Hawaiʻi Natural Energy Institute Research Highlights

Electrochemical Power Systems

Battery Electrode Optimization

OBJECTIVE AND SIGNIFICANCE: This project aims at the optimization of battery electrodes to improve performance by understanding local degradation mechanisms and by tuning the electrode architecture.

BACKGROUND: Advanced energy conversion devices typically rely on composites electrodes made of several materials interacting with one another. Understanding their individual and combined impact on degradation is essential in the pursuit of the best possible performance and safety. In this project, we use our expertise in Li-ion battery diagnosis as well as designs of experiments (DoE) to optimize formulations and to investigate the importance of process parameters while minimizing resources.

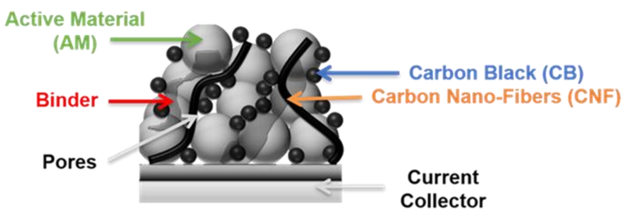

Figure 1. Schematic of the typical electrode architecture for intercalation-based batteries.

Defining new approaches to minimize experiments and time to reach an optimal battery electrode composition is highly beneficial to the field. To this end, we used a DoE mixture design that was applied for the first time in open literature to electrode formulation. Consequently, the relationship between electrode composition, microstructure, and electrochemical performance was uncovered.

PROJECT STATUS/RESULTS: In this project, the DoE approach was applied to two types of electrodes: high power electrodes for lithium batteries (ONR funded, in collaboration with the University of Montreal) and sodium intercalation electrodes to investigate the feasibility of desalination batteries (DOI then ONR funded, in collaboration with Trevi Systems). In addition, recent work focused on battery cooling and the development of a thermal dummy cell that thermally behaves like a battery without the risks associated with it. Taking a segmented approach will allow to account for the impact of thermal gradients, a major issue impacting cell durability and safety.

A high-power battery system was optimized in collaboration with the University of Montreal. This work has led to two publications. Current work on the desalination batteries showcased that Prussian blue analogues can intercalate and release sodium ions in real sea water more than 15,000 times with improved performance compared to traditional materials (CDI).

Finally, a first prototype of the segmented thermal dummy cell demonstrated the potential of the approach for the safe development of new innovative cooling solutions.

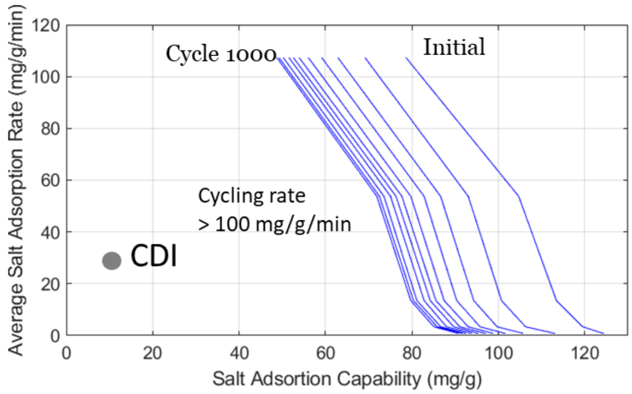

Figure 2. Performance characteristics of novel intercalation materials for desalination batteries.

In addition, our expertise in battery degradation was used to help researchers at the Naval Research Laboratory to characterize the impact of local temperature gradients on individual electrodes and by researchers at Sandia National Laboratories to investigate the impact of overcharge.

Research conducted for this project is completed in the **PakaLi Battery Laboratory**. This program has led to three publications and several presentations, which are listed on the following page.

Funding Sources: Office of Naval Research; U.S. Department of Interior; Trevi Systems

Collaborations: University of Montreal (Canada); University of Nantes (France); Naval Research Laboratory; Sandia National Laboratories

Contact: Matthieu Dubarry, matthieu@hawaii.edu

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ADDITIONAL PROJECT RELATED LINKS

PAPERS AND PROCEEDINGS:

1. 2021, R. Carter, et al., **Directionality of thermal gradients in lithium-ion batteries dictates diverging degradation modes**, Cell Reports Physical Science, Vol. 2, Issue 2, Paper 100351. (Open Access: **PDF**)
2. 2020, O. Rynne, et al., **Exploiting Materials to Their Full Potential, a Li-Ion Battery Electrode Formulation Optimization Study**, ACS Applied Energy Materials, Vol. 3, Issue 3, pp. 2935-2948.
3. 2019, O. Rynne, et al., **Designs of Experiments for Beginners—A Quick Start Guide for Application to Electrode Formulation**, Batteries, Vol. 5, Issue 4, Paper 72. (Open Access: **PDF**)

PRESENTATIONS:

1. 2023, C.T. Love, et al., **Evidence of the Interplay of Temperature on Local and Global Battery Phenomena**, presented at the 244th Electrochemical Society Meeting, October 8-12. *Keynote presentation*.
2. 2022, N. Sahin, et al, **Optimization of Prussian Blue Analogues for Na-Ion Desalination Batteries**, Poster presented at the Material Research Society Spring Meeting, May 8-13. *Best poster award Symposium EN05*.
3. 2022, C. T. Love, et al., **How Dynamic Thermal Evaluation of Battery Electrodes and Materials Better Replicate In-Service Operating Conditions**, Presented at the Material Research Society Spring Meeting, May 8-13.
4. 2021, T.A. Kingston, et al., **Altering the Degradation Mode in Li-ion Batteries Through Directional Application of an Interelectrode Thermal Gradient**, Presented at the International Mechanical Engineering Congress & Exposition, November 1-5.
5. 2021, C. T. Love, et al., **Electrode Specific Degradation Tailored By the Directionality of Thermal Gradients in Li-Ion Batteries**, Presented virtually at the 240th ECS Meeting, Orlando, FL, October 10-14.
6. 2021, C. T. Love, et al., **Directionality of Thermal Gradients in Li-Ion Batteries Dictates Diverging Failure Modes**, Presented virtually at the 239th ECS meeting, Chicago, IL, May 30 - June 3.
7. 2019. O. Rynne, et al., **Influence of the Formulation on the Microstructure and Thus Performance of Li-Ion Batteries**, Presented at the 235th ECS Meeting, Dallas, TX, May 26-30.