In-Operando Thermal Diagnostics of Electrochemical Cells

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June 12, 2019

Project ID: bat427

Overview

Timeline

- Project start: 7/1/16
- Project end: 9/30/19
- 85% complete

Budget

- Total project funding: $300k
- Funding for FY 2017: $300k*
  - *until project completion

Barriers and Technical Targets

- Barriers addressed
  - Extreme fast charging (can tolerate more Joule heating if improve battery thermal conductivity)
  - Safety (reduced risk of thermal runaway)
  - Performance & life (reduced cyclic thermal stresses; reduce “cold start” problem)

Partners

- Energy Storage Group, LBNL
- Project lead: Applied Energy Materials Group, LBNL

Relevance: Thermal Problems in Batteries

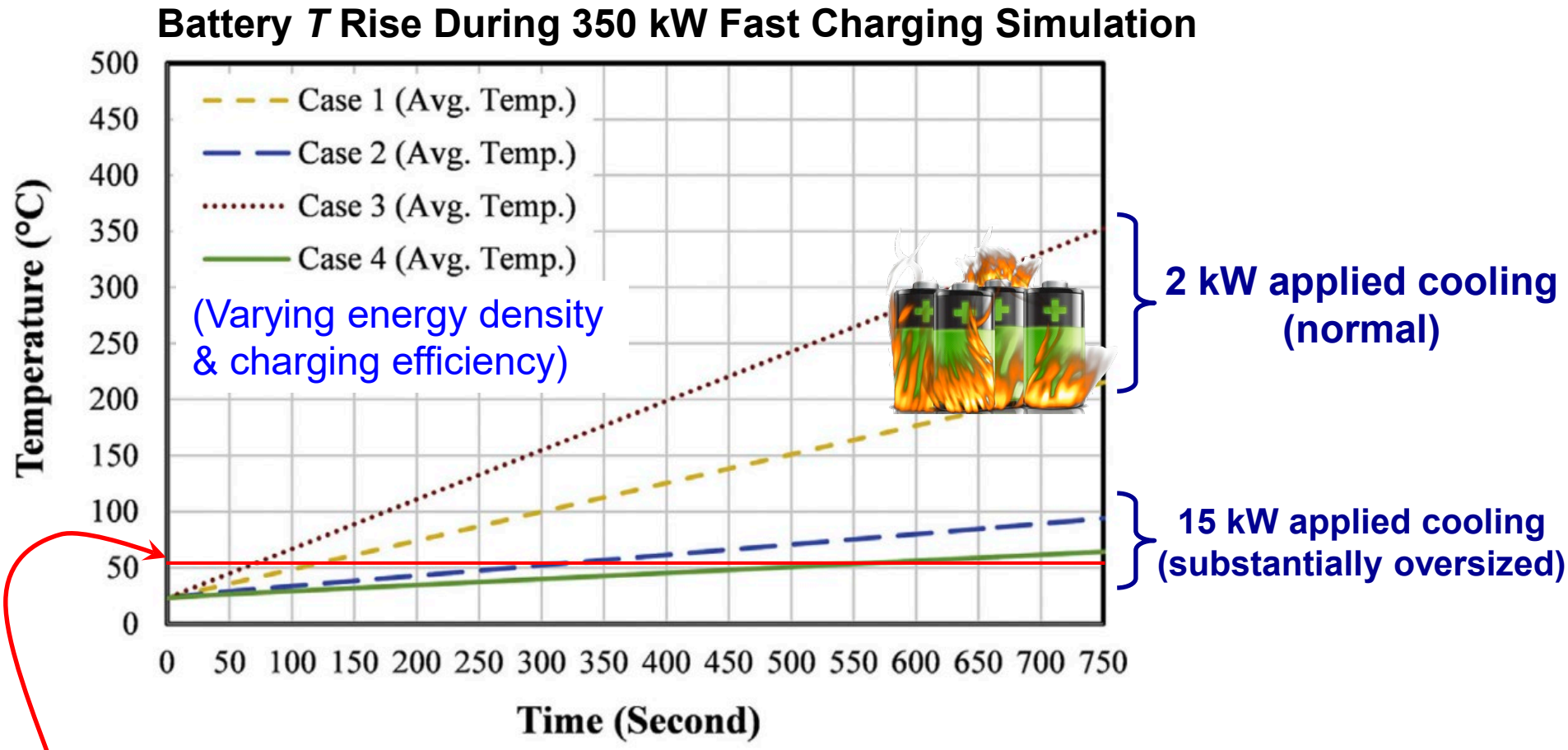
Reducing ΔT inside battery will improve…

1) Extreme Fast Charging (XFC; can tolerate more Joule heating)

2) Safety (reduced risk of thermal runaway)

