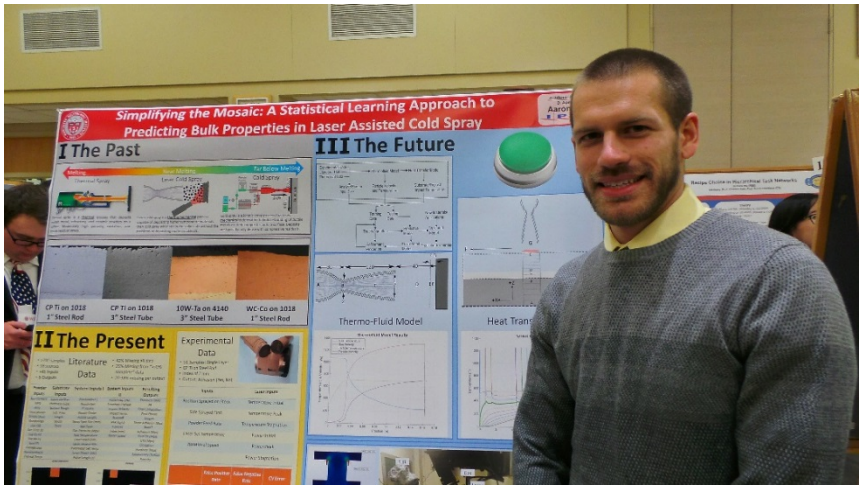
Student: Inigo Anza
Advisors: Makhlouf M. Makhlouf

Abstract:
Next generation of aluminum automotive engines will have to operate at temperatures approaching 300^{0}C. Traditional aluminum alloys cannot perform at these temperatures, but aluminum alloys reinforced with fine particles can. The synthesis of aluminum-titanium carbide composites by an in-situ gas-liquid reaction implies methane to be injected into molten aluminum that has been pre-alloyed with titanium. The gas is introduced by means of a rotating sparger-impeller unit into the hot alloy, and under the correct conditions of temperature, gas flow and rotation speed, it reacts preferentially with titanium to form titanium carbide particles that are well dispersed in the metal matrix. The apparatus design, the multi-physics phenomena and a mechanism proposal for particles formation is first given. The operation window in which to allocate the parametric analysis is next calculated. Finally, characterization of initial obtained material, its relationship to the processing parameters and guidelines to obtain the narrow distribution of fine particles is done.

Title: Simplifying the Mosaic: A Machine Learning Approach to Modeling the Laser Assisted Cold Spray Process

Finalist

Student: Aaron M. Birt
Advisors: Diran Apelian

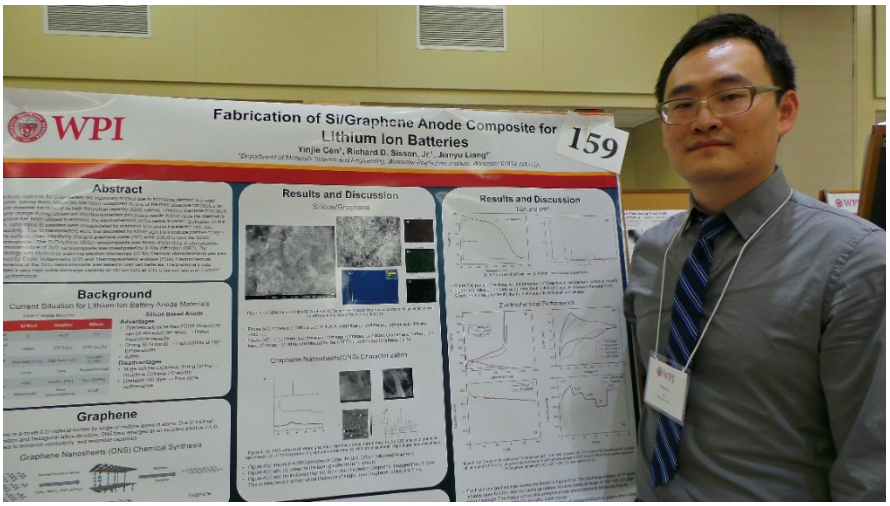


Abstract:
Modern manufacturing processes must become increasingly complex in order to reduce costs, increase efficiencies, and produce products to meet extreme working conditions. Many of these processes have variables so numerous that they are exceedingly difficult to model with accuracy and speed using physics based models. One such process that has been developed over the last decade is called laser assisted cold spray (LACS). The process includes such complex physics as supersonic fluid dynamics, submicrometer heat transfer, dynamic recrystallization, secondary phase formation, high strain rate deformation, and variable material systems. Rather than use physical models to quantify LACS, a data driven machine learning model was selected to encompass all of these variables. The work reported here discusses selection of the physical inputs and outputs that can be measured to accurately represent LACS. This representation is statistically validated and serves as the stepping block to a predictive machine learning model for LACS.

