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MS Graduate Students

High Energy Density Flow Batteries

Authors:
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Abstract:
In the drive towards improved electrical energy storage for applications ranging from electric vehicles to grid stabilization and renewable energy storage, the important role and great need of electrochemical storage and batteries specifically will continue, due to batteries’ high energy density, simplicity, reliability, and potential for favorable performance/cost ratio. A redox flow battery combines the advantages of conventional batteries and fuel cells, and can be designed for high power applications as well for high capacity electricity storage. However, they have low power density (~40mA/cm2) and energy density (~30Wh/L) because of the solubility limit of active materials in solution, which prevent them from being widely used. Here we propose to demonstrate a new type of flow battery with Ni/Zn chemistry in a state of suspension, which offers high power and energy densities. The success of the proposed research can provide a new solution for the energy storage with high energy density, high power density, high safety, low cost, and long cycle life.

Cold spray modeling: An analytical method for predicting bulk properties of cold spray deposits

Authors:
Student: Luke Bassett
Advisor: Richard D. Sisson, Jr.

Abstract:
Cold spray deposition is a rapidly growing material consolidation process in which ductile particles, typically metal, are accelerated by a high velocity gas stream and impinged onto a substrate with sufficient energy to induce bonding. The subsequent consolidated structure has very high strength and hardness when compared to a similar wrought alloy, and can be built up to any reasonable desired thickness. Predictive modeling has been carried out for various portions of the process; however there is currently no all-encompassing model that can calculate the final microstructure and bulk properties based on process parameters and material characteristics. The goal of this project is to develop a complete model that integrates existing models with new predictive calculations to fill in portions that are currently lacking or inadequate. The resulting model will be validated using experimental results.
Process Control Modeling for Laser Assisted Cold Spray: A Novel Deposition Technique

Authors:
Student: Aaron Birt
Advisor: Richard D. Sisson, Jr.

Abstract:
Cold spray is a deposition process whereby particles are accelerated via a high temperature and pressure gas through a DeLaval nozzle to supersonic speeds. The particle then impacts a substrate and adheres due to extreme localized conditions. These particles can range from metals and cermets, to polymers and composites, and can be deposited to generate either a coating or a free-standing structure. The cold spray process has many applications including corrosion repair, antimicrobial surfaces, structural repair of damaged systems, and additive manufacturing. However, cold spray has only recently become a mainstream process thus there are gaps in the knowledge bases for many applications. This thesis will focus on increasing the ability of the end user to control the deposition process by developing a series of models to control parameters such as particle velocity, temperature, and composition so that rather than estimating the parameters needed to achieve a desired quality the user may consciously choose the parameters. In order to have an added measure of control over the conditions of the substrate and particles, a high-powered laser will be attached directly to the cold spray nozzle so that the laser can preheat the substrate, ablate the existing oxide layer, or preheat the particles depending on the its exact orientation. The development of numerical and experimental models for the Laser Assisted Cold Spray process will enable the user to match the precise parameters needed to generate a deposit of the quality and size desired.

Friction Stir Processing in Wrought and Cast Aluminum Alloys

Authors:
Student: Ye Cao
Advisor: Diana A. Lados

Abstract:
Friction Stir Processing (FSP) of various aluminum alloys including wrought 6061 and cast A356, 319, and A390 has been systematically investigated in this study. These alloys were judiciously selected to understand the effects of Si level, type, and morphology and to evaluate the contributions of different secondary phases and strengthening precipitates on processing and properties. Critical processing parameters, including tool rotation and traverse speeds, have been systematically evaluated to determine the optimized processing conditions for each alloy. The effects of processing on microstructure, hardness, tensile properties, and fatigue crack growth behavior of the alloys were studied and will be presented and discussed.
Characterization of Rice Husks for Potential Development of Biopolymers

Authors:
Student: Ziyong Chen  Co-Author: Satya Shivkumar
Advisor: Satya Shivkumar

Abstract:
Rice husk is a major biomass that is abundant, renewable and thus promising for the development of biodegradable polymers. The physical structure of rice husks between two different varieties of long grain rice have been evaluated in this study. The results show that the wall of the rice husk consists of 3 different layers with full and hollow fibers with different orientations. The fibers consist predominantly of cellulose and hemicellulose. Rice husk also contains about 10% moisture and about 20-25% silica. The different varieties of rice husk have a similar structure, but different thicknesses of various layers and different diameters for the fibers. Silica is concentrated mostly in the outer layer and is the main reason why rice husks need to be modified before they can be used to develop biodegradable polymers or employed as reinforcing agents in other polymers.