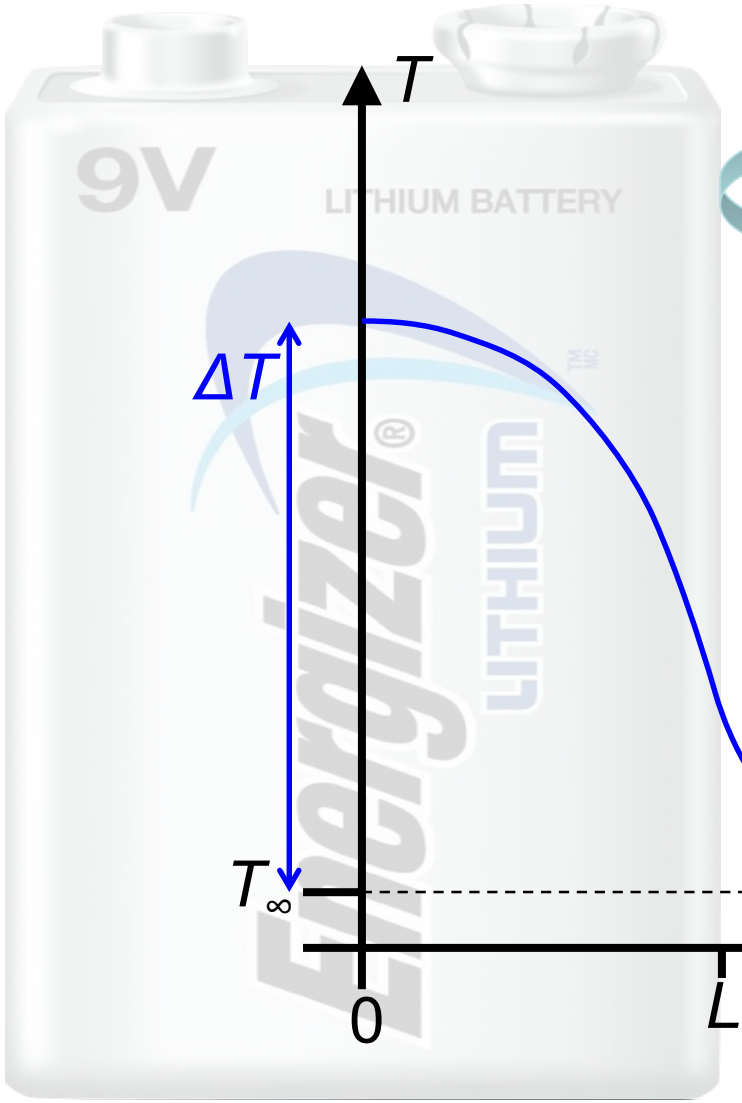
3) Performance & life (reduced cyclic thermal stresses)

Relevance: Thermal Problems in Batteries



M. Keyser *et al.*, "Enabling fast charging – Battery thermal considerations," *J. Power Sources*, vol. **367**, pp. 228–236, 2017.

We Need a Materials-Level Solution

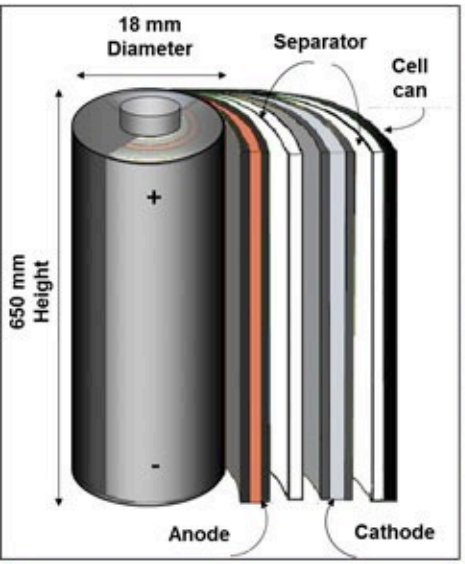


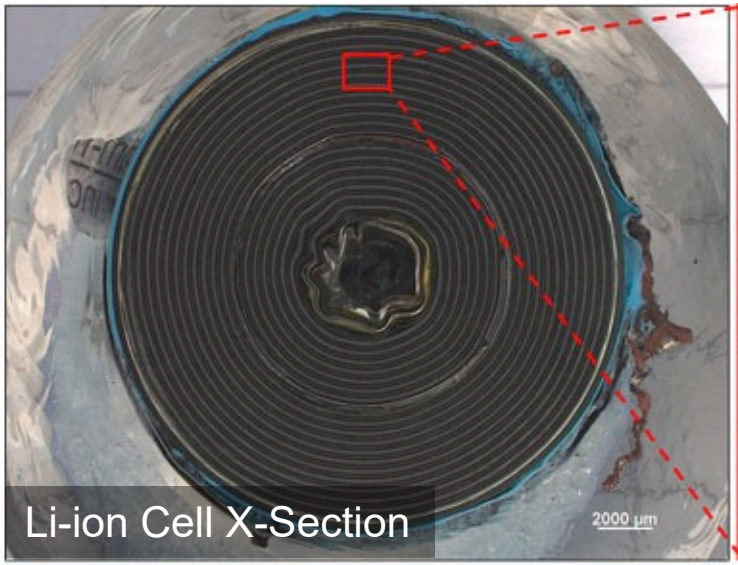
System-level thermal management
Forced convection (air or liquid)

$$\Delta T_{Battery} = \dot{Q}'''\left(\frac{L^2}{2k} + \cancel{\frac{L}{h}}\right)$$