Title: Fabrication Of Si/Graphene Anode Composite For Lithium Ion Batteries

Finalist

Student: Yinjie Cen
Co-Author: Richard D. Sisson, Jr., Jainyu Liang
Advisors: Jianyu Liang



Abstract:
Electrode materials for Li-ion battery are vigorously studied due to increasing demand in energy sources. Among them, silicon (Si) has been recognized as one of the most attractive candidates for anode materials because of its high theoretical capacity (4200 mAh/g). However, the more than 300% volume change during Lithium ion insertion/extraction processes results in poor cycle life. Meanwhile, graphene has been utilized to enhance the electrochemical performance in varied applications. In this work, nano-sized Si powders were encapsulated by graphene to improve the electric conductivity. The Si nanopowders were first decorated by silane agent to introduce positive charges on the surface. Then negatively charged graphene oxide (GO) were added to form the Si/GO nanocomposite. The Si/Graphene (Si/G) nanocomposite was finally obtained by *in-situ* reduction. The microstructure of Si/G nanocomposite was investigated by XRay diffraction (XRD). The morphology was studied by scanning electron microscopy (SEM) and transmission electron microscopy (TEM).Chemical characterization was also obtained by Fourier Transformation Infrared Spectroscopy (FTIR), Zeta potential and X-ray photoelectron spectroscopy (XPS). Electrochemical performance of the Si/G nanocomposite was tested in coin cell batteries. The preliminary data indicated a very high initial discharge capacity of 100 nm Si/G at 1/10 C current rate and improved cycle performance.

Title: Nano-Strength Testing of Additive Manufactured Parts Using Atomic Force Microscopy

Finalist

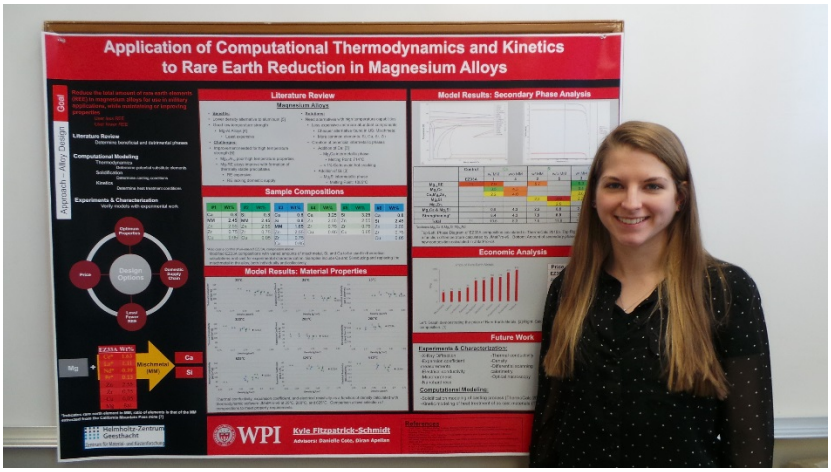
Student: Robert C. DelSignore
Advisors: Richard D. Sisson, Jr.

Abstract:
Additive manufacturing (AM) is growing in popularity in the automotive, aviation, military, medical, and prototyping industries. Therefore, it is important to understand the mechanical properties of parts built in a layer by layer fashion as a function of the manufacturing process parameters. This study describes how atomic force microscopy can be used to determine inter-layer bond strengths and, more specifically, powder particle-substrate adhesion strengths in AM applications, particularly cold spray. Individually bonded particles are sectioned from substrate materials and are formed into small cantilever specimens. By applying a known force to the micro-cantilevers, resolved stresses are determined at the particle-substrate adhesion zone. Loads are increased until fracture occurs, corresponding to the critical stress required for inter-layer separation. Analysis with scanning and transmission electron microscopy identifies the location

and method of fracture. Fracture mechanics is then applied to determine critical flaw sizes for the manufacturing parameters. Ultimately correlation between processing variables and flaw sizes enables design optimization.

Title: Application of Computational Thermodynamics & Kinetics to Rare Earth Reduction in Magnesium Alloys

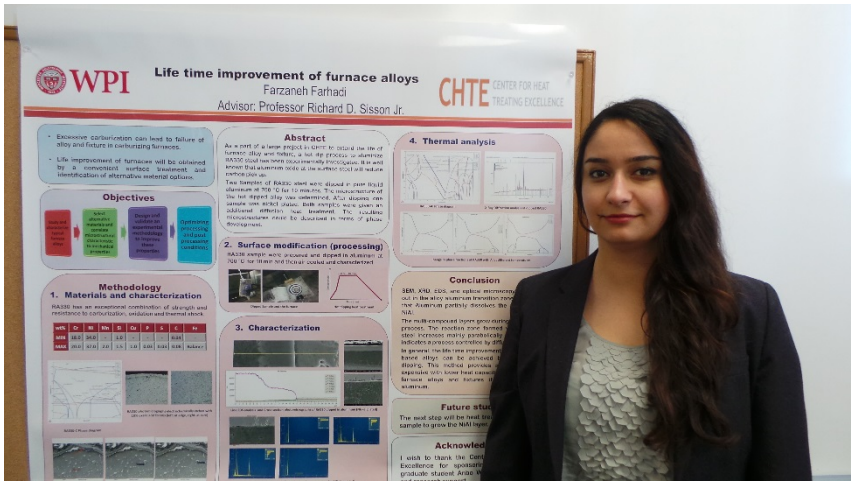
Student: Kyle Fitzpatrick-Schmidt
Advisors: Danielle Cote, Diran Apelian



Abstract:
Magnesium alloys are widely used in numerous applications due to their extremely low density. Through the addition of rare earth metals, the high temperature capabilities of magnesium alloys are increased by creation of thermally stable secondary phases. This research is focused on reducing the amount and number of rare earth elements used in these alloys, while simultaneously maintaining the high temperature capabilities and low density. Thermodynamic, kinetic, and strengthening mechanism models have been used to analyze the magnesium alloy EZ33A and seven new compositions with varied amounts of rare earths and additional elements. The theoretical analysis was followed by experimental investigation of the new alloy compositions.

