

Thermal and Thermodynamic Diagnostics for Battery Degradation and Reliability



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Motivation

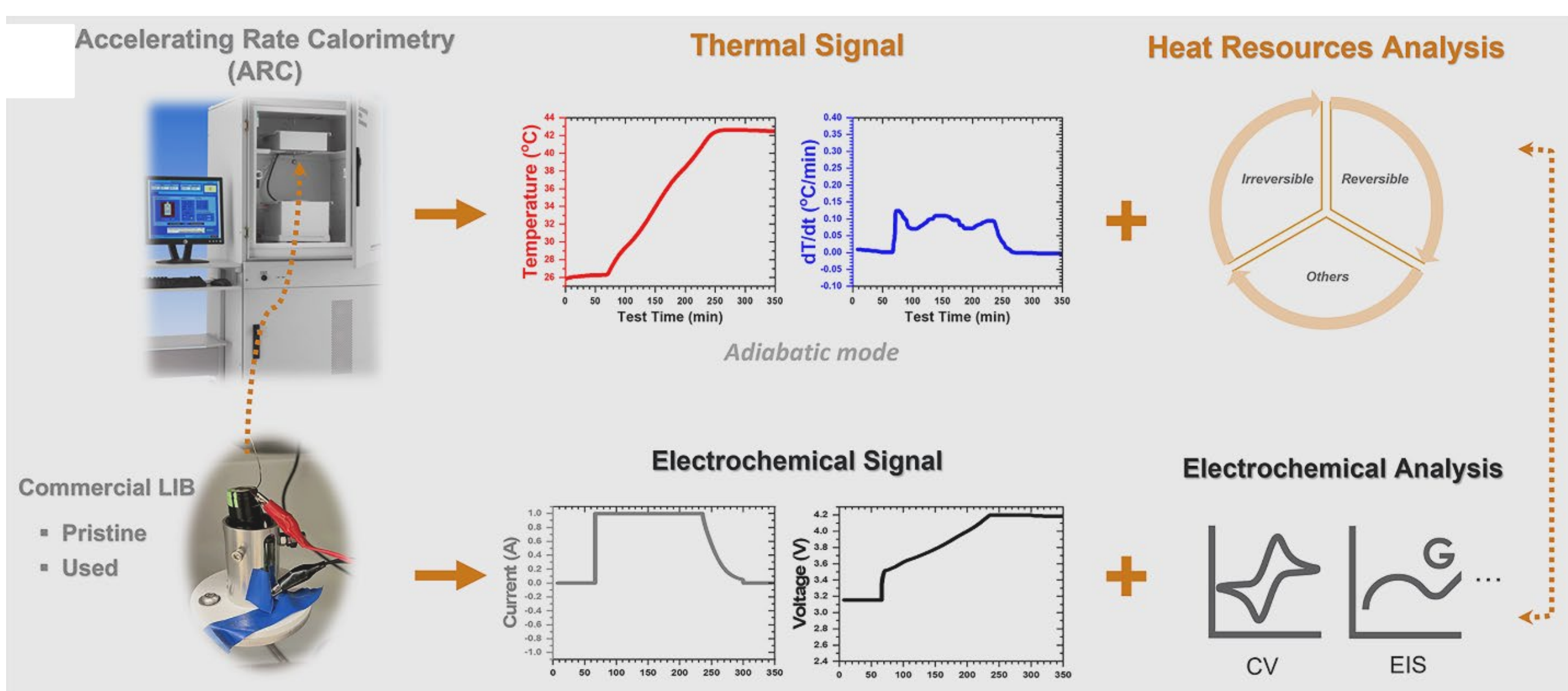
- Battery degradation are strongly influenced by coupled thermal and thermodynamic processes.
- Heat generation and entropy change measurements can reveal hidden degradation pathways.
- Diagnostic tools are needed to improve reliability, lifetime prediction and safety.

Objectives

- Quantify reversible and irreversible heat generation during cycling.
- Link thermal and thermodynamic signatures to degradation mechanisms.
- Build diagnostic indications for battery health, reliability, and abuse tolerance.

