

# GRIE POSTER PRESENTATIONS

## Manufacturing Engineering & Materials Science and Engineering

Wednesday February 8, 2017 – Odeum, Rubin Campus Center

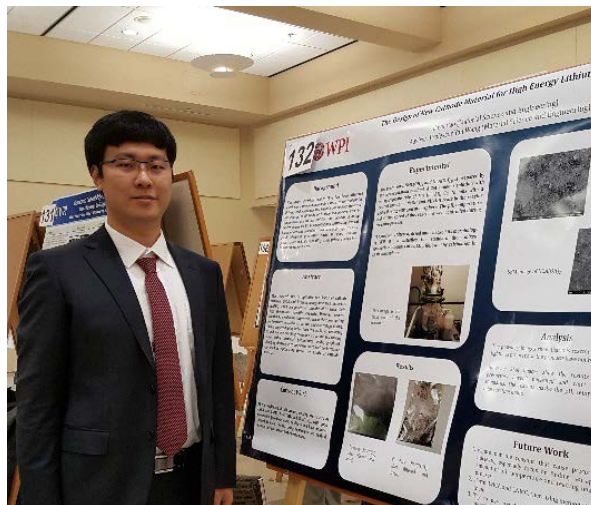
### Title: The Design of New Cathode Material for High Energy Lithium Ion Battery

Student: Jiayu Cao, PhD

Advisor: Yan Wang

#### ABSTRACT

This research aim to optimize two kinds of cathode material, LNCA and lithium manganese rich materials (LNMC), which are potential cathodes of EV since their high theoretical specific capacity. However several drawbacks need to be improved such as their low cycling performance, unstable structure, and fast voltage fading. In this project doping other ions (Na, K, Al, Sn) replacing Ni and Mn ions stabiling cathodes' structure and coating other stable material (Aluminum oxide, graphite), changing electrolyte to improve electrical performance are used to optimizing these two kinds of cathode material.



### Title: Growth Mechanism of NMC precursor particles

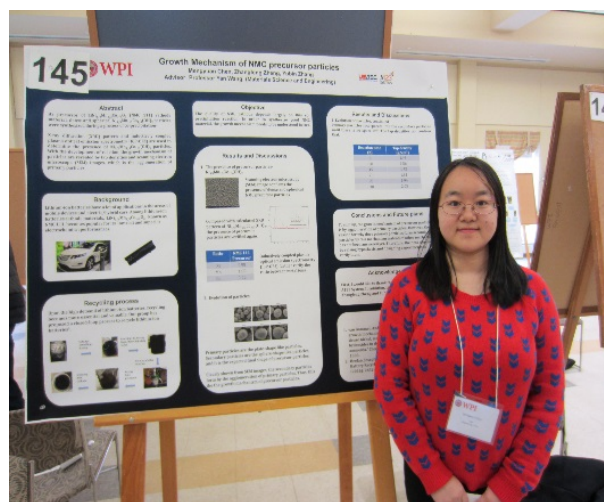
Student: Mengyuan Chen, PhD

Advisor: Yan Wang

#### ABSTRACT

As precursor of  $\text{LiNi}_{1/3}\text{Mn}_{1/3}\text{Co}_{1/3}\text{O}_2$  (NMC 111) cathode material, dense and spherical  $\text{Ni}_{1/3}\text{Mn}_{1/3}\text{Co}_{1/3}(\text{OH})_2$  particles were synthesized during a process of co-precipitation.

X-ray diffraction (XRD) pattern and inductively coupled plasma optical emission spectrometry (ICP-OES) are used to determine the presence of  $\text{Ni}_{1/3}\text{Mn}_{1/3}\text{Co}_{1/3}(\text{OH})_2$  particles. With the development of reaction, the growth mechanism of particles are revealed by tap densities and scanning electron microscope (SEM) images, which is the agglomeration of primary particles.