Title: Life Improvements of RA330 Steel

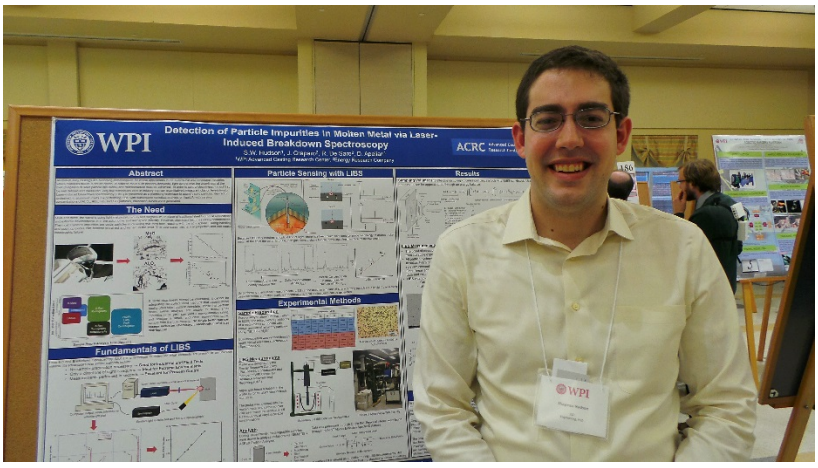
Student: Farzaneh Farhadi
Advisors: Richard D. Sisson, Jr.



Abstract:
As a part of a large project in CHTE to extend the life of furnace alloy and fixture, a hot dip process to aluminize RA330 steel has been experimentally investigated. It is well known that aluminum oxide at the surface steel will reduce carbon pick up. Two Samples of RA330 steel were dipped in pure liquid aluminum at 700 °C for 10 minutes. The microstructure of the hot dipped alloy was determined. After dipping, one sample was nickel plated. Both samples were given an additional diffusion heat treatment. The resulting microstructures could be described in terms of phase development.

Title: Detection of Particle Impurities in Molten Metal via Laser-Induced Breakdown Spectroscopy

Student: Shaymus W. Hudson
Advisors: Diran Apelian

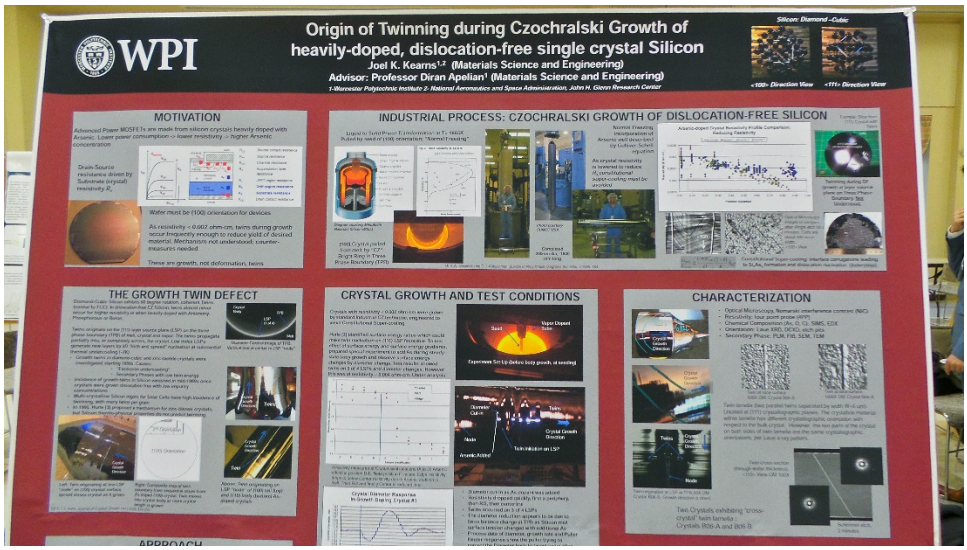


Abstract:

Aluminum alloy castings are becoming commonplace for critical applications in the automotive and aerospace industries where materials failure is not an option. In order to meet such property demands, tight control over the cleanliness of the melt (mitigation of solid particle inclusions) and microstructure must be achieved. In order to control cleanliness, it must first be well defined and measured. Very few techniques exist in industry that can quantitatively measure inclusion levels in-situ. Laser-induced breakdown spectroscopy (LIBS) is presented as a promising technique to quantify solid particles, desired or undesired, in aluminum melts. By performing LIBS with subsequent statistical analysis on liquid Al with varying concentrations of Al2O3, AlB2, and SiC particles, calibration curves were generated. Ongoing progress of this work is presented and discussed.

Title: Origin of Growth Twinning during Czochralski Growth of Heavily doped dislocation-free single crystal Silicon

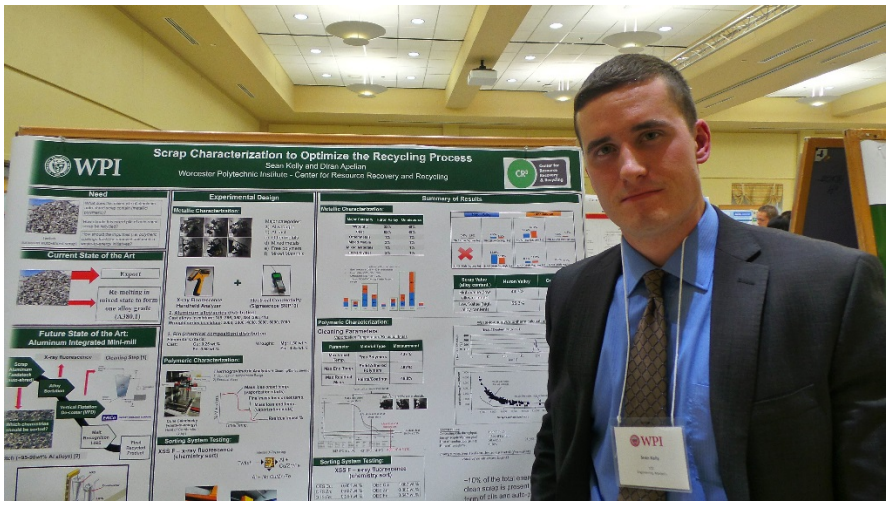
Student: Joel K. Kearns
Advisors: Diran Apelian



