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Development of Batteries for In Operando Neutron Imaging

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RCEU 2022 Project Proposal

Project Title

Development of Batteries for In Operando Neutron Imaging

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I. Project Description

A variety of direct 3D imaging methods have been applied to observe lithium-ion battery electrode microstructure. X-ray tomography permits the non-destructive studies of battery materials at resolutions of microns down to 17 nm. This method has been performed to observe microstructural changes in lithium-ion batteries that occur due to operation and to observe catastrophic failures like thermal runaway in real-time. While X-ray imaging is well suited for observing micron and nanometer scale phenomena in batteries, it has limited ability to connect the microstructure of lithium-ion battery electrodes to their aggregate performance. Current state-of-the-art approaches focus on finding representative microstructural properties and connecting those representative properties to performance through modeling and measurement of battery electrochemical behavior. Neutron imaging can provide the capability to observe lithium within composite electrodes at larger scales. Furthermore, pulsed neutron sources permit time-of-flight imaging of batteries that can reveal variations in crystal structure related to battery state-of-charge. However, test battery geometry tailored for neutron imaging experiments must be specially design to permit extraction of useful image data.

The Multiscale Transport and Energy Conversion research group at UAH has an on-going effort to design custom lithium-ion batteries that can be used in neutron imaging experiments. These experiments include: *i.*) correlating the real-time movement of lithium during battery cycling to electrode microstructural through multiscale imaging and ii.) application to time-of-flight neutron imaging techniques to observe localized crystal structure changes in lithium batteries.

II. Student Duties, Contributions, and Outcomes

a. Specific Student Duties

The student researcher will assist in several aspects of the project. Primary responsibilities will focus on the fabrication and testing of batteries. The student will perform a brief literature survey to assess current research on battery imaging methods using X-rays and neutrons. An initial set of sources will be provided. The student will be tasked with finding 4-5 additional journal papers related to the papers provided, and a brief review of these papers will be completed. The student researcher will then be introduced to methods for mixing electrode inks, casting battery electrodes, and the 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 to characterize performance of custom batteries designed to support neutron imaging efforts. Throughout the research experience, the student researcher will work with graduate research assistants to update and improve documentation of lab practices.

The student researcher may also assist with electrochemical testing of sodium-ion batteries, as well as radiographic and tomographic image analysis. Contributions in these areas will be tailored based on the student's interest and aptitude for experimental or computational work.

b. Tangible Contributions by the Student to the Project *(10% of Review)*

The student will fabricate batteries and acquire data from testing batteries that will support development of neutron imaging methods for batteries. The faculty advisor, graduate research assistant, and the selected RCEU student will develop an experimental plan for a set of studies that fit within the broader context of this research effort. The batteries tested may be shared with collaborators at Department of Energy User Facilities for neutron imaging tests. In addition to these project specific contributions, the student will contribute to updates and improvements in the documentation of lab practices.

c. Specific Outcomes Provided by the Project to the Student *(30% of Review)*

Several benefits can be expected from completion of this project. In the first task the student researcher will be introduced to the basics of literature reviews for research purposes. The selected student will receive training in the fabrication and testing of batteries that are critical to future energy infrastructure. This training will include: *i*) mixing of electrode inks and casting of electrodes, *ii*) battery assembly in a controlled atmosphere glove box *iii*) electrochemical performance testing *iv*) documentation and presentation of research results. In addition to these outcomes, the student will receive training in laboratory safety and an introduction to fundamental concepts related to electrochemical energy storage.

III. Student Selection Criteria

Sophomore or higher standing is preferred for participation in this project. Experience with hands-on work that may translate well to a laboratory setting is preferred. Knowledge of data processing tools such as Excel and Matlab is also preferred.

IV. Project Mentorship *(30% of Review)*

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, monthly research group meetings, and regular lab sessions with the faculty mentor and graduate research 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.