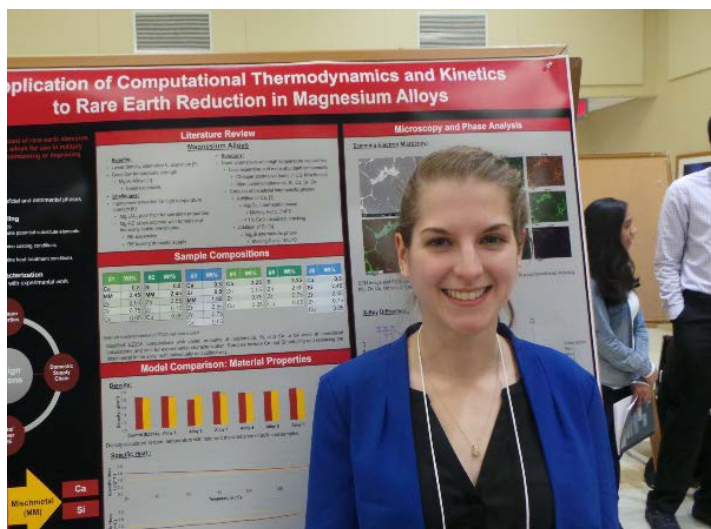
## Title: Application of Computational Thermodynamics & Kinetics to Rare Earth Reduction in Magnesium Alloys

**Student:** Kyle Fitzpatrick-Schmidt, PhD **Finalist**

**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



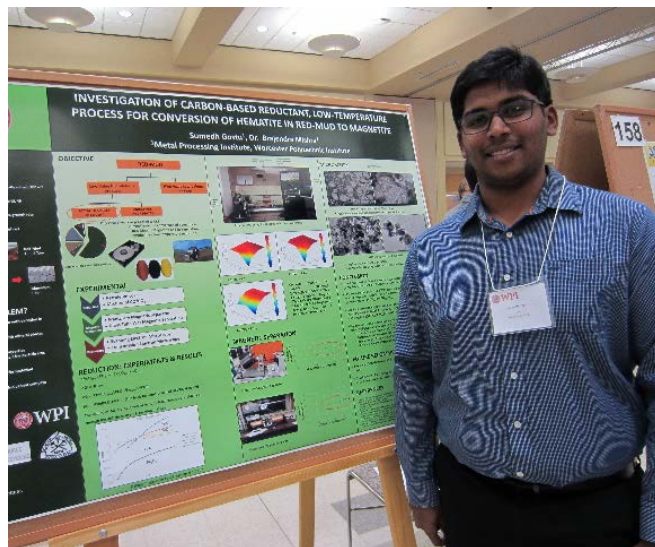
## Title: Investigation of a Low Temperature Reduction Process to Convert Hematite in Red-Mud to Magnetite

**Student:** Sumedh Gostu, PhD

**Advisor:** Brajendra Mishra

### ABSTRACT:

The alkaline residue red-mud is generated at a rate of 120 million tons per annum from current day primary alumina refineries, total accumulation being 3 billion tons worldwide. Due to lack of commercial utilization, vast amounts of untapped residue are landfilled, discharged in water bodies. The research reported focuses on extraction of metallic values namely Iron, Aluminum and Titanium from Jamaican red-mud, thereby contributing to environment and resource sustainability. The hematite in red-mud was converted to magnetite using a gaseous reduction route. Optimum conditions for reduction achieved were: a processing temperature of  $540^{\circ}\text{C} \pm 10^{\circ}\text{C}$ , partial pressures  $\text{CO}(\text{g})$  and  $\text{CO}_2(\text{g})$  each of  $0.070\text{atm} \pm 0.001\text{atm}$ , inert diluent-gas:  $\text{N}_2(\text{g})$ , for a conversion-time of 30min. Initial magnetic separation tests wet and dry on reduced magnetite are also reported.