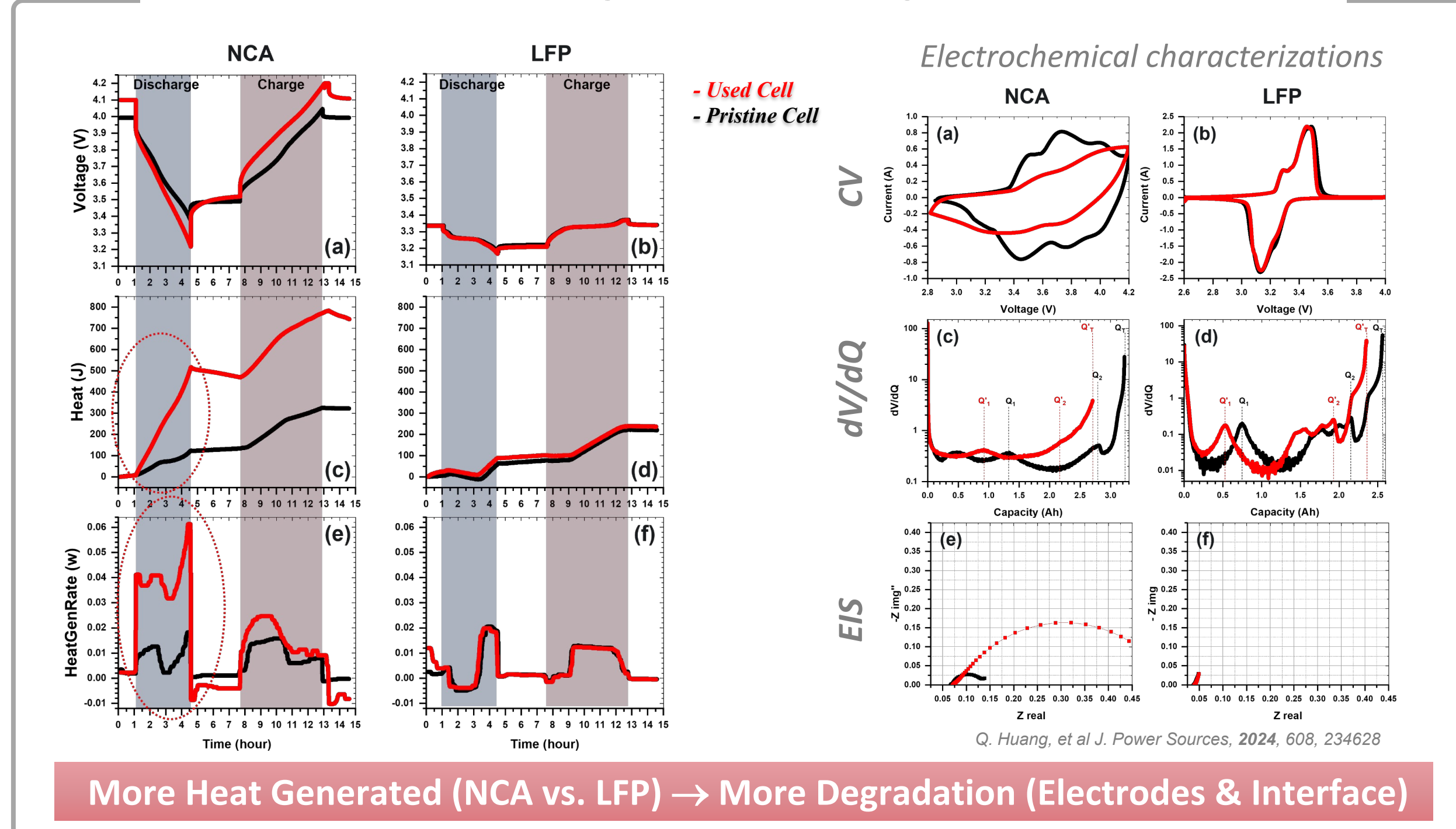
Thermal Diagnostics

Approaches



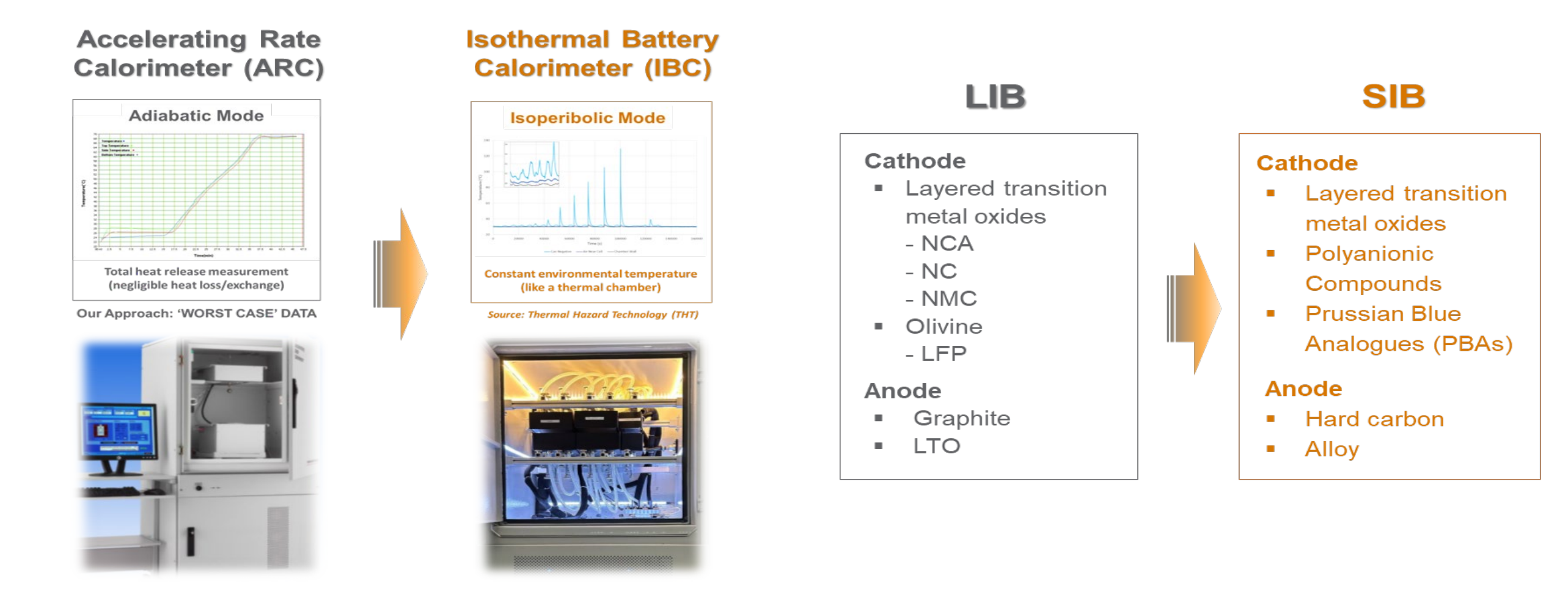
The flowchart of developed in-situ heat measurement via direct calorimetry (ARC)

Heat Measurement @ Peak Shaving Service (2+ Years)