The Synthesis and Stabilization of Porous Silicon-Carbon Core-Shell Anode Material for Li- ion Batteries

Authors:
Student: Meinan He
Advisor: Yan Wang

Abstract:
Problems
Silicon is a very promising anode material for lithium ion battery. It has a 4200mAh/g theoretical capacity, which is ten times higher than that of commercial graphite anode of lithium ion battery. However, the pulverization and capacity fading is caused by the dramatic volume changes, when the lithium ions diffuse to silicon anode, and the volume of silicon will expand to almost 400% of its initial size. Such huge volume change would cause significant capacity fade. Also, the solid electrolyte interphase (SEI), which is generated during the cycling, would reduce the discharge capacities. That is still challenging its widespread application of this material.
Solutions
1. Etching the silicon particles to form a porous structure, the pores in silicon can provide much more space for the lithium ions diffusion.
2. Forming a layer of amorphous carbon inside the pore, so that it could become a good buffer area for the volume change and improve the conductivity of the Si, and stabilize the SEI.
**Semi-Solid Redox Ni/Zn Flow Battery**

**Authors:**
Student: Wenhuan Li  
Advisor: Yan Wang

**Abstract**
Unlike traditional flow battery that has a low capacity as the solubility's limit of the solvent, we make a new kind of flow battery with semi-solid suspension. It has the advantage of flow battery that is easy to change anode/cathode materials and a capacity almost 20 times higher than conventional ones. The new semi-solid redox flow battery has a widely usage in areas of electric dynamic (electric automobile), energy storage and electric power for industry.

**High Voltage Cathode Material LiNi$_{0.5}$Mn$_{1.5}$O$_4$**

**Authors:**
Student: Fan Liu  
Advisor: Yan Wang

**Abstract**
LiNi$_{0.5}$Mn$_{1.5}$O$_4$ is a promising material since it has high energy density. Synthesized the material through a solid-state reaction and assembled the battery. Tested its capacity and stability. XRD test was used to characterize the crystal structure and phase purity. SEM images clearly revealed the shape of the particles and degree of agglomeration. Charge/discharge tests indicated that the LNMO sample had good cyclic performance.

**Microstructural Characterization and Analysis of Cold Spray Al Alloys**

**Authors:**
Student: Baillie McNally  
Advisor: Richard D. Sisson, Jr.

**Abstract:**
The U.S. Military requires structural materials that offer significant weight reduction with improved performance, multi-functionality, durability, and cost reduction to enhance the lethality and survivability of military vehicles and advanced weapon systems. To meet that need, new high strength, high toughness, lightweight alloys are being developed. The primary focus of this effort is to develop an aluminum alloy powder that can be consolidated by the cold spray process, as well as by more conventional means. Thermomechanical process parameters will be manipulated in thermodynamic and kinetic models to establish the optimum microstructure of the material. Current work focuses on the experimental characterization used to verify and enhance our thermodynamic and kinetic modeling efforts. Microstructural analyses of powder and consolidated cold spray Al 6061 will be presented through optical, scanning electron and transmission electron microscopy, and x-ray diffraction techniques.
A Novel and Cheap Method to Make Safe Solid State Lithium Ion Batteries

Authors
Student: Fan Yang
Advisor: Yan Wang

Abstract:
The rechargeable lithium ion battery market was approximately $11.8 billion in 2010 and is expected to be $53.7 billion in 2020. It is evident that lithium ion batteries will dominate the electric car industry within the next 5-10 years due to their high energy density and auto makers’ striving to meet CO2 emission standards. However, conventional lithium ion batteries with liquid electrolyte can be dangerous for fire and/or explosion. Sony has recalled 7 million lithium ion batteries on laptops due to the safety concern in 2006. Hybrid and electric vehicles, for example the GM volt, Nissan Leaf, and Tesla Roadster, need to use large lithium ion battery packs with thousands of cells. Safety with the use of lithium ion batteries in hybrid or electric vehicles is a big concern. Also, GM Volt battery fires has threatened all electric vehicle manufacturers and Boeing 787 groundings also trace to lithium ion batteries. Solid-state lithium ion batteries can be one of the candidates for next-generation lithium ion batteries, which leads to high cost. In this research, we adopted Sol-Gel to fabricate the solid state lithium ion batteries. Different sol solutions are coated on Aluminum current collector by spin coating, which can significantly lower the cost of solid state lithium ion batteries. The electrochemical results shown that the batteries we made works well, which has a great potential to revolutionize the lithium ion battery industry.

Additive Manufacturing of Ti-6Al-4V: Microstructure, Properties, and Fracture Mechanisms

Authors
Student: Yuwei Zhai
Advisor: Diana A. Lados

Abstract:
High strength-to-weight ratio, high melting point, and excellent corrosion resistance give Ti alloys significant advantages for structural transportation applications. However, up to 95% material waste caused by traditional subtractive manufacturing makes this material prohibitively expensive for regular use. Additive Manufacturing (AM) represents an advanced “Layered Forming” technology that offers a promising solution to this problem. In the AM process, a solid 3D CAD model is first “sliced” into layers, which will be the "tool-path" for directly accumulating material powders or wires into net/near-net shapes layer-wise. Hence, AM ensures design flexibility, less material waste, and manufacturing efficiency. A variety of AM techniques, including Laser Engineered Net Shaping (LENS), Electron Beam Freeform Fabrication (EBF3), and Laser Powder Bed (LPB) have been developed to fabricate metallic materials with intricate and precise geometries. Studies have shown that metallic components fabricated by AM are fully-dense and have properties comparable to those of wrought materials. However, systematic fundamental studies and property databases of AM fabricated metallic materials are very limited. In this study, Ti-6Al-4V alloy fabricated using the LENS technology was investigated. The resulting microstructures were extensively characterized and correlated to relevant processing parameters. Room temperature tensile and fatigue crack growth tests were performed to understand the static and dynamic behavior of these materials. Fatigue crack propagation mechanisms in AM materials have also been identified and used for material/component design and optimization.