Abstract:
Single crystal silicon must be dislocation free and [100] crystallographic orientation to be used for low voltage power devices. Power devices demand very low resistivity silicon, doped with large concentration of arsenic, antimony or phosphorous. As crystal resistivities have been lowered to achieve lower device power losses, twinning on the crystal habit line location at the three-phase boundary (TPB) has unexpectedly occurred. Twinning renders that section of the crystal unusable for devices, and that same section is the section with the desirable low resistivity. Such a limit on achievable resistivity would impede further required development of low voltage power semiconductor performance for mobile computing, communications devices, internet routing and automobiles.The only mechanism previously proposed to explain growth twinning in diamond cubic semiconductors such as silicon does not predict such twinning under these conditions. It is possible that the high electronic impurity content or impurity concentration gradients in the crystal or melt provide a different mechanism to generate twins during growth. The source of the twins must be identified so that crystal growth process conditions can be modified to eliminate this defect mechanism, allowing lower resistivity crystals to be grown reliably.

Title: Scrap Characterization To Optimize The Recycling Process

Student: Sean M. Kelly
Advisors: Diran Apelian

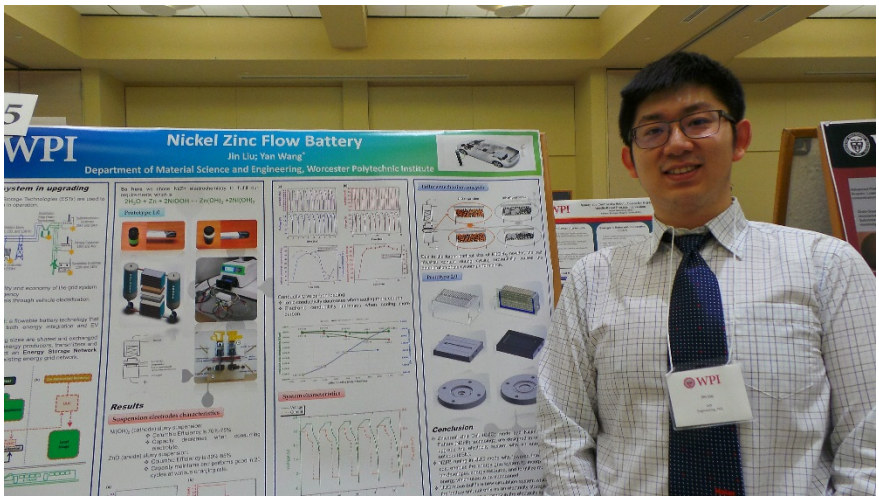


Abstract:
Managing the secondary production process for aluminum auto-shred scrap is of prime importance considering the projected demand increase for aluminum alloys in the transportation, electronic and packaging industries. Aluminum auto-shred scrap is a major end-of-life, mixed metallic stream that must be recovered and recycled effectively and efficiently to ensure infinite lifetime involving a broad distribution of re-use applications determined by specific alloy chemistry. Some issues that are preventing the aforementioned distribution include proper understanding of the sortable chemical composition in these mixed scrap classes and the removal of carbon-based impurities in the form of free polymers, oils, lubricants, paints and coatings by such a method that recovers energy from the by-products formed. A developing secondary aluminum recycling plant should utilize a proper inline process to sort, clean, re-melt and cast multiple secondary aluminum alloy types from this mixed scrap stream. This work is focused on characterizing aluminum auto-shred in terms of metallic chemistry and through thermal analysis of the organic content to aid development of intelligent sorting systems and waste-to-energy cleaning processes, respectively.

