Battery Safety Overview

Flex Lab Safety Committee Meeting

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Frequent accidents involving Li-ion batteries capture attention of consumers, lawmakers, and researchers alike.
• Consumers grow wary as personal electronics and electric vehicles unexpectedly combust
• TSA restricts shipment of batteries after multiple fires during flights
Li-ion Battery Thermal Safety

Thermal safety issues plague high energy Li-ion batteries

- Heat Generation
- Exothermic Side Reactions
- Increased Cell Temperature
- Improved Reaction Kinetics

**Table:**

<table>
<thead>
<tr>
<th>Onset T (°C)</th>
<th>Side Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>660</td>
<td>Aluminum melts</td>
</tr>
<tr>
<td>330</td>
<td>Anode collapse</td>
</tr>
<tr>
<td>160-225</td>
<td>Electrolyte vaporization and combustion</td>
</tr>
<tr>
<td>130-180</td>
<td>Separator melts, internal short</td>
</tr>
<tr>
<td>140</td>
<td>Cathode decomposition and electrolyte reaction</td>
</tr>
<tr>
<td>110-140</td>
<td>Secondary SEI formation and decomposition</td>
</tr>
<tr>
<td>85-105</td>
<td>Primary anode SEI decomposition</td>
</tr>
</tbody>
</table>

*Lopez, Jeevarajan, and Mukherjee, *J. Electrochemical Society*, 162, A2163 (2015).*
Overcharge

Cell 8
Overcharge C/3-rate

Cell 18
Overcharge C/3-rate

Cell 18
Overcharge C/3-rate

Top View
Side View
Tabs

Top View
Side View
Tabs

(a) Anode

(b) Pouch – Electrolyte degradation charring marks
Lithium Dendrites in Fast Charging

Lithium dendrite growth during fast charging can cause internal short and rapid heat generation

*N. Fear et al., ACS Appl. Mater. Interfaces 2020, 12, 27, 30438–30448*
External Short

0% CF

10% CF

15% CF

20% CF

Deposition on cathode

Cathode SEM

Separator SEM

Sand-dune Pattern

Fluorine

Cobalt Fracture

(a)

(c)

(d)
Standard Test Setup

- Appropriate for charge/discharge cycling tests within manufacturer-recommended voltage and current windows
Examples of Mild Risk Tests

- Instrument cells with reference electrodes to detect lithium plating
- Perform fast charging at rates higher than manufacturer recommendation
Safety Options for Mild Risk Tests

Charging Sack:
- Low cost option to contain (not eliminate) fire risk during charging

Explosion-Proof Box:
- Good option for abusive cycling tests or instrumented cells, where fire is not expected but is possible
In Case of Failure...

- **Leave the room**
  - Combustible gases can build up in enclosed spaces, leading to explosion
  - Trace amounts of HF can be present due to decomposition of electrolyte salts

- **Let the sprinkler system do its job**
  - Water is best way to put out a battery fire
  - Decomposition reactions will continue until cell temperature is reduced
  - High heat capacity of water makes it excellent for absorbing heat from cell
Accelerated Rate Calorimeter (ARC)

- ARC is designed to study thermal stability and heat release during thermal runaway events.
- Increases sample temperature in 5°C increments until exothermic reaction is detected.
- Maintains adiabatic environment while cell self-heats to thermal runaway.
- Allows for comparison of safety characteristics between cell chemistries and form factors.
Test Setup – Cell Level Thermal Runaway

Cylindrical Cell Test

- Voltage Leads
- Thermocouples
- Test Fixture

Pouch Cell Test

- Voltage Leads
- Thermocouples
- Test Fixture
Cells after Thermal Runaway