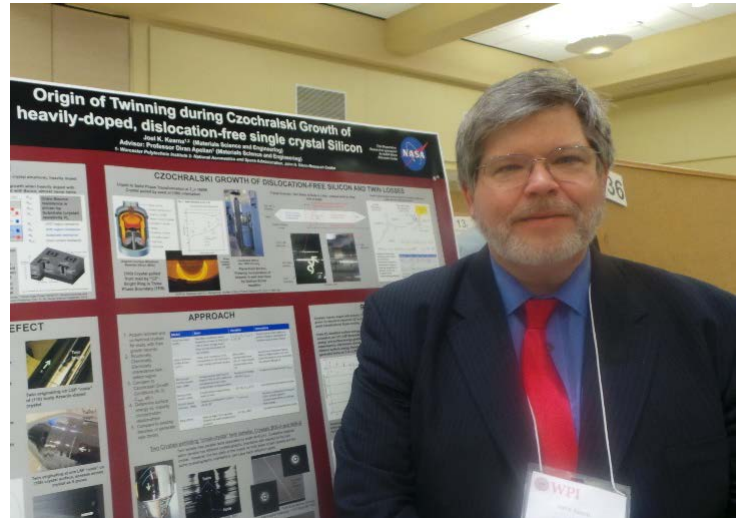
## **Title: Origin of Twinning during Czochralski Growth of heavily-doped, dislocation-free single crystal Silicon**

**Student:** Joel K. Kearns, PhD **Finalist**

**Advisor;** Diran Apelian

### **ABSTRACT**

Lower voltage power electronics are needed to enable low power consumption computers, routers, telecommunications and automotive devices. Low voltage power electronics are made from dislocation free silicon heavily doped with arsenic or antimony to provide low electrical resistivity. As crystal resistivities have been lowered to attempt to achieve lower device power losses, twinning of the crystal has unexpectedly occurred during growth, so that the crystal no longer possesses the required crystallographic orientation for device fabrication. Twinning renders the crystal unusable for devices. The only mechanism previously proposed to explain growth twinning in diamond cubic semiconductors such as silicon does not predict 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 designed to eliminate this defect mechanism, allowing lower resistivity crystals to be grown reliably. Several potential models are reviewed which may explain the twinning. Crystals that twinned during attempted growth are characterized for electrical, chemical and structural defects related to the proposed twin mechanisms. The presence of defects during growth, which encourage twin nucleation, are examined by electrical resistivity measurements, transmission and scanning electron microscopy, energy dispersive X-ray spectroscopy, secondary ion mass spectrometry, photoluminescence and x-ray diffraction. Initial results of optical microscopy, SEM, EDS and diffraction by Laue back-reflection will be discussed.



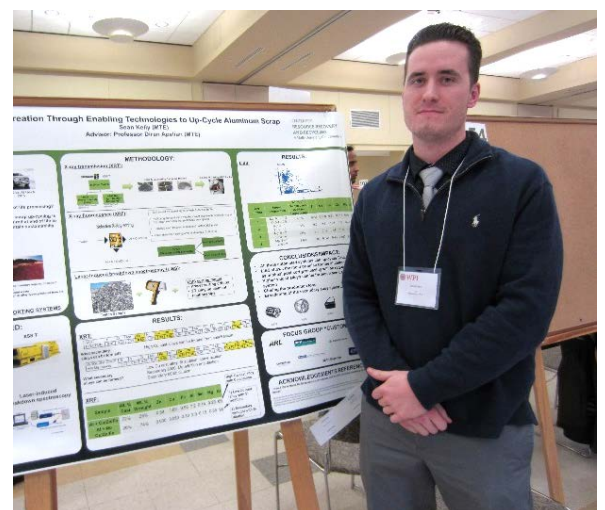
## **Title: Value Creation through Enabling Technologies to Up-cycle Aluminum Scrap**

**Student:** Sean Kelly **Finalist**

**Advisor:** Diran Apelian

### **ABSTRACT**

Many forms of aluminum scrap are down-cycled at end-of-life. Unfortunately, end-of-life processing of products containing aluminum is not optimized to allow for maximized reuse opportunities. By not creating value in our waste or scrap streams, one down-cycles rather than up-cycle, resulting in scrap surpluses and diminishing domestic utilization. The recycling loops of many old aluminum scrap classes are extensively open (not closed loop). With the advent of optoelectronic sorters and other enabling technologies, we can now up-cycle, create value from scrap; these developments have transformed how one deals with end-of life of products. The presentation will review these developments; investigating the capabilities and limitations of metallic sorting systems and characterizing mixed scrap classes to enhance end of life recycling rates.