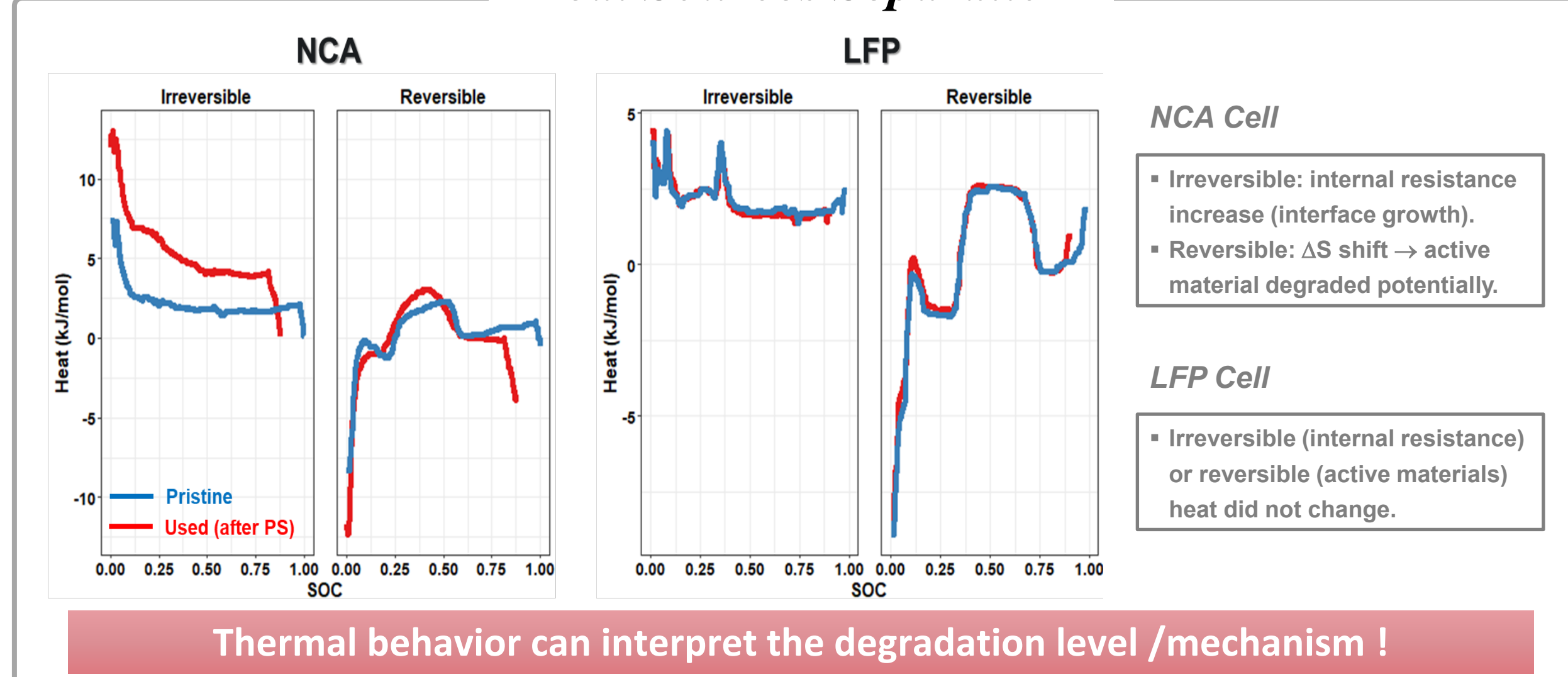


More Heat Generated (NCA vs. LFP) → More Degradation (Electrodes & Interface)

