Battery Electrode Optimization

OBJECTIVE AND SIGNIFICANCE: The objective of this project is to improve battery 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.

PROJECT STATUS/RESULTS: 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.

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.

Recent work focused on battery cooling and the development of a segmented thermal dummy cell that thermally behaves like a battery without the risks associated with its usage. Taking a segmented approach will allow to account for the impact of thermal gradients, a major issue impacting cell durability and safety.

Most efforts over the past year were devoted to the development of the second prototype of the segmented thermal dummy cell that demonstrated heating and cooling rate similar that of the ones of real lithium-ion batteries. In addition, our expertise in battery degradation was used to help researchers at the Naval Research Laboratory 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 work has led to three publications and several presentations, which are linked on the following page.

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

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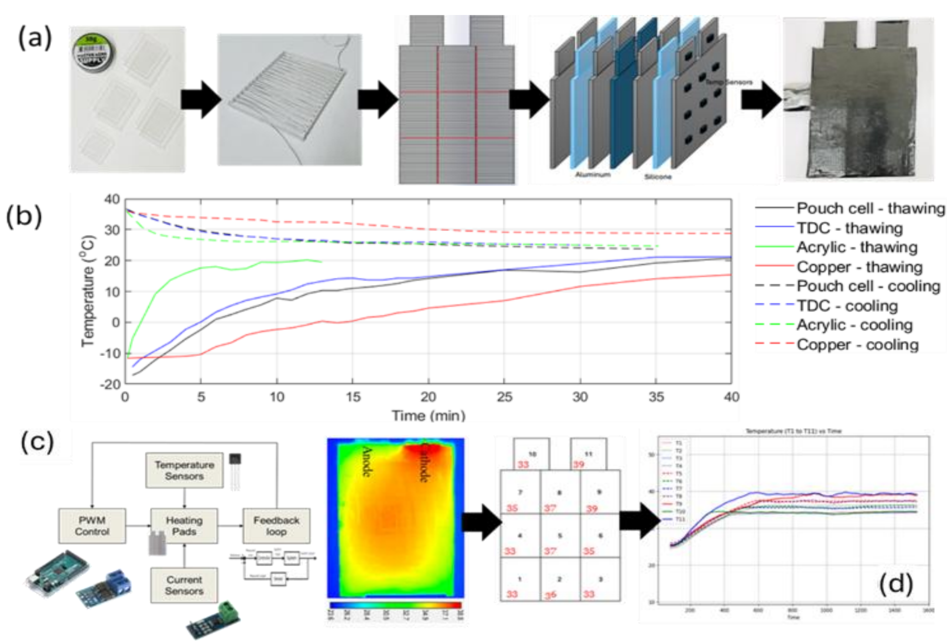

Figure 1. Generation 1 TDC with (a) the fabrication of the segments and assembly into the device; (b) comparison of the thawing and cooling rate between the TDC, a real pouch cell, an acrylic panel, and a copper plate; (c) the control scheme allowing the simulation of inhomogeneous heating; and (d) an example of inhomogeneous heating.

<u>ADDITIONAL PROJECT LINKS</u>

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. 2025, R. Carter, T.A. Kingston, P.J. West, J. Knuerr, J-S. Park, V. Cooley, L.V. Morris, M. Dubarry, G.H. Waller, C.T. Love, **The Role of Thermal Variations in Battery Degradation: In-Situ Detection in 18650s Correlated to Fundamental Phenomena Investigation in Single-Layer Pouch and Coin Cells**, Presented at the 248th Electrochemical Society Meeting, Chicago, IL, October 12-16.
2. 2025, M.M.U. Ishtiaque, J. Ramamurthy, Q. Alahmad, M. Dubarry, C.L. Pint, T.A. Kingston, **Correlating Thermal Gradient and Ionic Migration Directionality to Lithium-Ion Battery Electrochemistry**, Presented at the 247th Electrochemical Society Meeting, Montréal, Canada, May 18-22.
3. 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*.
4. 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.*
5. 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.
6. 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.
7. 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.
8. 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.
9. 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.