# Title: Chemically etched fiber based optical tweezers

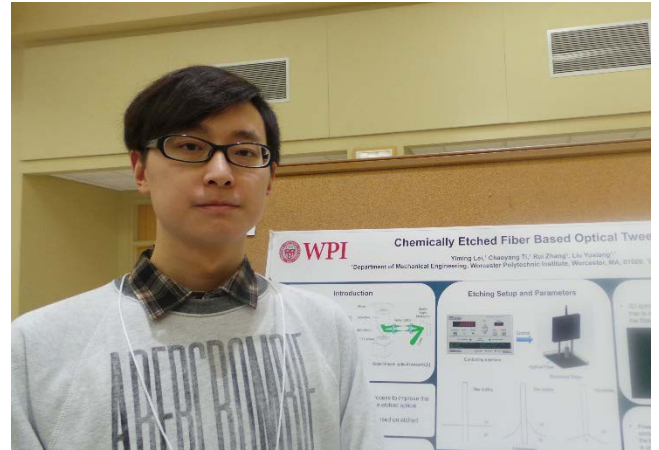
**Student:** Yiming Lei, MS

**Advisor:** Richard Sisson, Jr.

## ABSTRACT

Optical tweezers are scientific tools that can use optical beams to manipulate micro/nanoscale particles. It can apply force to particles due to the momentum transfer between the photons in the optical beam and particles. In most existing research, objective based optical tweezers have been used to accomplish 2D/3D trapping of micro/nanoscale particles. However, it's bulky, expensive, and inflexible. Fiber based optical trapping provides a solution to this challenge but has not been thoroughly studied.

Here we used chemically etched fibers to carry out the optical manipulation of microscale particles. Our objectives are: (1) to characterize the parameters of etching process to improve the repeatability and optical performance of the etched optical fibers; and (2) to design and characterize optical tweezers based on etched fibers. We explored the influence of etching time, solution proportioning, and fiber traction speed on the etching results. According to our experiment, the etching time has significant effect on final fiber geometry. In addition, we successfully achieved the 3D trapping of micro particles by single etched fiber. Particles with size ranging from 1 micrometer to 15 micrometer can be 3D trapped in water. The trapping spring constant was experimentally calibrated to be 90 pN/micrometer. Abilities of 3D trapping and force measurements allows the etched fiber optical tweezers to serve as a versatile tool in scientific research, especially in biology, physics and chemistry.



## Title: Solvent-Free Fabrication of Electrodes for Lithium-Ion Batteries via Additive Manufacturing

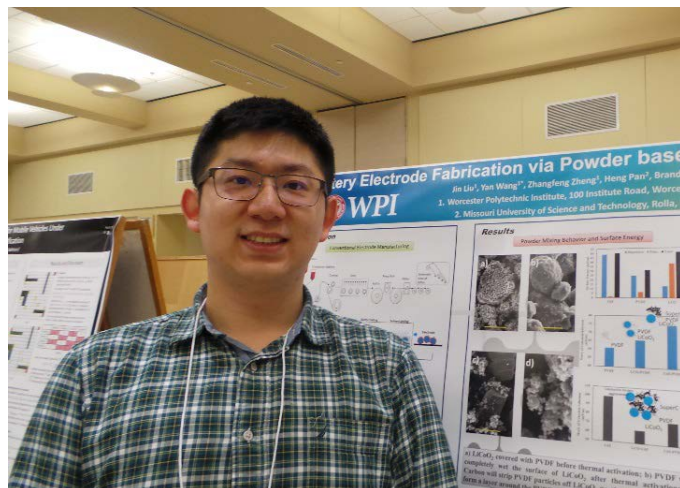
**Student:** Jin Liu, PhD **Finalist**

**Advisor:** Yan Wang

### ABSTRACT:

In the fabrication of lithium-ion electrodes, N-Methyl-2-pyrrolidone (NMP) is necessary as the solvent to make slurry. Due to its high cost and potential pollution problem, NMP have to be recovered by the drying procedure, which can take up to 24 hours at 120 °C for some electrodes. Therefore, electrodes fabricated in a completely dry processing way represent an ideal development orientation of manufacturing, thereby eliminating the usage of solvents and the disadvantages that come with using them.

