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Mitigation of Failure Propagation in Multi-Cell Lithium-ion Batteries

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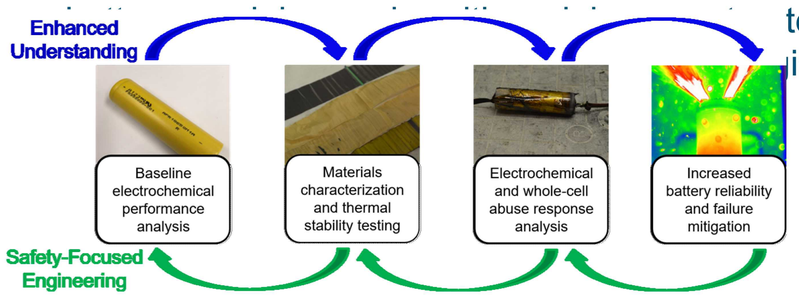
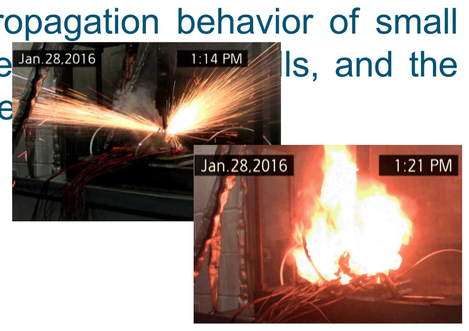
Introduction

- Stationary energy storage systems (ESS) are increasingly deployed to maintain a robust and resilient grid.
- As system size increases, financial and safety issues become important topics.
- Holistic approach: electrochemistry, materials, and whole-cell abuse will fill knowledge gaps.
- Safety of LIB has long focused on the impact and aftermath of a single cell failure.
- Failure of a single cell (inside a pack) may solely have little impact on the safety of the system; however, the thermal and electrical impact on other cells in the pack may be sufficient to cause a cascading runaway effect.
- Work presented here examines the failure propagation behavior of small te ls, and the ie





Methodology

Part I: No Thermal Management

5 pouch cells packed together → Cells in pack charged to 100% SOC → Failure initiated by mechanical nail penetration

Part II: Passive Thermal Management Between Cells

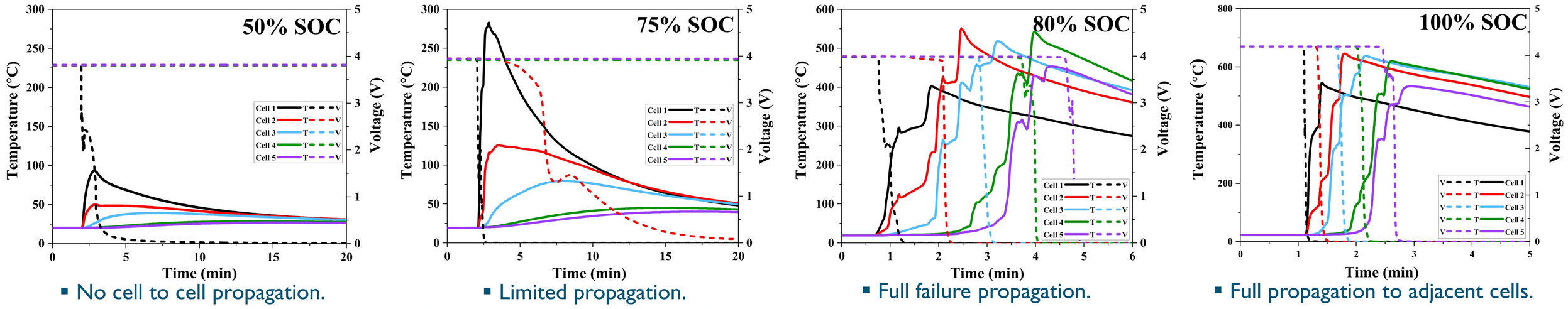
5 pouch cells pack together with Al or Cu plate separators → Cells in pack charged to 100% SOC → Failure initiated by a mechanical nail penetration

Part III: Passive Thermal Management Between Modules

Packs electrically connected in a 3S3P configuration with Al or Cu spacers between modules → Modules charged to 100% SOC → Failure initiated by a mechanical nail penetration

Part I. No Thermal Management

Failures initiated by mechanical insult to edge cell of COTS LCO packs (3Ah cells)