Cannot solve thermal problem with cooling systems alone

Thermal Transport *Within* Li-Ion Battery





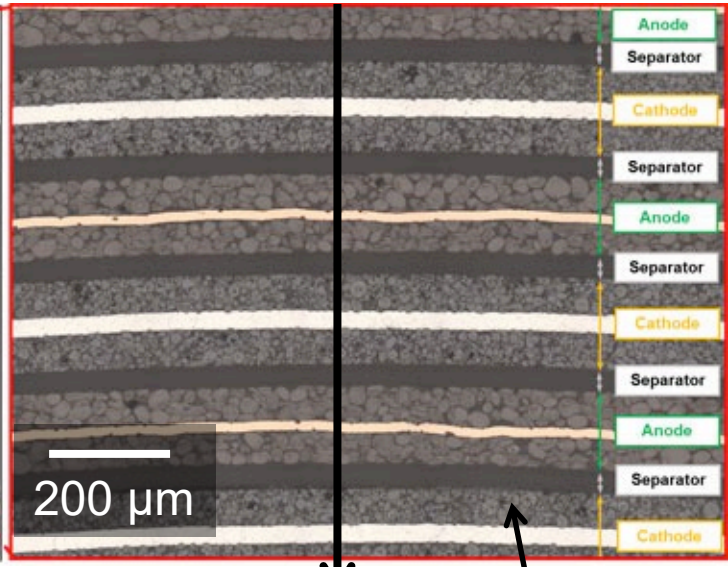
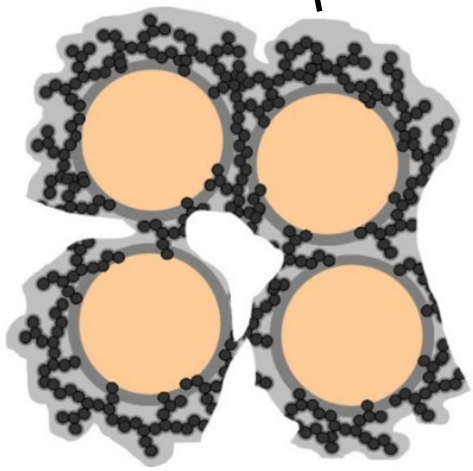


Image from www.zeiss.com



Messy! Porous, composite, polydisperse…

Metrology Needs: measure thin multilayered system *in-situ* with electrolyte

$$k(z)\frac{\partial^2 T}{\partial z^2} + \dot{Q}'''(z) = C(z)\frac{\partial T}{\partial t}$$

Milestones

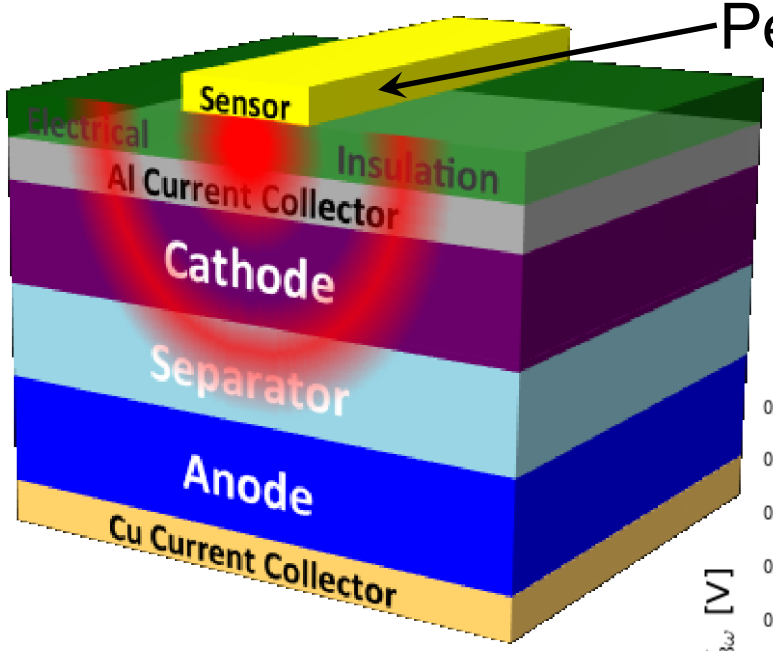
Quarter	Milestones & Go/No-Go	Status
Q1, FY18	TDTR Measurements of ideal battery samples	Complete
Q2, FY18	3*ω* sensors fabricated; metrology developed	Complete
Q3, FY18	3*ω* sensors integrated onto battery electrodes	Complete
Q4, FY18	Baseline *operando* measurements performed (**Go/No-Go**)	Complete
Q1, FY19	*Ex-Situ* high accuracy measurements	Complete
Q2, FY19	Robust thermal model developed	Complete
Q3, FY19	3*ω* measurements from cathode & anode side	On Track
Q4, FY19	Detailed *operando* measurements performed	On Track

Approach

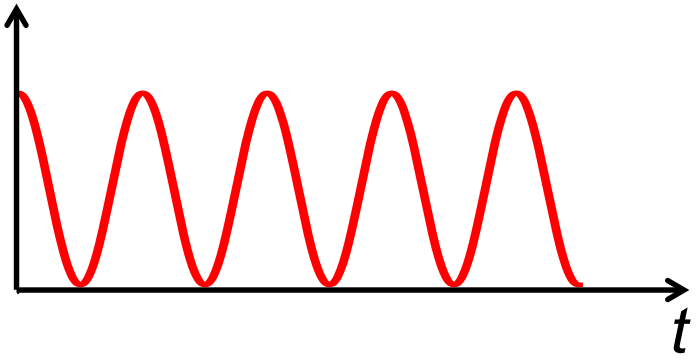
- Develop metrology that can measure thermal transport properties within a functioning li-ion battery

- Apply metrology to understand source of “thermal bottleneck” inhibiting fast transport of heat in/out of the cell