Here we fabricated electrodes using a new, completely dry powder painting process. Thermal activation time has also been tremendously reduced due to a lowered time and resource requirement when the evaporation process is no longer needed and replaced by a hot rolling process. It has been found that inducing the mechanical bonding of the thermoplastic polymer to the remaining active electrode particles only takes a few seconds. Furthermore, this allows large-scale Li-ion battery production to be more economically viable in markets. Electrochemical results also show that our dry-painted electrodes outperform conventional slurry processed electrodes, which are due to their unique binder distribution based on our analysis. Bonding tests of the dry-deposited particles onto the current collector show that the bonding strength of them are greater than the ones of slurry-cast electrodes, 127.14 kPa as compared to 84.29 kPa. In addition, more electrodes design and optimization possibility on this new fabrication method are conducted and tested, and the fundamental researches on its specific electrode microstructure during manufacture and cycling are studied and recognized.



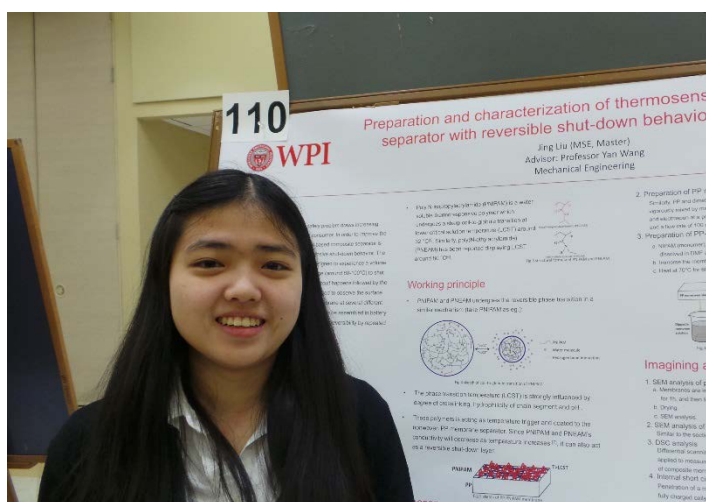
## Title: Preparation and characterization of thermosensitive composite separator with reversible shut-down behavior in batteries

**Student:** Jing Liu, MS

**Advisor:** Yan Wang

### ABSTRACT:

In daily application of batteries, the safety problem draws increasing attention from both manufacturer and consumer. In order to improve the safety of batteries, a functional polymer-based composite separator is developed with reversible thermos-responsive shut-down behavior. The polymer-based composite separator is designed to experience a volume phase transition at a high temperature range (around 80-100°C) to shut down the batteries when an internal short circuit happens followed by the thermal runaway effect. SEM analysis is applied to observe the surface structure of thermos-sensitive composite membrane at several different temperatures. The multi-layer separator will then be assembled in battery for further testing on its shut-down efficiency and reversibility by repeated increasing working temperature of battery.





# Title: Endoscopic shape and transient response measurements of tympanic membrane

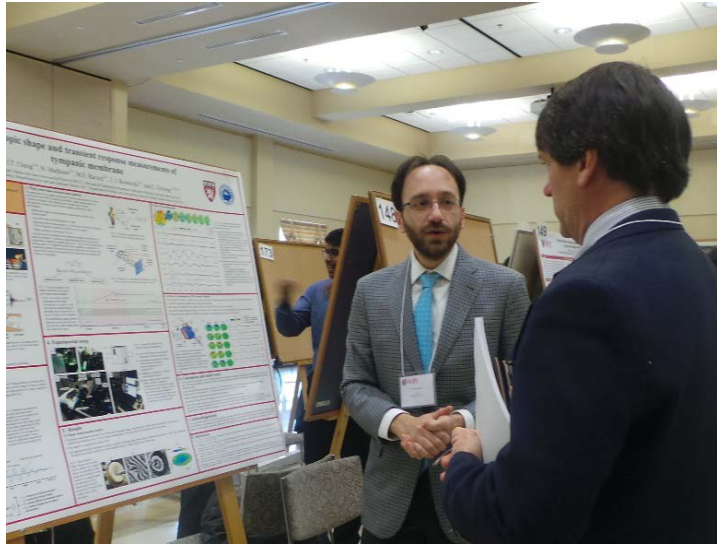
**Student:** Payam Razavi (PhD) **Finalist**

