THE DEVELOP OF SAFE HIGH ENERGY DENSITY LIBS

2022 NASA Aerospace Battery Workshop
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Coulometrics, LLC
Date: November 15th, 2022
Outline

• Coulometrics Overview
• Development of Trion Silicon Anode Material
• Nail Penetration Testing of NMC622 Cells
• Conclusion
Coulometrics, LLC

History

2008: Founded as an “Advanced Energy Storage Consulting Company”

2011: First lab building coin cells and providing basic echem testing

2013: 10,000 sq ft building, installed coating lines / cell assembly

2016: Started PUREgraphite, LLC (sold to Novonix in 2019)

2017: Expanded to 31,000 sq ft.

2021: Expanded to 54,000 sq ft.

2022: Material Lab

2023: Cylindrical cell production facility
Coulometrics, LLC
What do we do?

- Provide state-of-the-art cell assembly, testing services, material development, and cylindrical cell production capabilities.
CM – Equipment
Mixing / Coating
CM – Equipment
Production Coating / Calendering
CM – Equipment
Dry room (x2) Cell Assembly
CM – Equipment
2,500+ testing channels
CM – Equipment

Full Analytical Lab
### EUCAR Ratings for Lithium-Ion Batteries

<table>
<thead>
<tr>
<th>Hazard Level</th>
<th>Description</th>
<th>Classification Criteria &amp; Effect</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>No effect</td>
<td>No effect. No loss of functionality.</td>
</tr>
<tr>
<td>1</td>
<td>Passive protection activated</td>
<td>No defect; no leakage; no venting, fire, or flame; no rupture; no explosion; no exothermic reaction or thermal runaway. Cell reversibly damaged. Repair of protection device needed.</td>
</tr>
<tr>
<td>2</td>
<td>Defect/Damage</td>
<td>No leakage; no venting, fire, or flame; no rupture; no explosion; no exothermic reaction or thermal runaway. Cell irreversibly damaged. Repair needed.</td>
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<td>3</td>
<td>Leaking δ mass &lt; 50%</td>
<td>No venting, fire, or flame; no rupture; no explosion. Weight loss &lt;50% of electrolyte weight (electrolyte = solvent + salt).</td>
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<td>4</td>
<td>Venting δ mass ≥ 50%</td>
<td>No fire or flame; no rupture; no explosion. Weight loss ≥50% of electrolyte weight (electrolyte = solvent + salt).</td>
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<td>5</td>
<td>Fire or Flame</td>
<td>No rupture; no explosion (i.e., no flying parts).</td>
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**Fig. 3:** Various hazard levels defined by EUCAR members for the use of a cell level safety performance in EV

Minimum rating for a nail penetration test as the cell is going to be limited to: “irreversibly damaged”
NMC/Graphite

• EUCAR of ???
  + Stack is still visible
  + Aluminum foil at top of electrodes is gone
  + Copper foil is still present
  + Massive hole where the nail penetration occurred
• EUCAR ?
  + Rupture: 6
  + Explosion: 7
• Trion Si was added to the anode to increase the energy density of the cells
  + Energy density was increased from 700 to 800 Wh/L
• Same nail penetration was done on the new cells to compare to the standard graphite
• Metalized current collectors increase the energy density ~3%
  + The metalized current collectors are ~7µm thinner
  + Metalized current collector cells have 20-30x the impedance
    ➢ 30mΩ compared to just over 1mΩ
High Capacity Cell
NMC/Gr+20%Si

• EUCAR of 7
NMC/Gr+20%Si

• EUCAR of 7
  + Cathode is gone
  + Anode is gone
  + Tabs are gone

• Copper is melted
  + Melting point of copper is 1085°C
All of the higher energy density cells made with Si show similar behavior.
What can you do to make these batteries SAFE?

• **New separator?**
  + All ceramic or coated separator films
  + Higher temperature resistance
  + Better able to separate anode / cathode
New Separator
High Capacity NMC622

• EUCAR 7
What can you do?

- Metalized Current Collectors?

Plastic Core (~5µm)

Metal coating (~1µm)

Cathode Coating (~3.5 mAh/cm²)
Metalized CC
High Capacity NMC622

• EUCAR 2!!
Metalized CC (TAKE 2)  
High Capacity NMC622

• EUCAR 2
• AGAIN!
Metalized CC (TAKE 3)
High Capacity NMC622

- EUCAR 2
  + Voltage remains stable
  + No smoke
  + No fire
  + Minimal if any temperature increase
Metalized CC (TAKE 4)  
High Capacity NMC622

- Bottom the chuck into cell for increased abuse
  + Cell is still safe!
EUCAR Ratings for Lithium-Ion batteries

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Improvement from a 7 to a 3 with only changing the current collector!
#3 Metalized Current Cells

Other Repeat Cells

Cells with Metalized Current Collectors

No Smoke, No Fire, No Explosion, No Voltage Drop, 2-3°C increase in Temperature
Trade-offs

• Lots more testing needs to be completed in order to prove this technology is viable
• Cells limited to 1C or lower
• Significant issues remain with tab welding
• However – the cell production process is almost **exactly** the same with limited impact on the entire process
• Can enable a next generation of high energy density cells >900 Wh/L