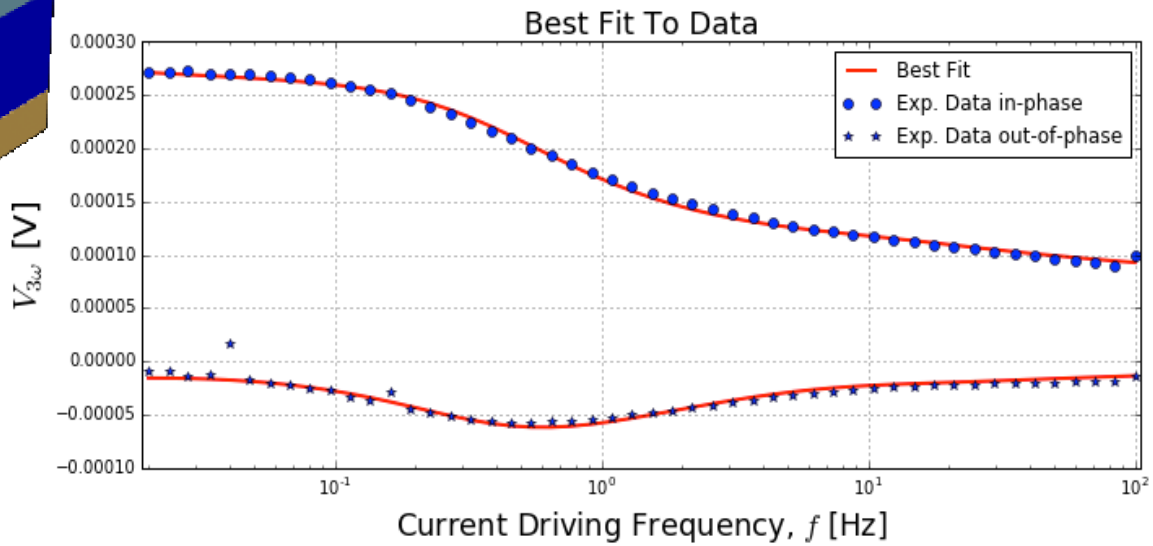
Approach: *Operando* Measurements



Periodic Joule Heating



The "3ω Method"