**Advisor:** John Rosowski, Cosme Furlong

## ABSTRACT

We are developing a High-speed Digital Holographic (HDH) system to measure acoustically induced transient response of live mammalian Tympanic Membrane (TM or eardrum) for hearing research and clinical applications. The optical head of the system is based on an otoscope configuration to illuminate and observe the TM with a single sensitivity vector and enabling full-field (i.e., >150,000 points) measurements of displacements with nanometers spatial and microseconds temporal (i.e., >80 kHz) resolutions, respectively. Due to the TM's characteristics such as its millimeter-scale cone shape and angled orientation at the end of the ear canal, knowledge of shape and TM orientation with respect to the otoscope head are necessary to compensate for spatial variations of the sensitivity vector for improved measuring accuracy.

In this paper, we report the incorporation of high-speed shape measurement capability into the HDH system. This task is performed with minimum hardware modifications, using the same imaging optics for shape and deformation measurements, under the limited triangulation space of a confined volume, and in the presence of in-vivo physiological motions. Based on these constraints a multiple wavelengths technique that utilizes a high-speed frequency sweep is developed to extract the shape of TM concurrently with transient displacement measurements. Shape measurements are validated by use of standardized gauges and applied to the transient measurements of displacements to compensate for the spatial variations of the sensitivity vector. The compensated measurements are compared against those obtained with a single sensitivity vector to demonstrate the importance of having shape information for the interpretation of transient displacements data.



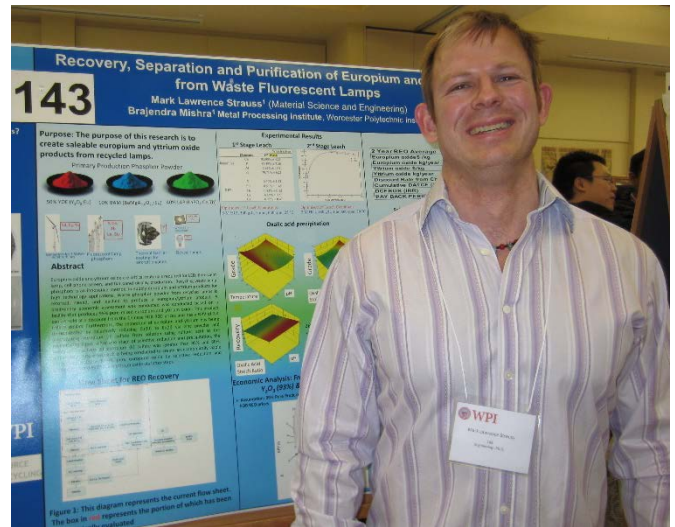
## Title: Selective Reduction and Separation of Europium from Mixed Rare-Earth Oxides from Waste Fluorescent Lamp Phosphors

**Student:** Mark L. Strauss **Finalist**

**Advisor:** Brajendra Mishra

### ABSTRACT:

Europium oxide and yttrium oxide are critical materials required for LED, florescent lamp, cell phone screen, and flat panel display production. The goal of this research is to produce a saleable europium oxide and yttrium oxide product. Recycling waste lamp phosphors is an innovative method to supply europium and yttrium products for high technology applications. Waste phosphor powder from recycled lamps is retorted, sieved, and leached to produce a europium/yttrium product. A preliminary economic assessment was conducted based on a facility that produces 99% pure mixed europium and yttrium oxide. This product can be sold at a discount from the Chinese FOB REO prices and has a NPV of 17.7 million dollars. Furthermore, the separation of europium and yttrium has being demonstrated by selectively reducing Eu(III) to Eu(II) via zinc powder and precipitating europium (II) sulfate from solution using sulfuric acid as the precipitating agent. After one stage of selective reduction and precipitation, the purity and recovery of europium (II) sulfate was greater than 95% and 80%, respectively. Future research is being conducted to create an economically viable process to produce 99.9% pure europium oxide by selective reduction and precipitation and 99.9% pure yttrium oxide via latter steps.



