Electrochemical Abuse Testing

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Approach and Capabilities

Cell and Module Testing
Battery Abuse Testing Laboratory (BATLab)

Battery Pack/System Testing
Thermal Test Complex (TTC) and Burnsite

Battery Calorimetry
Understanding Battery Safety

Materials R&D
- Non-flammable electrolytes
- Electrolyte salts
- Coated active materials
- Thermally stable materials

Testing
- Electrical, thermal, mechanical abuse testing
- Large scale thermal and fire testing (TTC)
- Failure propagation testing on batteries/systems
- Diagnostic techniques for battery state of stability
- Development for DOE Vehicle Technologies and USABC

Simulations and Modeling
- Multi-scale models for understanding thermal runaway
- Validating vehicle crash and failure propagation models
- Fire Simulations to predict the size, scope, and consequences of battery fires

Procedures, Policy, and Regulation
- SAE J2464/UL 1642 procedures and standards
- R&D programs with NHTSA/DOT to inform best practices, policies, and requirements
Motivation for propagation testing

- Results of single cell nail penetration and 1S10P propagation test
- 26650 LFP cell
- Single cell has relatively minor failure
- Significant increase in intensity with a 10 cell pack
Failure Propagation: No Thermal Management

*Failures initiated by mechanical insult to edge cell of COTS LiCoO$_2$ packs (3Ah cells)*

- Successful initiation at Cell #1
- Propagation to adjacent cells
- Cascading failure to entire battery over 60 s

**Observed complete propagation when cell are close packed with no thermal management**
Mitigation through de-rating cells

- 50% SOC no cell to cell propagation observed
  - Thermal runaway of initial cell failure also fairly minimal
- Limited propagation at 75%
  - Cell 2 went into thermal runaway following the failure of cell 1
  - Some other cell damage was observed but no high rate thermal runaway events seen in cells 3-5
Limits to cell de-rating

- Full failure of pack observed starting at 80% SOC
- Compared to unmitigated baseline, peak temperatures observed were only marginally lower (550 °C vs 620 °C)
- Total pack propagation observed after ~4 minutes vs ~80 seconds at 100% SOC
Failure Propagation Testing: Inclusion of Thermal Management

Methodology:
- Experimentally determine a reproducible thermal runaway initiator for each cell type
- Use this initiator to trigger a single cell thermal runaway failure in a battery
- Evaluate the propagation of that failure event

Experiment
- COTS LiCoO$_2$ 3Ah pouch cells
- 5 cells closely packed
- Failure initiated by a mechanical nail penetration along longitudinal axis of edge cell (cell 1)
- The current effort is focused on understanding extent of propagation with inclusion of passive thermal management in the form of heat sinks between pouch cells (aluminum and copper)

For more detail on these results please see poster titled “Mitigation techniques for failure propagation” presented by Dr. Loraine Torres-Castro
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Discussion

- A cell may exhibit dramatically different failure response when in a string, module or pack than during single cell abuse testing.
- Limiting the SOC can have a meaningful impact in propagating failure, however this comes at a significant cost to total energy storage.
- Propagation can be mitigated through system engineering, however the results can be unpredictable. Further, electrical design will play a role in susceptibility to failure testing.
- Failure testing of large, complex systems is fairly resource intensive. Model based design presents a potential remedy to this, allowing us to infer a large amount of information from a relatively small number of tests.
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