Title: Study Of Zinc Nickel Flow Battery

Finalist

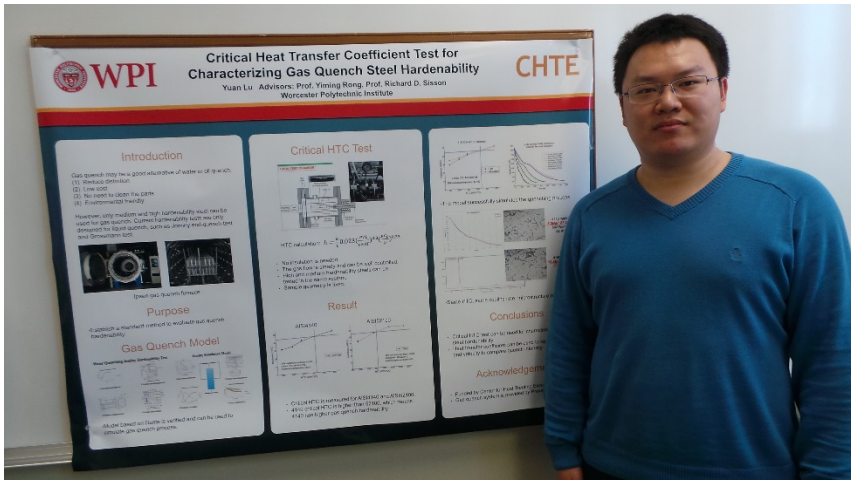
Student: Jin Liu
Advisors: Yan Wang



Abstract:
The escalation of power system promotes the development of battery technologies with its huge application market. Redox flow batteries (RFBs) are very attractive to customers in the energy grid system, and their noticeable technological innovations in the past decades have driven them to gradually replace the conventional energy storage methods under certain circumstance. Portable batteries used in electronics and fully electric vehicles ought to be designed to fulfill the growing desires on supplying energy quicker and longer. Therefore, many significant improvements have been achieved on battery manufacture and mechanism optimization. Here, the first fully-flow-able zinc–nickel flow battery (ZNFB) is studied, whose performance is supposed to be suitable for various scales. Through using semi-solid fuel cell (SSFC) technology, we incorporate the beneficial features of aqueous Zn/Ni chemistry (essentially sustainable, eco-friendly and deposit-abundant) into RFB structure to make a “hybrid” flow battery system with nano-size carbon network. Basic electrochemical properties of ZNFB are reported, and its suspension and electrode characters have been studied and improved.

Title: Gas Quenching Steel Hardenability Standard

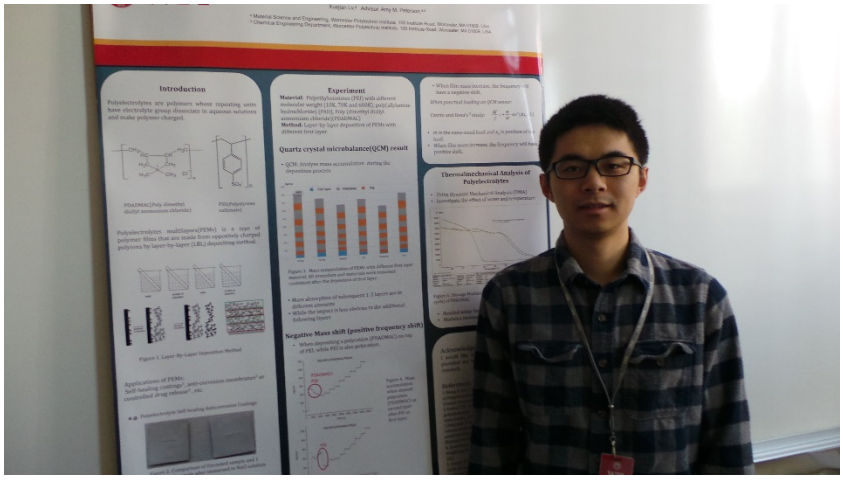
Student: Yuan Lu
Advisors: Richard D Sisson, Jr., Yiming (Kevin) Rong



Abstract:
With the development of modern heat treatment technology, gas quenching, with advantages such as reduced distortion and dry and clean parts than water quenching, has been widely used. While not all steels can be hardened by gas quenching, since its quenching capability is different from water quenching.The purpose of this project is to develop a standard to verify steel hardenability in gas quenching process. Jominy test and Grossmann test, as traditional water quenching steel hardenability standards, have been studied. The modified Jominy gas quenching test model and Grossmann gas quenching test model have been developed by Abaqus and Dante based on finite element method. The related devices have been designed and assembled to find the proper parameters for gas quenching hardenability standard, such as gas velocity, gas pressure and sample geometry.If gas quenching steel hardenability standard can be successfully created based on the simulation and experiment, it will help to quickly and accurately determine the proper steel for gas quenching process and accelerate the replacements of water quenching process in many traditional industries.

Title: The Effect Of The First Layer On Polyelectrolyte Multilayer Structure

Student: Xuejian Lv
Advisors: Amy M. Peterson

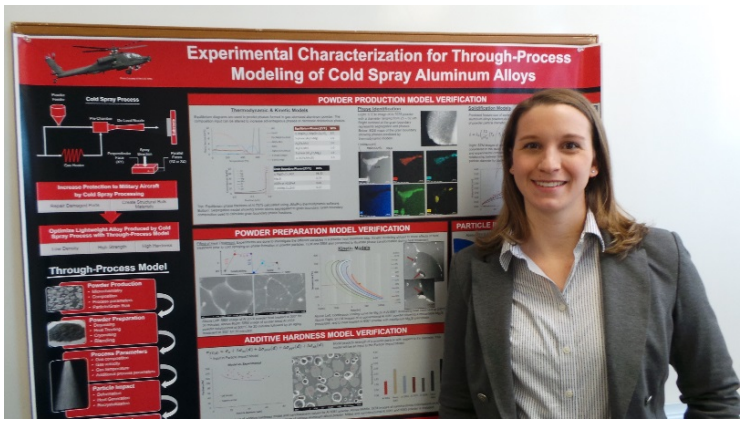


Abstract:
Polyelectrolyte multilayers (PEMs) were prepared by alternating deposition of polydiallyldimethylammonium chloride (PDADMAC) and poly(sodium 4-styrenesulfonate) (PSS) on titanium substrates. We have previously observed that surface roughness, as measured by contact mode atomic force microscopy (AFM), is highly dependent on the chemistry as well as the deposition conditions of the first adsorbed layer of a PEM. In this study, the impact of the first layer was examined further using a range of techniques. Quartz crystal microbalance with dissipation monitoring (QCMD) was used to analyze adsorption of each individual layer during the deposition process. When using different polyelectrolytes as the first layer, subsequent 1-2 layers adsorbed in different amounts, while additional layers remained consistent across samples. These results imply that the effect of the first layer on amount of adsorption is short range, while the resulting structure is impacted over longer scales. Ellipsometry was used to measure the increase of PEM thickness, while x-ray photoelectron spectroscopy (XPS) was used to track the interpenetration between polyelectrolyte layers.