Extended Approach & Chemistry: In Progress



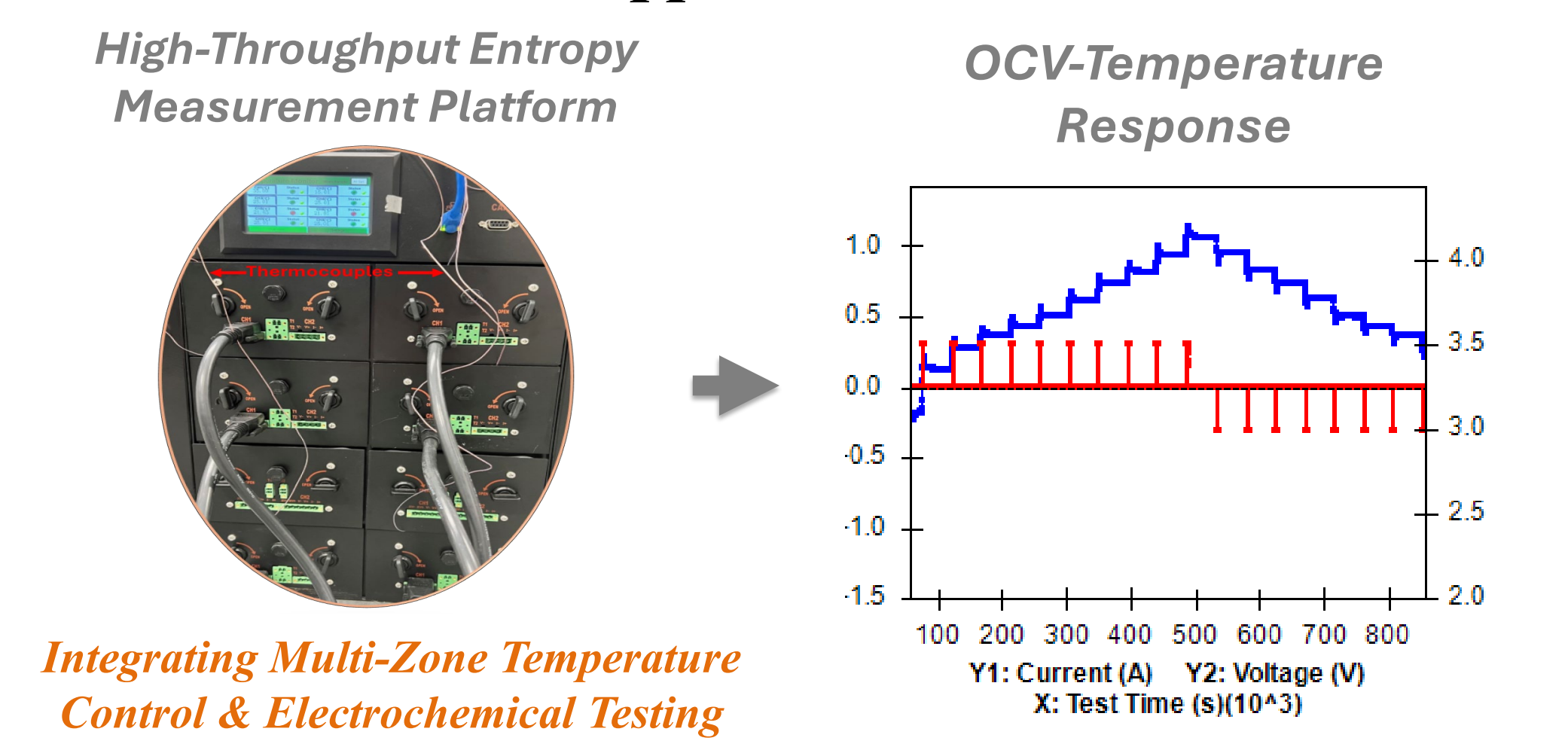
Heat Sources Separation



Thermal behavior can interpret the degradation level / mechanism !