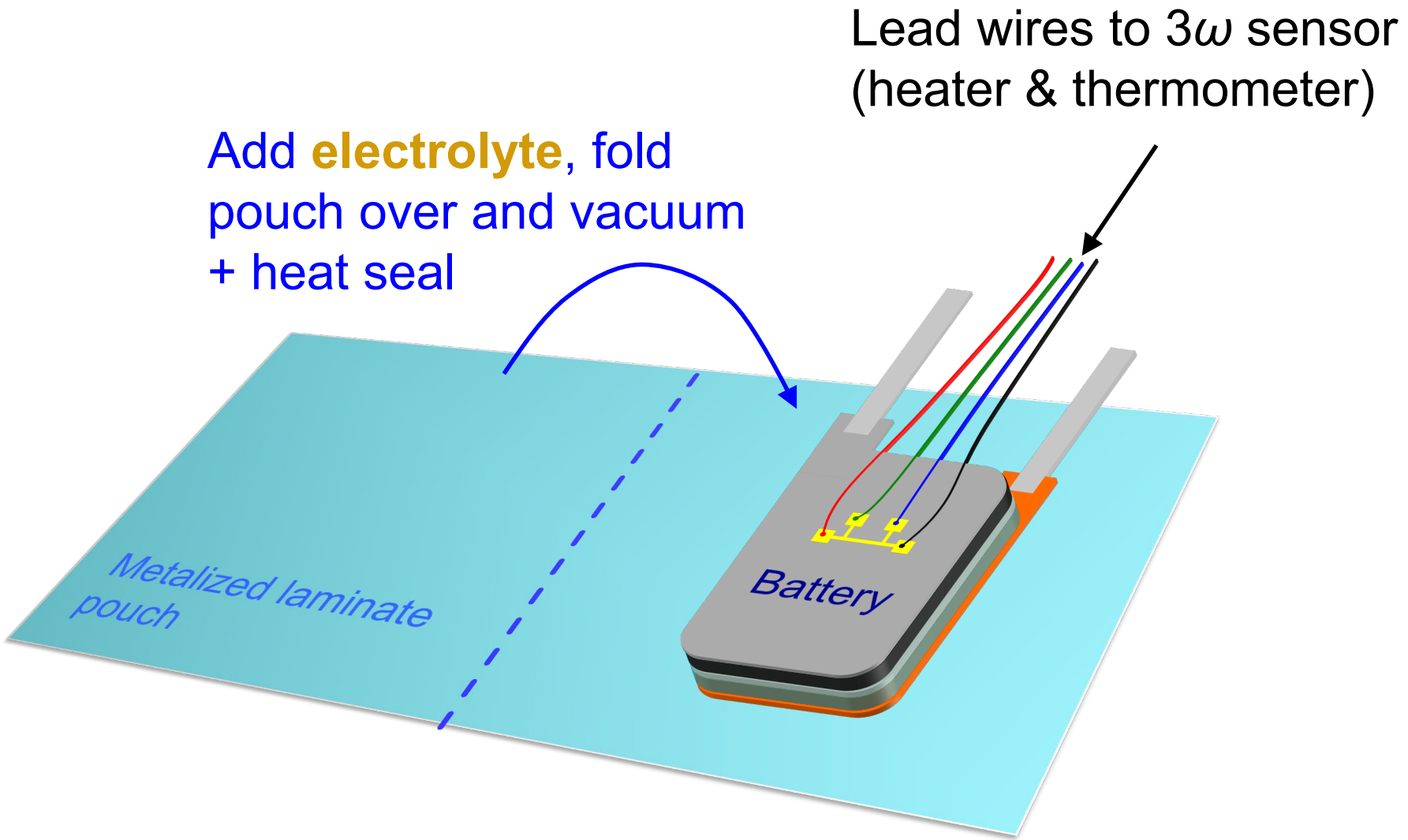


Sensitive to **bottom** layers/interfaces

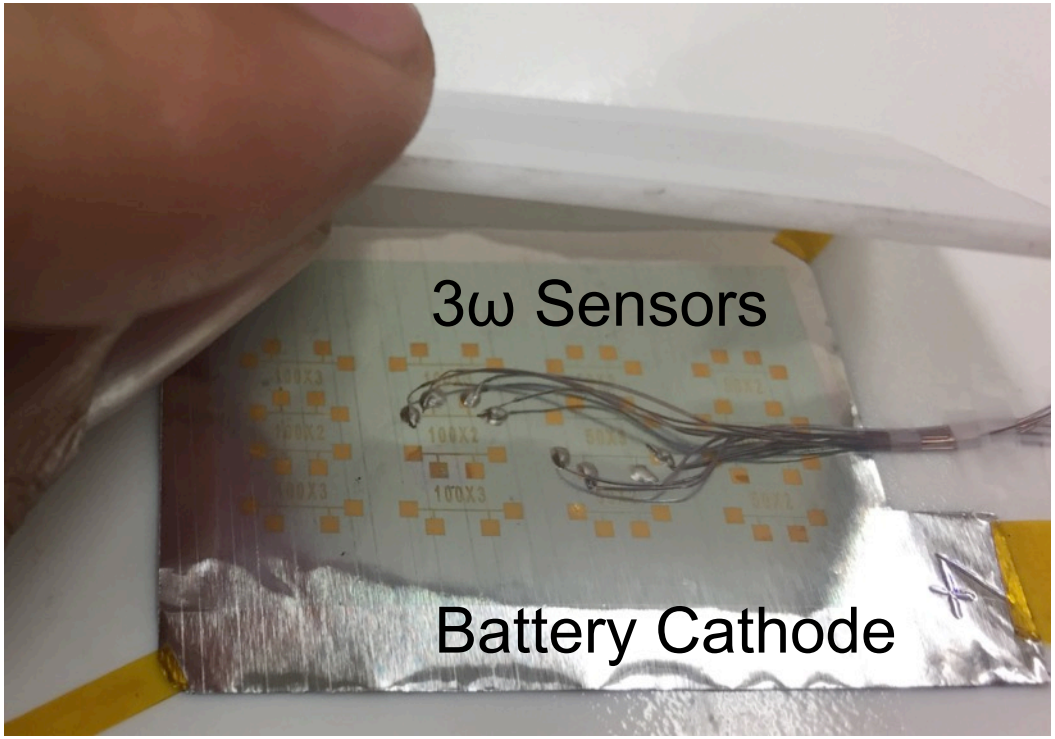
Sensitive to **middle** layers/interfaces