Title: Experimental Characterization for Through-Process Modeling of Cold Spray Aluminum Alloys

Finalist

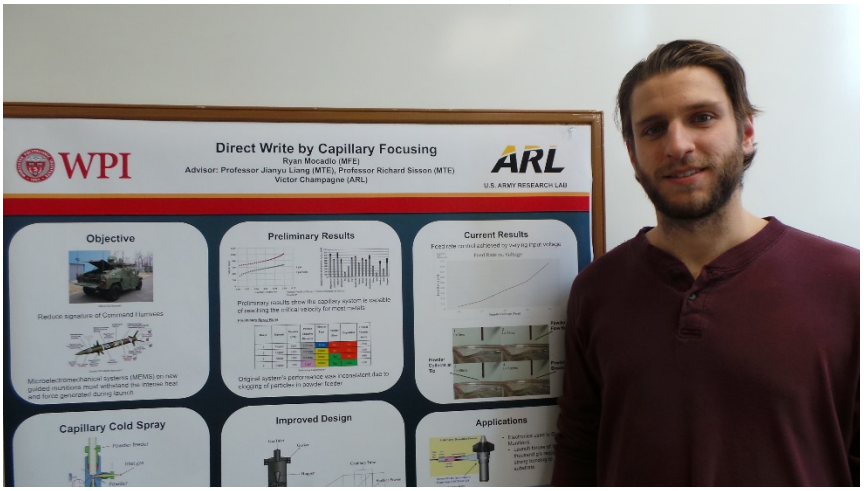
Student: Baillie R. McNally
Advisors: Richard D. Sisson, Jr.



Abstract:
Currently, the cold spray process is used as a cost effective method to restore corroded or damaged parts of military aircraft that require high maneuverability, durability, ballistic protection, and energy efficiency. This process can be made even more robust with a predictive tool that would tailor the material and processing parameters to a variety of repair applications. A through-process model that includes powder production, powder pre-processing, the cold spray process, and post-processing would benefit the current trial and error cold spray process immensely and would aid in the search for an optimal cold spray alloy for different applications. Current work focuses on the characterization of the microstructural evolution of several aluminum alloys to verify and enhance the powder production, processing, and impact stages of the model. Microstructural morphology, phase identification, and properties of various aluminum alloys powders are determined through scanning and electron microscopy, and nanoindentation.

Title: Direct Write Of Micro-Circuitry Via Capillary Focusing

Student: Ryan N. Mocadlo
Advisors: Jianyu Liang



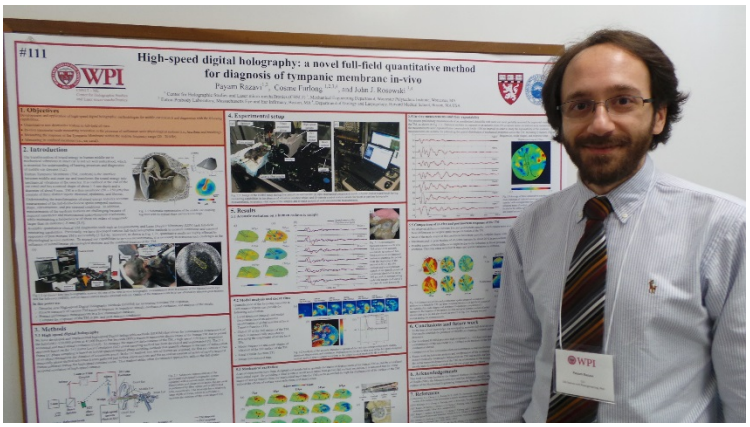
Abstract:
Micro-cold spray is a process which could achieve the solid state deposition of metal powders through capillary focusing. In this process, ultra-fine particles are accelerated using high pressure helium through a capillary nozzle to a substrate, where they impact and subsequently deposit. Finer feature sizes have been a longstanding aspiration of the cold spray community, but have remained elusive despite extensive efforts. The Department of Defense has shown interest in using this type of additive process to create robust conformal antennas, and electronic packaging with strong enough adhesion to withstand the extreme G forces experienced at projectile launch. The main obstacle to micro cold spray is the use of ultra-fine powders which exhibit poor flowability. In the past, several novel feeding systems have been unsuccessfully attempted; this work describes an innovative system, utilizing vibration to feed powder in a controlled and consistent manner. Once powder flow is consistent this system will be able to deposit lines with widths of less than 110 µm. This process will produce micro-circuitry with stronger bonds, without the use of harmful masks, and at a faster throughput than traditional processes.