Thermodynamic Diagnostics

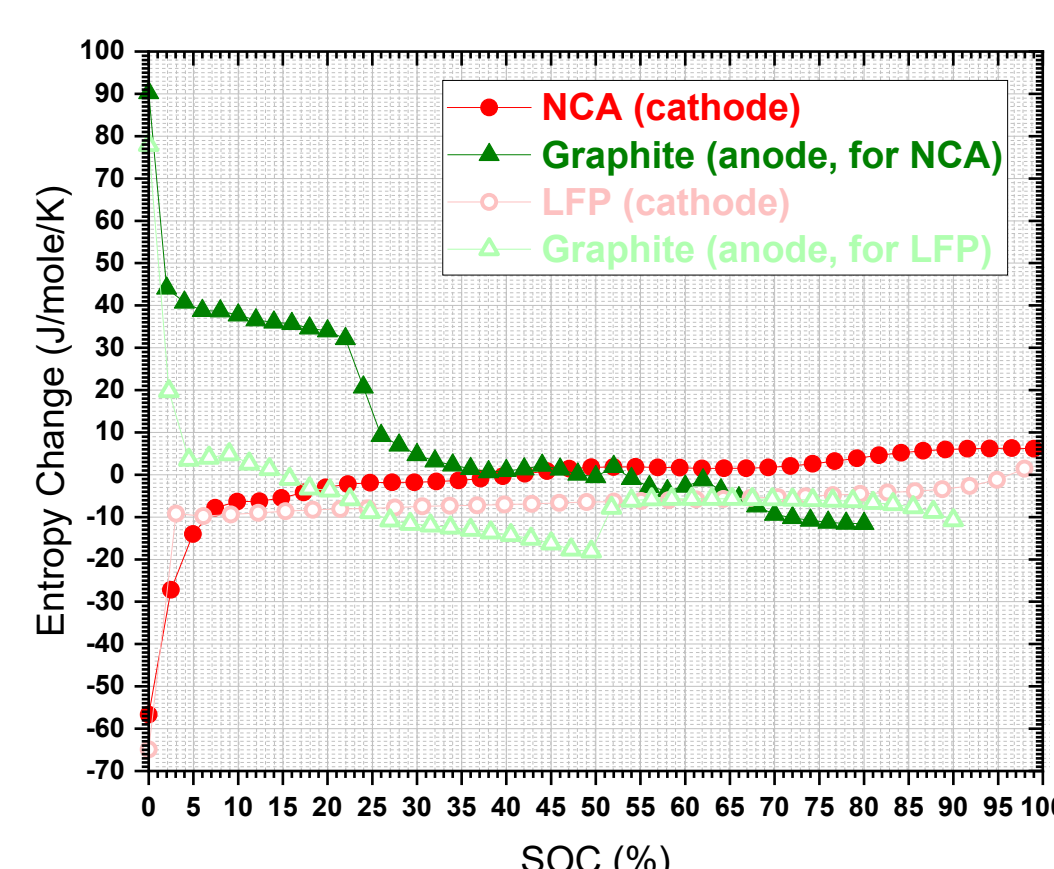
Approaches



Integrating Multi-Zone Temperature Control & Electrochemical Testing

Baseline Entropy Profiling

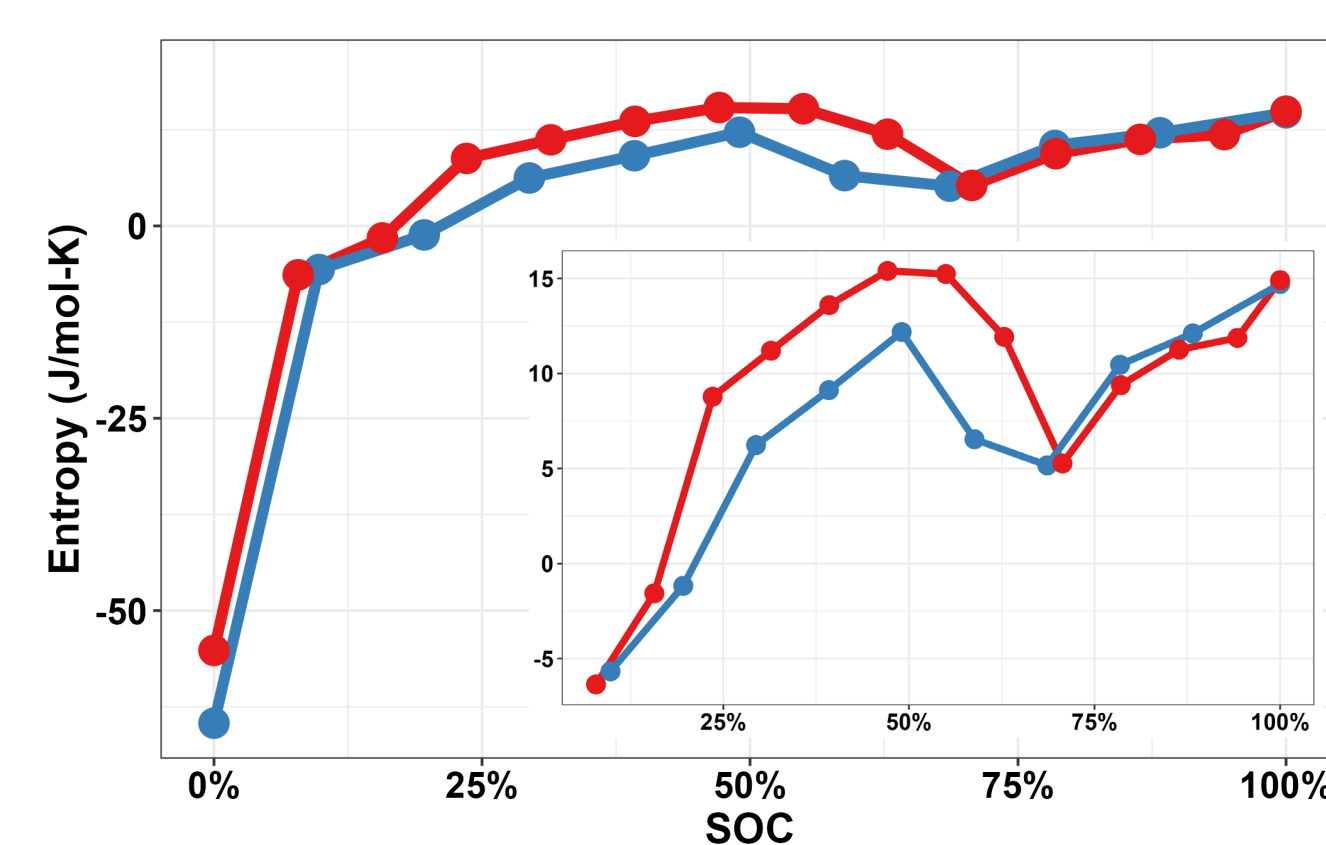
Across Full SOC Range (0-100%)



Cathode & Anode Half Cell (Coin Cell)

Large-Scale Cell Measurement

Used vs. Pristine



Cylindrical NCA Full Cell

ΔS Shift
Active material degradation & changes in electrode behavior during cycling

Summary

- We developed and validated two complementary diagnostics in LIBs across chemistries: in situ adiabatic calorimetry and entropy-based electrochemical measurements.
- These methods revealed degradation-dependent heat release patterns and provided insight into changes in the cell's thermal and electrochemical state.
- Combined thermal and thermodynamic diagnostics improve mechanistic understanding of battery aging and support reliability and safety assessment.

Future Work

- Expand these diagnostics to sodium-ion batteries for grid-scale applications.
- Add isothermal calorimetry to complement adiabatic measurements and better represent service conditions.
- Use the resulting datasets to improve state-of-health modeling for battery reliability forecasting.

Acknowledgements

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