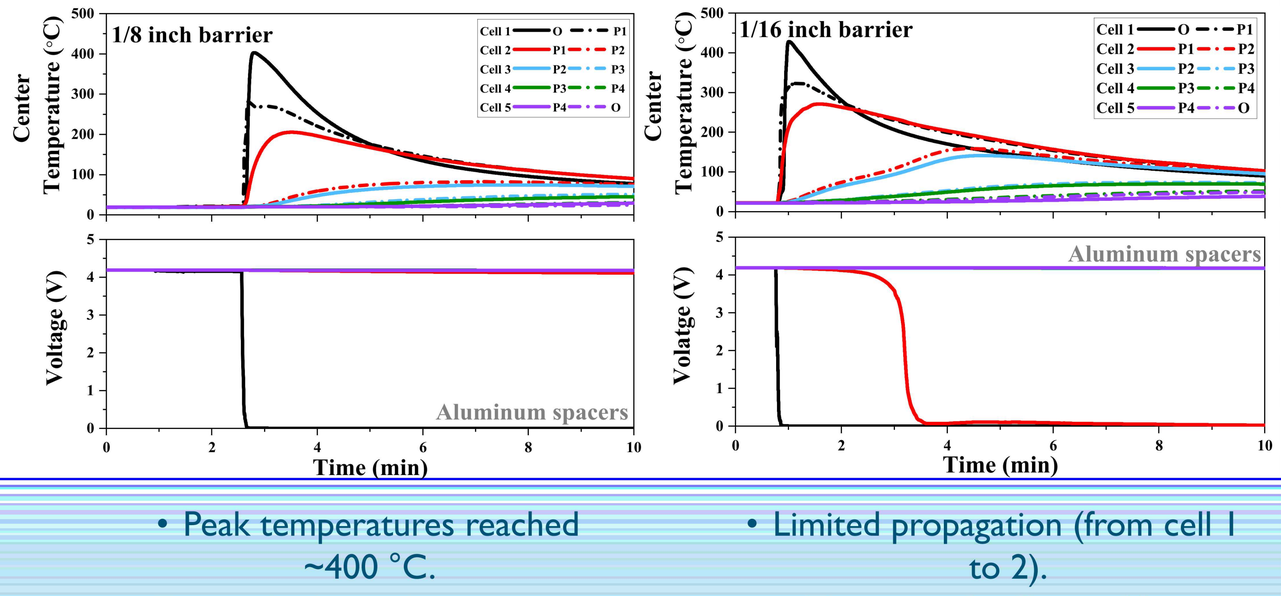
- No cell to cell propagation.
- Thermal runaway of initial cell failure was minimal.

- Limited propagation.
- Damage was observed for Cell 2, but no thermal runaway events seen for Cell 3 to Cell 5.

- Full failure propagation.
- Cascading failure to the entire battery over ~240 s.

- Full propagation to adjacent cells.
- Cascading failure to entire battery over ~82 s.

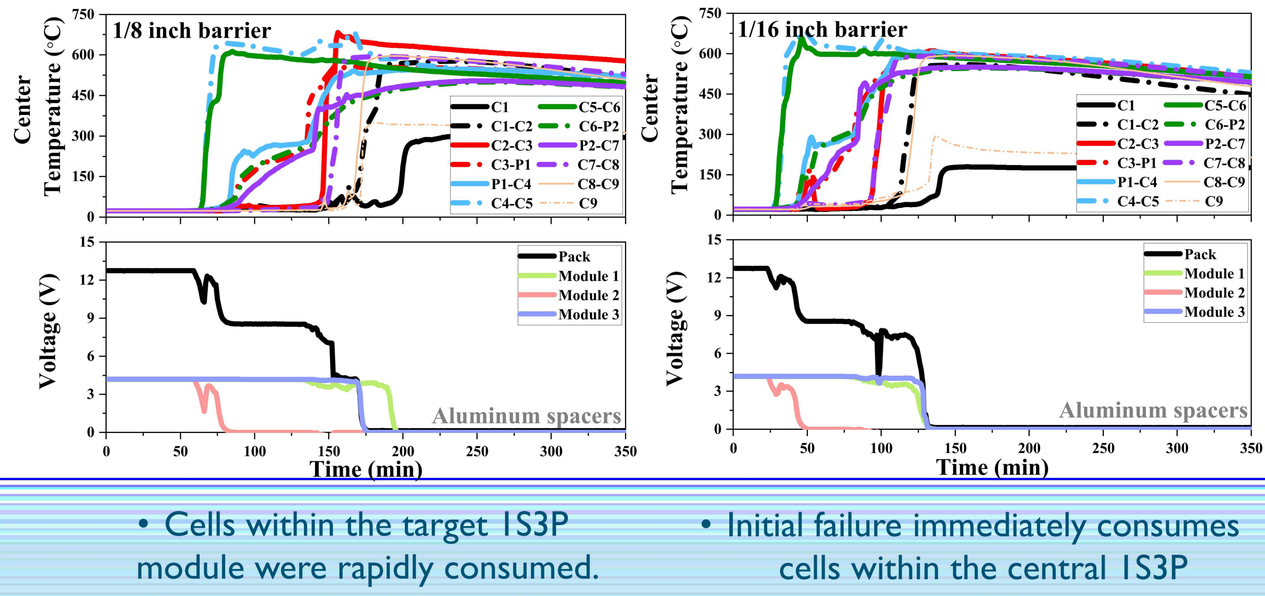
Part II. Thermal Management Between Cells



- Peak temperatures reached ~400 °C.
- Energetic thermal runaway was not observed beyond the initial failed cell.

- Limited propagation (from cell 1 to 2).
- The second cell was able to reach ~300 °C and eventually lost voltage.

Part III. Thermal Management Between Modules



- Cells within the target 1S3P module were rapidly consumed.
- Outer modules did not initiate thermal runaway until ~120 seconds after initial failure.

- Initial failure immediately consumes cells within the central 1S3P module.
- Outer modules show signs of failure ~20 seconds after initial initiation.

Summary

- As the size and complexity of battery packs increases, single cell failures within a pack become significantly more likely – this work looked at the mechanisms of how a single-cell failure might impact a larger battery, as well as how it might be mitigated.
- Limiting the SOC exhibited a meaningful impact on propagating failure; however, this comes at a high cost to total energy storage.
- Unmitigated fully charged pouch cells saw a complete consumption of the packs.
- Al barriers were used as a means of passive thermal management to slow or halt thermal runaway propagation between cells.
- 1/16” plates limited propagation to a single cell, while 1/8” plates arrested it altogether for single module battery packs.
- The same plates between modules of a 3S3P pack configuration were not sufficient to mitigate the failure propagation.

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