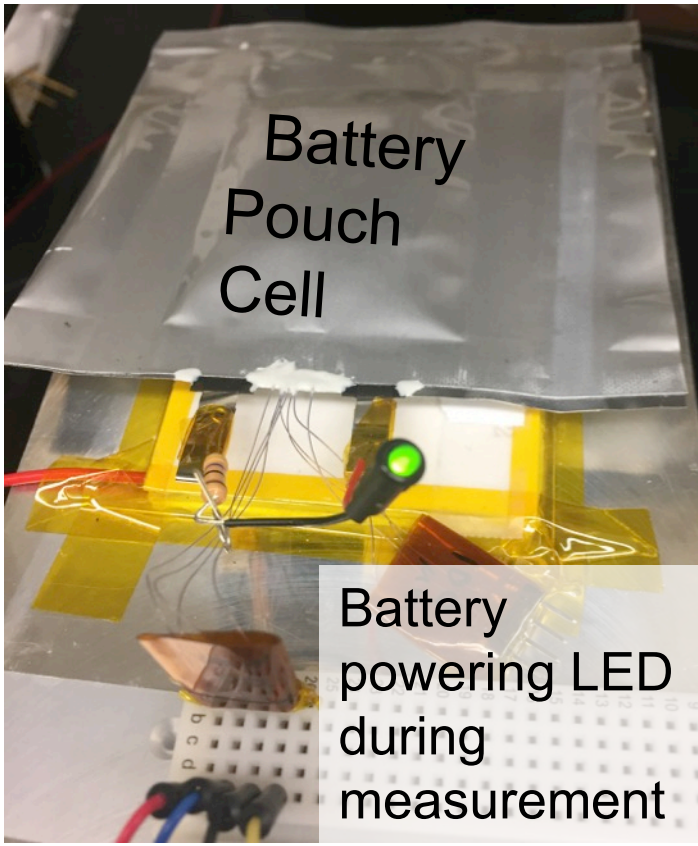
Sensitive to **top** layers/interfaces

Approach: *Operando* Measurements

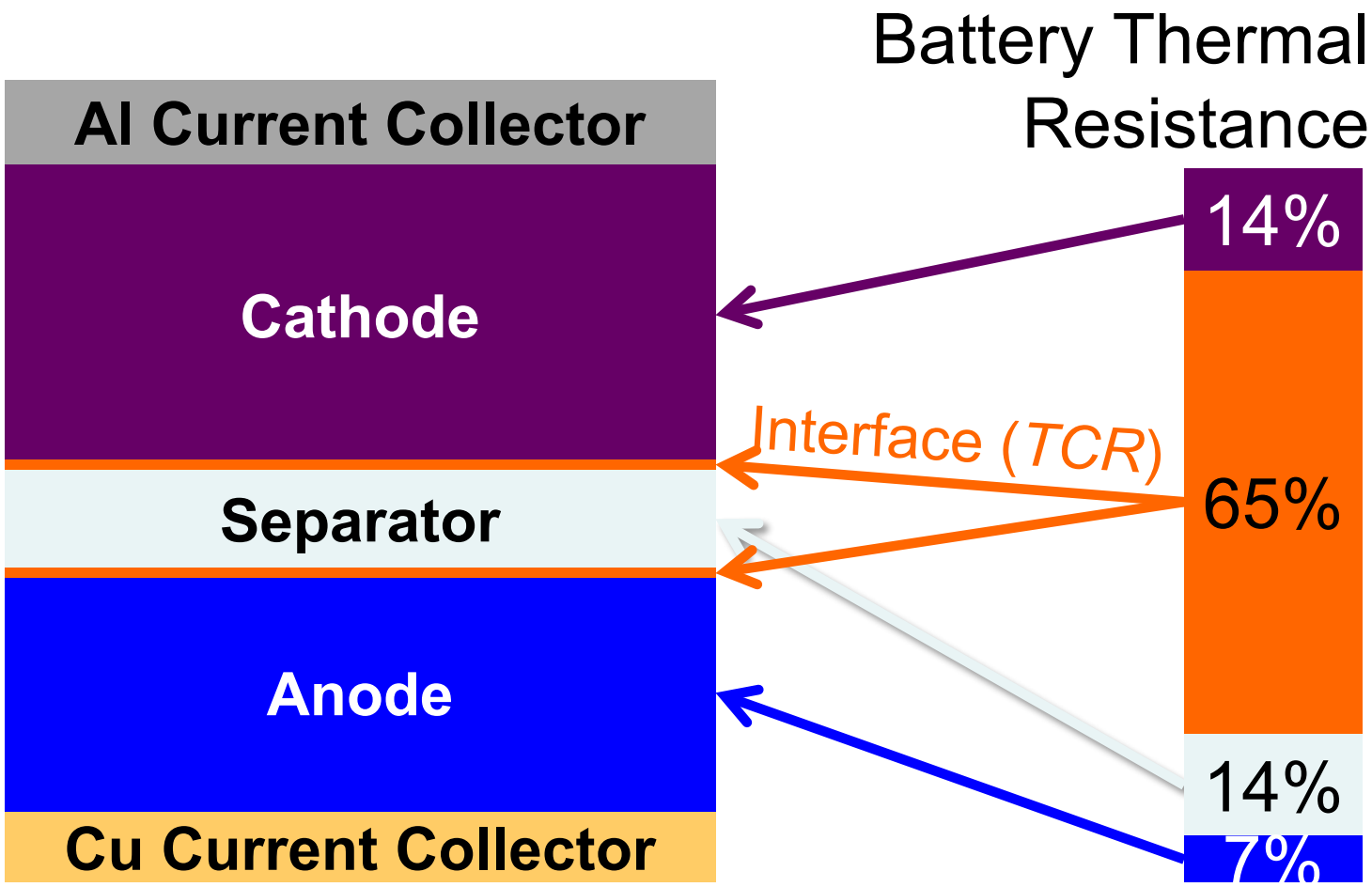


Approach: *Operandi* Measurements



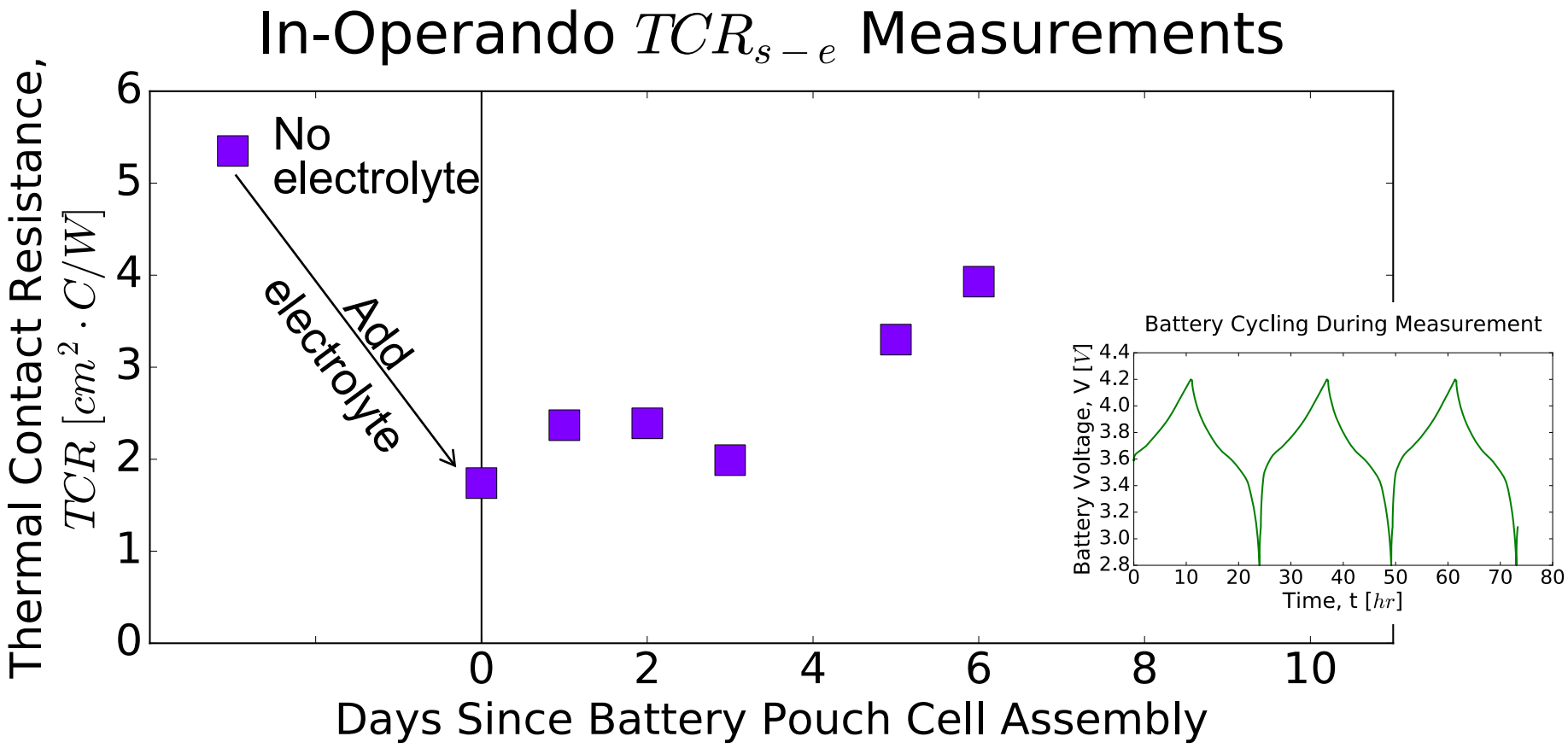