Title: High-speed digital holography: A novel full-field quantitative method for in-vivo tympanic membrane diagnostics

Finalist

Student: Payam Razavi

Advisors: Prof. Cosme Furlong; John J. Rosowski



Abstract:

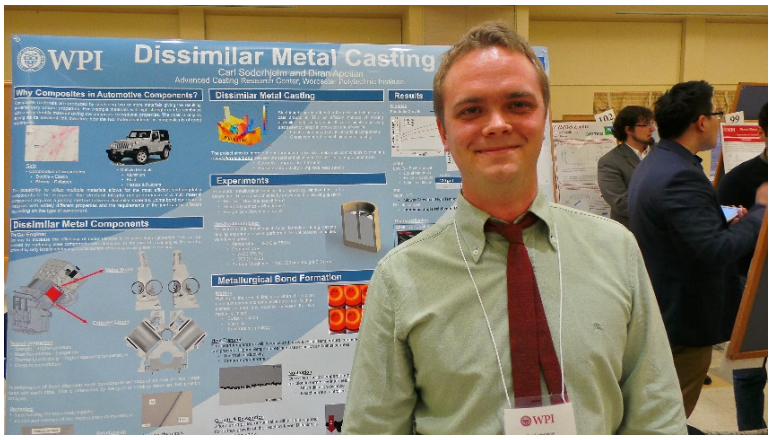
Measurements of human Tympanic Membrane (TM, eardrum) motions is challenging due to its required nanometer and microsecond spatio-temporal resolutions while maintaining a field-of-view of about six orders of magnitude larger than motions (~1 cm). Previously, we have developed holographic methods to measure continuous and transient responses of post-mortem TM's successfully. Available clinical TM diagnostics tools are currently limited to tympanometry and Laser Doppler Vibrometry, which lack the full-field motions. To expand our capabilities to invivo measurements, it is necessary to overcome such challenges as the influence of submillimeter physiological motions as well as the confined location of the TM. We are developing novel High-speed Digital Holographic Methods (HDHM) in combination with recently developed image and data processing algorithms to overcome such challenges. Our developments have unique capabilities that utilize the full spatio-temporal resolution of high-speed cameras (i.e., >147,000 points at >42,000 fps) to measure nanometer-scale TM motions in the audible range (0.02-20kHz). In this poster, we present, to the best of our knowledge for the first time, our preliminary holographic measurements on an anesthetized live chinchilla in a controlled anechoic chamber. The results establish the potential of HDHM as a hearing research and clinical tool to expand our understanding of the human hearing processes one-step further.

Title: Dissimilar Metal Casting

Finalist

Student: Carl Soderhjelm

Advisors: Diran Apelian



Abstract:

In nature and in life, it is the combination of different attributes together that provide unique properties. This is the case in bamboo, in cork, and in fact in ancient Chinese philosophy of yin and yang. In this vein, dissimilar metal casting is a cost effective production method for making bimetallic composite components. By combining the strength of steel with lightweight aluminum (Al) specific critical sections of a component can be strengthened. The metallurgical bond between the steel and the Al has to be strong enough to withstand stresses related to solidification, residual stresses, thermal expansion stresses, and all other stresses coupled with the use of the component. The objectives of this work have been to develop a ferrous insert that promotes the growth of a strong metallurgical bond with the aluminum during the casting process.

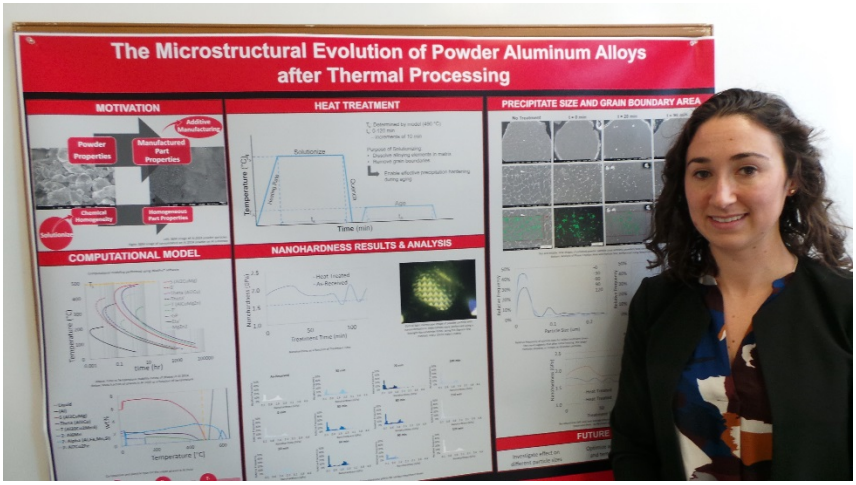
Title: Coronary Heart Disease Policy Analysis: A Simulation Of Medicare Patients

Student: Christine K. Tang
Advisors: Renata Konrad

Abstract:
Heart disease is the leading cause of death in the US. There lacks a cost-effectiveness model that considers the impact of both physician and patient incentives to determine the effect of physician and patient policies on patient health outcomes and costs. Our study focuses on Medicare beneficiaries. An Agent-Based Model simulates individual heterogeneous patients—each patient is assigned characteristics such as age, gender, and comorbidities. Patients enter the model in three possible states: no heart disease, having heart disease, or having heart disease with a heart attack in the prior year. Patients are simulated until death and can transition between different health states. Chances of a patient having a heart attack and/or dying are influenced by medication and procedures. These probabilities are determined from logistic regression models of Medicare data which consider patient characteristics. The probabilities were converted into rates and modified to adjust for mortality and heart attack risk reductions due to medication and
procedures. Certain medications and procedures are found to be more clinically effective than others. We evaluate different reimbursement and out-of-pocket payment policies. Utilization of medications and procedures change depending on costs. Using this model, we can better understand the effect of patient and provider incentives on patient outcomes and cost. We hypothesize that the model will confirm that eliminating the patient out-of-pocket costs for medication and incentivizing patients and providers towards more effective procedures will provide substantial cost savings for both Medicare and patients as well as improve patient health outcomes.