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

**Student:** Derek Tsaknopoulos, PhD **Finalist**

**Advisors:** Danielle Cote, Richard 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.



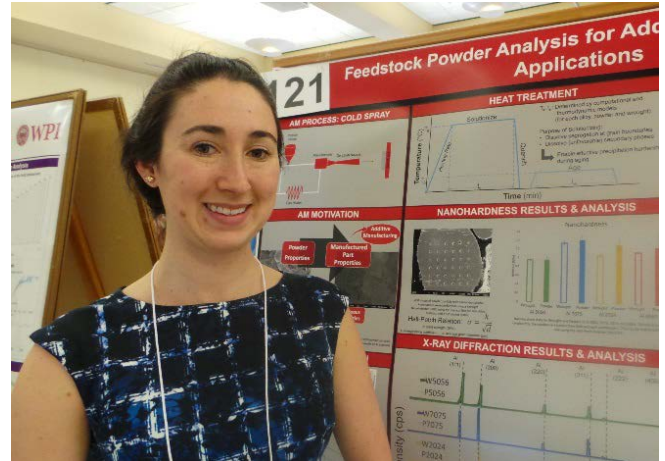
## Title: Feedstock Powder Analysis for Additive Manufacturing Applications

**Student:** Caitlin Walde, PhD

**Advisors:** Danielle Cote, Victor Champagne, Richard Sisson, Jr.

### ABSTRACT:

Gas-atomized metallic powders are commonly used in additive manufacturing processes. While their bulk and post-process consolidated properties are widely studied, there is little research on the properties of the powders before processing. Understanding the powder characteristics before use in additive manufacturing could lead to fine-tuning properties of additively manufactured materials, as the consolidated material properties are often dependent on the feedstock powder properties. This research compares the properties of four gas atomized aluminum alloy powders to their wrought counterparts in an effort to gain a comprehensive understanding of feedstock powder properties to improve effectiveness of additive manufacturing processes. Differential scanning calorimetry, x-ray diffraction, and microscopy techniques will be used.



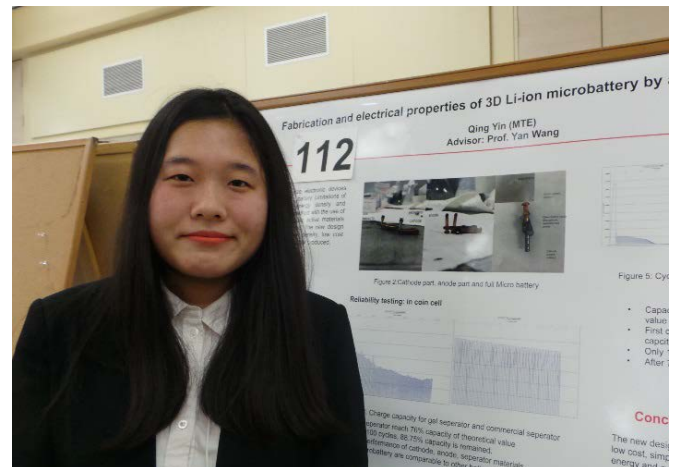
## Title: Fabrication and electrical properties of 3D Li-ion microbattery by a new sealing method

**Student:** Qing Yin, MS

**Advisor:** Yan Wang

### ABSTRACT:

The rapid development of the micro-size electronic devices require the downscaling of the lithium-ion battery. Limitations of the microbattery include size, cost, energy density and degradation. In this project, a new sealing method with the use of glass tubes, rod current collectors, injectable active materials and PVDF based gel separator is developed. The new design provides good hermeticity, high areal power density, low cost microbattery that has potential to be commercially produced.