Technical Accomplishments and Progress



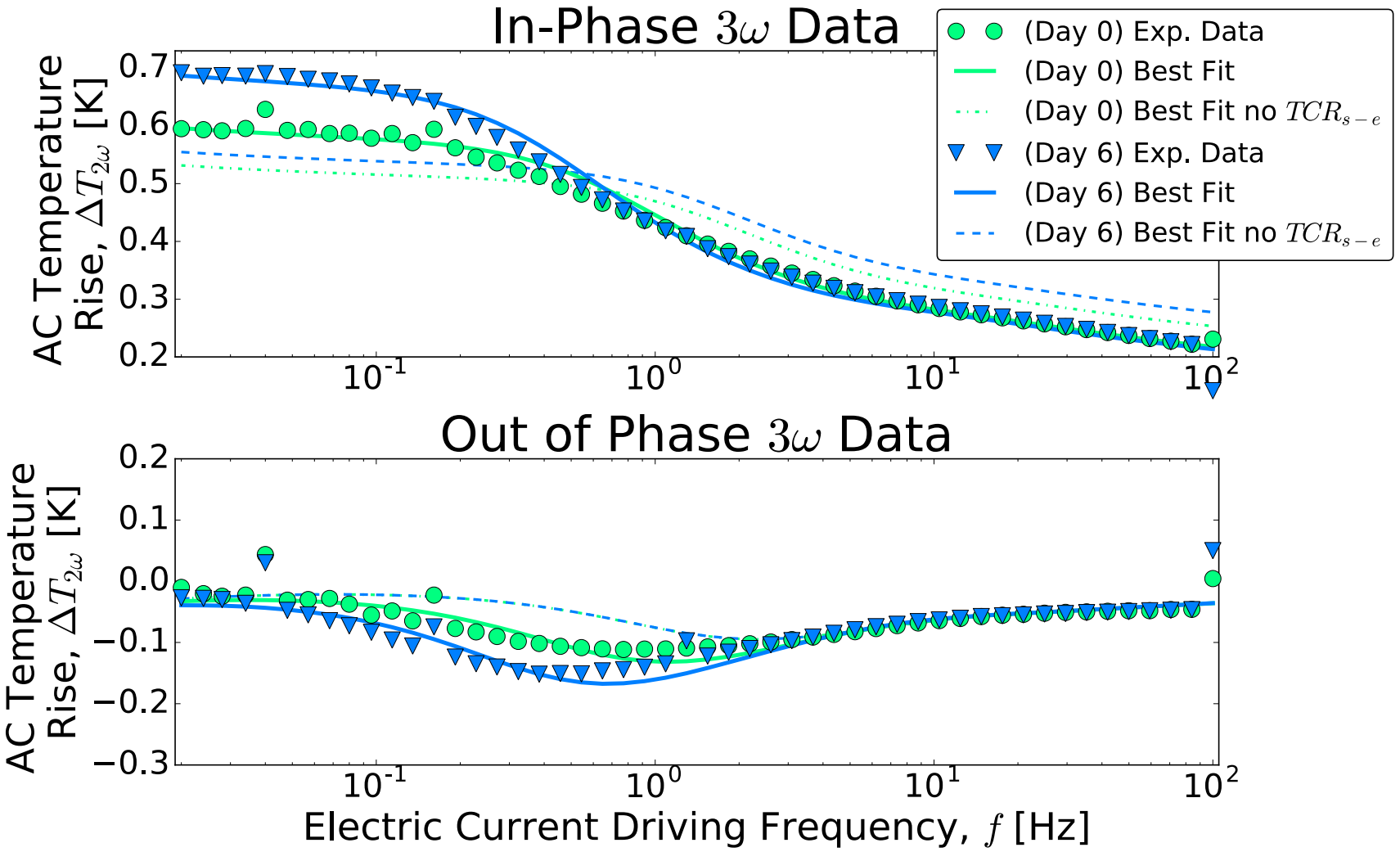
Thermal resistance of battery is dominated by thermal contact resistance (TCR) between the separator and electrodes

Technical Accomplishments and Progress



TCR gets worse with battery cycling.