Title: The Microstructural Evolution of Powder Aluminum Alloys after Thermal Processing

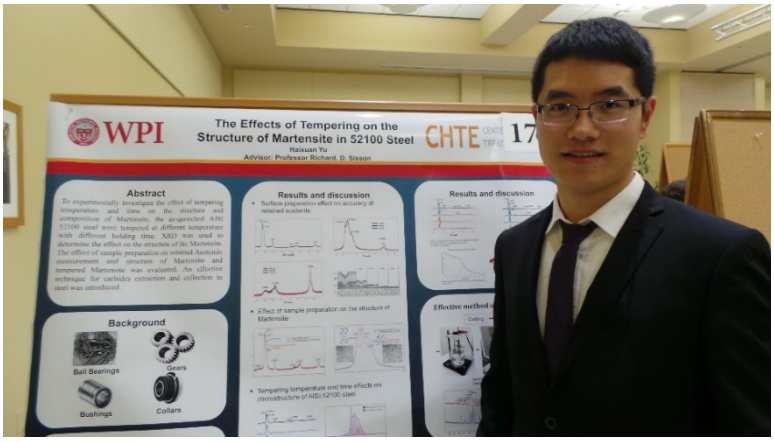
Student: Caitlin Walde
Advisors: Danielle Belsito, Victor Champagne, Richard D. Sisson, Jr.



Abstract:
Gas-atomized metallic powders are used in the additive manufacturing industry, and their post-processed properties are widely studied. However, little research has been done on the properties of the powders before processing, and how these properties may differ from those of a bulk sample of the same alloy. Understanding the characteristics of the powder before processing could lead to fine-tuning of the properties after the additive manufacturing process. This research studies the effect of various heat treatment processes on the characteristics and microstructural evolution of powder aluminum alloys. Treatment times and temperatures were guided by thermodynamic and kinetic modeling. Optical microscopy, scanning electron microscopy, and nanohardness were used to evaluate each condition. Experimental results are compared model predictions.

Title: The Effects Of Tempering On The Structure Of Martensite In 52100 Steel

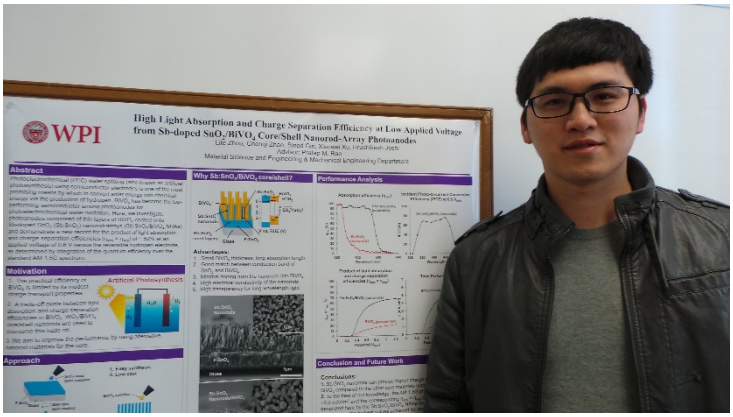
Student: Haixuan Yu
Advisors: Richard D Sisson, Jr



Abstract:
To experimentally investigate the effect of tempering temperature and time on the structure and composition of Martensite, AISI 52100 was Austenized at 1000°C for 40 minutes and quenched in agitated water at 21°C. The asquenched steel contained body-centered tetragonal (BCT) Martensite with 22% retained Austenite. These samples were tempered at 100°C, 200°C and 300°C with different holding time and characterized by X-ray Diffraction (XRD) to determine the effect on the structure of the Martensite. It was found that the content of retained Austenite didn't change after tempering at 100°C. Retained Austenite decomposed after tempering for 40 minutes at 300°C. The change of crystal structure and lattice parameter for tempered Martensite with different holding time and temperature were measured. The effect of sample preparation on retained Austenite measurement and structure of Martensite and tempered Martensite was evaluated. An effective technique for carbides extraction and collection in steel was introduced.

Title: High Light Absorption And Charge Separation Efficiency At Low Applied Voltage From Sb Doped Sno2/Bivo4 Core/Shell Nanorod-Array Photoanodes

Student: Lite Zhou
Advisors: Pratap Rao



Abstract:
BiVO4 has become the top-performing semiconductor among photoanodes for photoelectrochemical water oxidation. However, BiVO4 photoanodes are still limited to a fraction of the theoretically-possible photocurrent at low applied voltages because of modest charge transport properties and a trade-off between light absorption and charge separation efficiencies. Here, we investigate photoanodes composed of thin layers of BiVO4 coated onto Sb doped SnO2 (Sb:SnO2) nanorod-arrays (Sb:SnO2/BiVO4 NRAs) and demonstrate a new record for the product of light absorption and charge separation efficiencies (ηabs × ηsep) of ~52% at an applied voltage of 0.6 V versus the reversible hydrogen electrode, as determined by integration of the quantum efficiency over the standard AM 1.5G spectrum. To the best of our knowledge, this is the highest ηabs × ηsep efficiency achieved to date at this voltage for any photoanode, based on BiVO4 or any other material. Moreover, although WO3 has recently been extensively studied as a core material for core/shell BiVO4 photoanodes, the Sb:SnO2/BiVO4 NRAs generate larger photocurrents, especially at low applied voltages. In addition, we present control experiments on planar Sb:SnO2/BiVO4 and WO3/BiVO4 heterojunctions, which indicate that Sb:SnO2 is more favorable as a core material. These results indicate that integration of Sb:SnO2 nanorod cores with other successful strategies such as doping and coating with oxygen evolution catalysts, can move the performance of BiVO4 and related semiconductors closer to their theoretical potential.