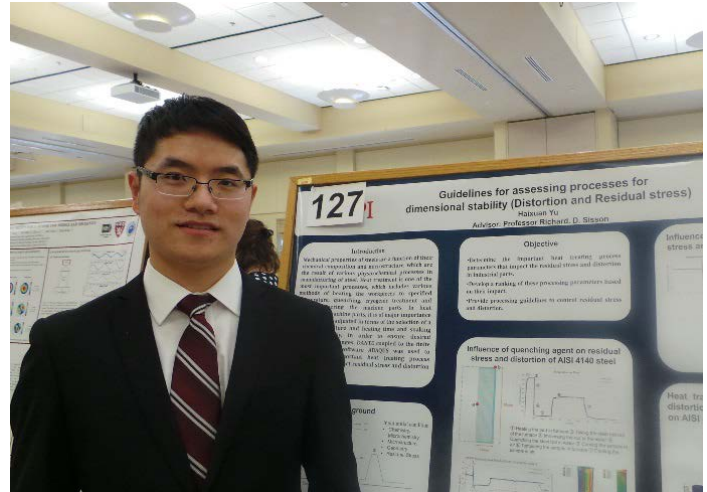
## **Title: Identification of the important process parameters to control distortion and residual stress during heat treating**

**Student:** Haixuan Yu, PhD

**Advisor:** Richard Sisson Jr.

### **ABSTRACT:**

Mechanical properties of steels are a function of their chemical composition and microstructure, which are the result of various physicochemical processes in manufacturing of steel. Heat treatment is one of the most important processes, which includes various methods of heating the workpieces to specified temperature, quenching, cryogenic treatment and finally tempering the machine parts. In heat treatment of machine parts, it is of major importance that heating be adjusted in terms of the selection of a proper temperature and heating time and soaking time, respectively, in order to ensure desired microstructure changes. DANTE coupled to the finite element analysis software ABAQUS was used to determine the important heat treating process parameters that impact residual stress and distortion in industrial parts.



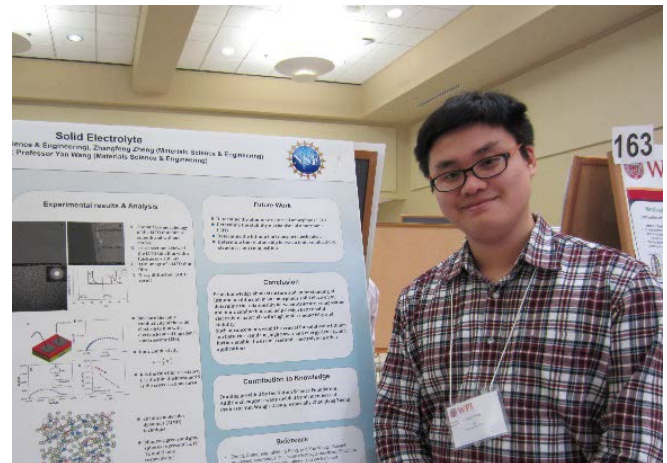
## **Title: Solid Electrolyte**

**Student:** Yubin Zhang, PhD

**Advisor:** Yan Wang

### **ABSTRACT:**

In this project, we apply Amorphous Lithium Lanthanum Titanium Oxide (LLTO) to determining the fundamental relationships between structure, composition and ionic transport properties of amorphous lithium ion solid electrolyte. The project fills the knowledge gap on structure, stability and lithium ionic transport mechanism in amorphous solid electrolytes. The high performance solid electrolyte developed in the project can be used in lithium ion batteries which require high stability, performance and durability.



# Title: Photoanode with enhanced performance achieved by coating BiVO<sub>4</sub> onto ZnO-templated Sb-doped SnO<sub>2</sub> nanotube scaffold

**Student:** Lite Zhou, PhD

**Advisor:** Yan Wang

## ABSTRACT:

Photoelectrochemical (PEC) water splitting (also known as artificial photosynthesis) using semiconductor electrodes is one of the most promising means by which to convert solar energy into chemical energy via the production of hydrogen. BiVO<sub>4</sub> has become the top-performing semiconductor among photoanodes for photoelectrochemical water oxidation. Here, we investigate photoanodes composed of thin and uniform layers of BiVO<sub>4</sub> particles coated onto Sb-doped SnO<sub>2</sub> (Sb:SnO<sub>2</sub>) nanotube arrays that were synthesized using a sacrificial ZnO template with controllable length and packing density. We demonstrate a new record for the product of light absorption and charge separation efficiencies ( $\eta_{\text{abs}} \times \eta_{\text{sep}}$ ) of  $\sim 54.3\%$  and  $56.3\%$  under front- and back-side illumination at  $0.6 V_{\text{RHE}}$ .