Technical Accomplishments and Progress



Measurement data can only be explained by the existence of a TCR between the separator and electrodes.

Remaining Challenges and Barriers

- Perform operando 3ω diagnostic measurements from both cathode and anode side.

- Perform more detailed measurements.

Proposed Future Research

We are on track to meet the next two milestones, corresponding to the listed remaining challenges:

- Perform operando 3ω diagnostic measurements from both cathode and anode side.
- Perform more detailed measurements.

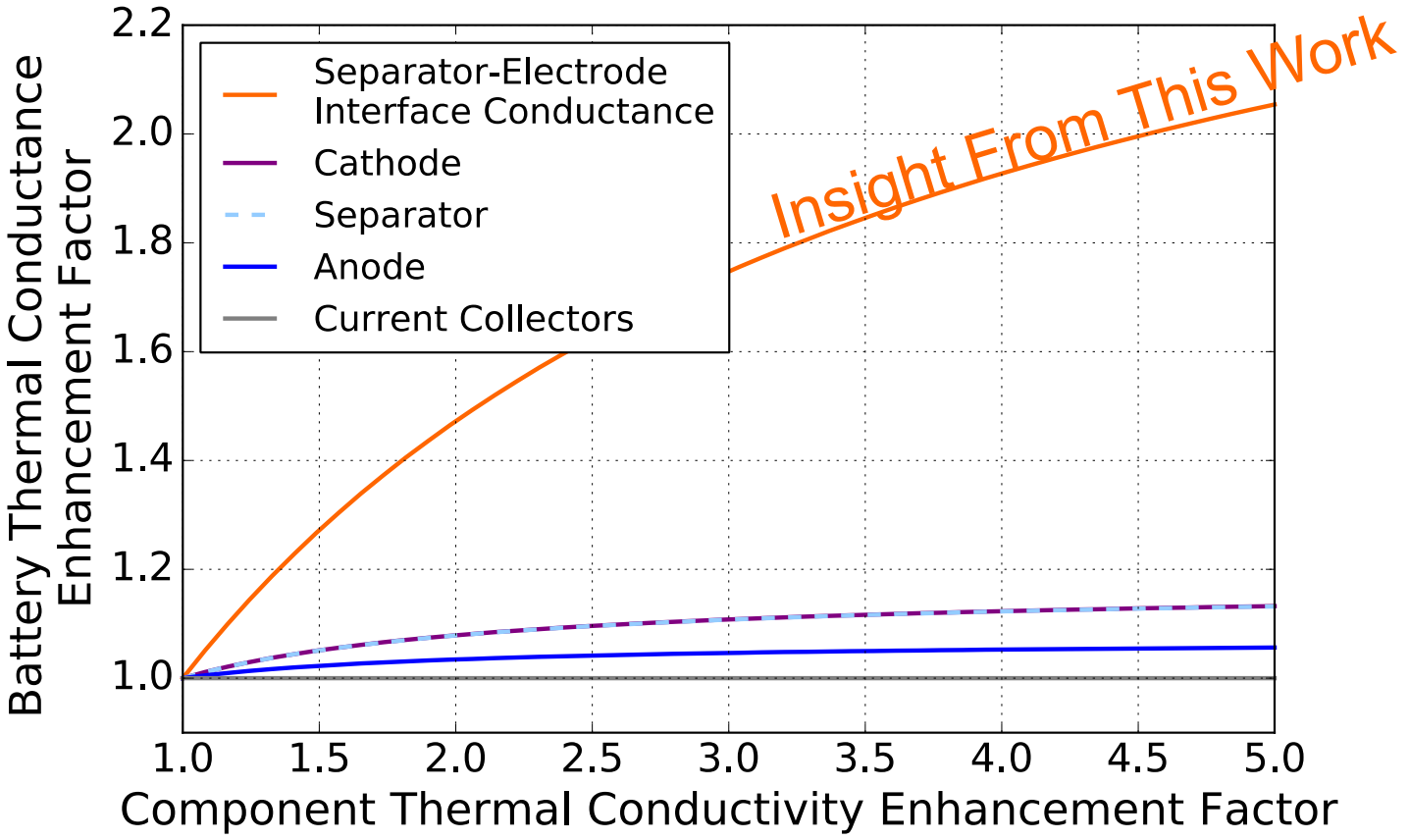
Additionally, we hope to make progress on:

- Understanding the origin of the worsening thermal performance with battery use.
- Investigate ways to improve the separator-electrode TCR.

Any proposed future work is subject to change based on funding levels.

Proposed Future Research

Impact Of Improving Each Component



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Summary

- Battery thermal management cannot be solved by external cooling alone, and affects XFC, safety, performance, and lifetime.

- We developed the first successful *operando* battery thermal transport measurement technique.

- Our measurements revealed that the electrode-separator thermal contact resistance dominates battery thermal resistance, and worsens with cycling.