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Cycling and X-ray Diffraction Studies of Battery Electrode Materials
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Project Summary
Adopting the Li-ion battery as a large-scale grid energy storage technology is likely to place increased pressure on the limited global supply of lithium as burgeoning markets compete for supply [1,2]. The sodium (Na) ion battery presents a cost-effective alternative based on a more earth abundant electroactive material [2]. Analogous electrode materials can be used in Li-ion and Na-ion batteries [1–5]. However, the interaction between Na ions and these materials manifests in distinct behavior compared to their Li-ion analogs [3,4]. Tin (Sn) is one such material that demonstrates high capacity in both Li-ion and Na-ion systems [5–7]. Some of the microstructural changes seen in Sn-based anodes for Li-ion batteries exist for Na-ion batteries. However, volume expansion may be delayed during sodiation and significant pulverization on the removal of Na from Sn has not been observed [3,4].

The current project seeks to expand the understanding of interactions between microstructure and chemistry in high capacity Sn anodes for Na-ion batteries. It is expected that volume expansion reduces specific surface area available for electrochemical reaction and degrade mesoscale networks that support mass and charge transport. As an initial step we are working to connect changes in Sn anode crystal structure with electrochemical performance. Electrochemical testing and X-ray diffraction are being applied to discern phase transitions underlying changes in Sn anode electrochemical performance and capacity loss.

Student Prerequisites: Sophomore or higher standing is preferred for participation in this project.

Student Duties
The student researcher will assist in several aspects of the project. Primary responsibilities will focus on the fabrication and testing of batteries and supporting XRD studies of pristine and cycled anode materials. The student will perform a brief literature survey to assess reaction rates, voltages and relevant reaction mechanisms, and the related microstructural changes that occur during the sodiation of Sn. The student researcher will then be introduced to methods for mixing electrode inks, casting battery electrodes, and assembly of batteries. Once initial batteries are assembled the student researcher will be introduced to electrochemical testing methods with a focus on performing battery cycling tests. The student researcher will then develop a basic design of experiments (DOE) to test the influence of cut-off voltages and cycle number on the phases present in the cycled Sn active material.

The student researcher may also assist with electrochemical testing of Li-ion batteries, tomographic image processing, and 3D image analysis. Contributions in this area will be tailored based on the student’s interest and aptitude for experimental or computational work.

Several benefits can be expected from completion of the above tasks. In the first task the student researcher will be introduced to the basics of literature reviews for research purposes. Test matrix development based on findings from the literature review will introduce the student to statistical
design of experiments concepts and related statistical analysis methods. The student researcher will also perform a number of basic laboratory tasks to support analysis efforts. Most notably materials preparation and handling experience will be gained. The opportunity for introduction to optical and electron microscopy and other materials characterization and electrochemical testing methods will be available.

**Mentor Supervision and Interaction**

The student researcher will work with the above faculty mentor and a graduate research assistant on the above project. The student researcher will have daily contact with the graduate research assistant during a standard work week. The student researcher will have several interactions with the faculty mentor during the week as well. These interactions will include a weekly one-on-one meeting with the faculty mentor, weekly research group meetings, and regular lab sessions with the faculty mentor and graduate assistant present.

During one-on-one meetings the student researcher will be expected to provide a brief weekly update on progress, challenges, and plans for the coming week. Additional discussion of research methods and career interests will be handled during these meetings as well. At the end of the first three weeks of the research project the student will be expected to provide a brief presentation on their literature review efforts and planned activities for the remainder of the summer. This presentation will be given at a broader research group meeting. At the end of the summer, the student researcher will be expected to provide a presentation to the research group summarizing their efforts and findings.

**Prior Awards**

2015, Affordable Additive Manufacturing of Electrochemical Energy Conversion Devices: This project focused on characterizing inks for printing of dye-sensitized solar cells. The student was introduced to ink fabrication and characterization processes. Following the RCEU the student continued working in my group, ultimately completing a M.S. degree through the JUMP program.

2017, Inkjet Printing of Composite Electrodes for Battery Applications: This project focused on adapting an inkjet printer to produce battery electrodes from customized inks. The student was introduced to electrode fabrication processes and contributed to developing a means of handling foil current collectors in a standard inkjet printer. Following the RCEU the student continued working in my group prior to taking an industry internship.

**References**