THE DEVELOP OF SAFE HIGH ENERGY DENSITY LIBS

2022 NASA Aerospace Battery Workshop

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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.

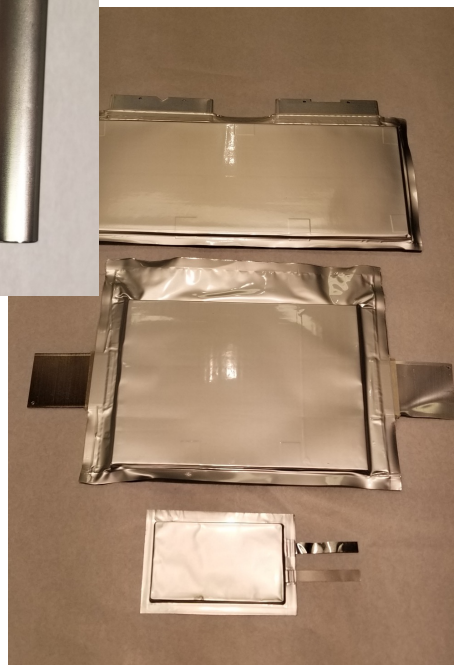
2021: Expanded to 54,000 sq ft.

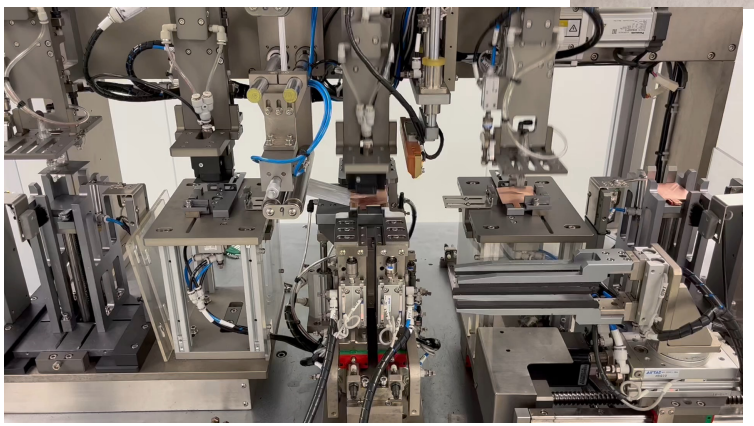
2022: Material Lab

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

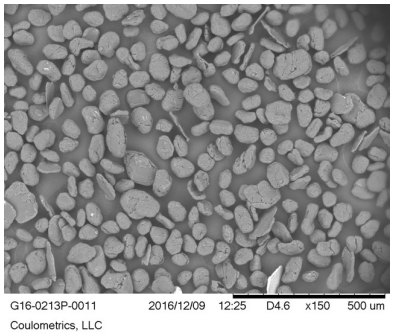
CM – Equipment

Production Coating / Calendering

CM – Equipment
Dry room (x2) Cell Assembly

CM – Equipment
2,500+ testing channels

CM – Equipment
Full Analytical Lab



NMC/Graphite

EUCAR Ratings for Lithium-Ion Batteries

Hazard Level	Description	Classification Criteria & Effect
0	No effect	No effect. No loss of functionality.
1	Passive protection activated	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.
2	Defect/Damage	No leakage; no venting, fire, or flame; no rupture; no explosion; no exothermic reaction or thermal runaway. Cell irreversibly damaged. Repair needed.
3	Leakage Δ mass < 50%	No venting, fire, or flame*; no rupture; no explosion. Weight loss <50% of electrolyte weight (electrolyte = solvent + salt).
4	Venting Δ mass ≥ 50%	No fire or flame*; no rupture; no explosion. Weight loss ≥50% of electrolyte weight (electrolyte = solvent + salt).
5	Fire or Flame	No rupture; no explosion (*i.e.*, no flying parts).
6	Rupture	No explosion, but flying parts of the active mass.
7	Explosion	Explosion (*i.e.*, disintegration of the cell).

Minimum rating for a nail penetration test as the cell is going to be limited to: **"irreversibly damaged"**

Fig. 3: Various hazard levels defined by EUCAR members for the use of a cell level safety performance in EV

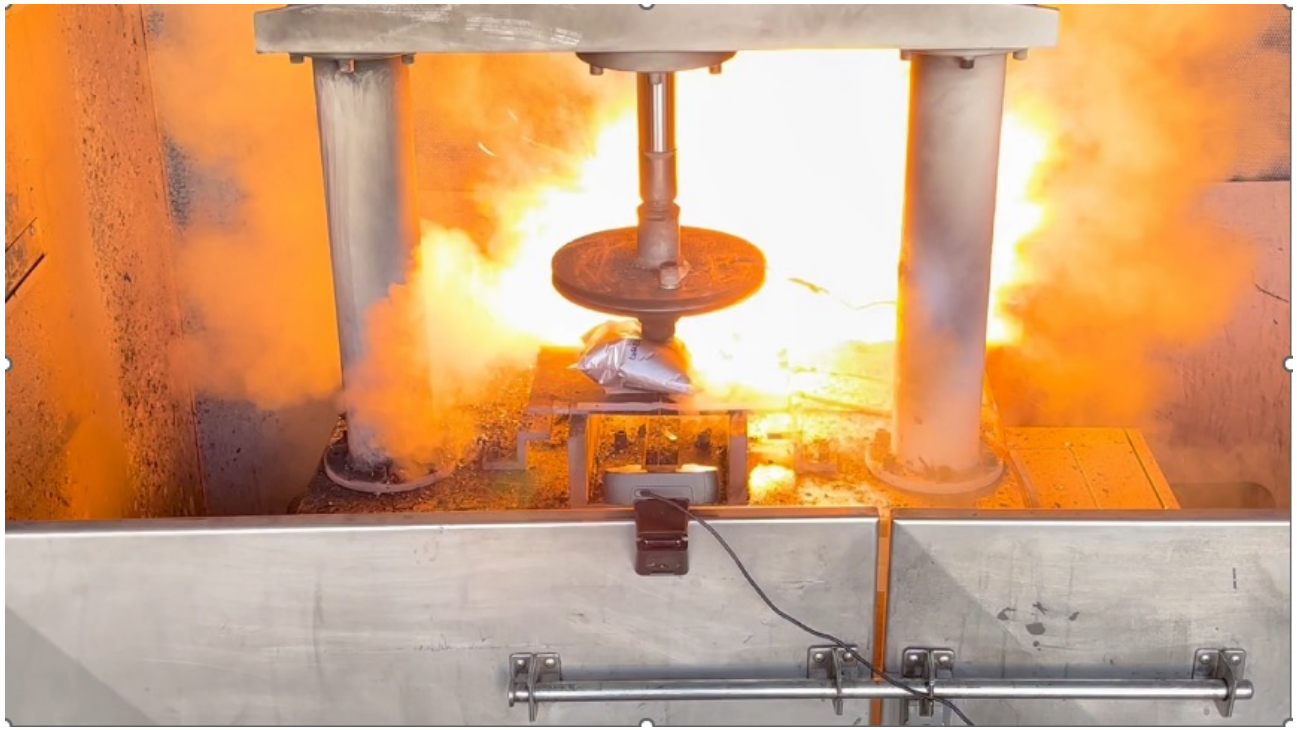
NMC/Graphite

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

NMC/Graphite

- EUCAR ?
  - + Rupture: 6
  - + Explosion: 7



High Energy Density Cell Build

- 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

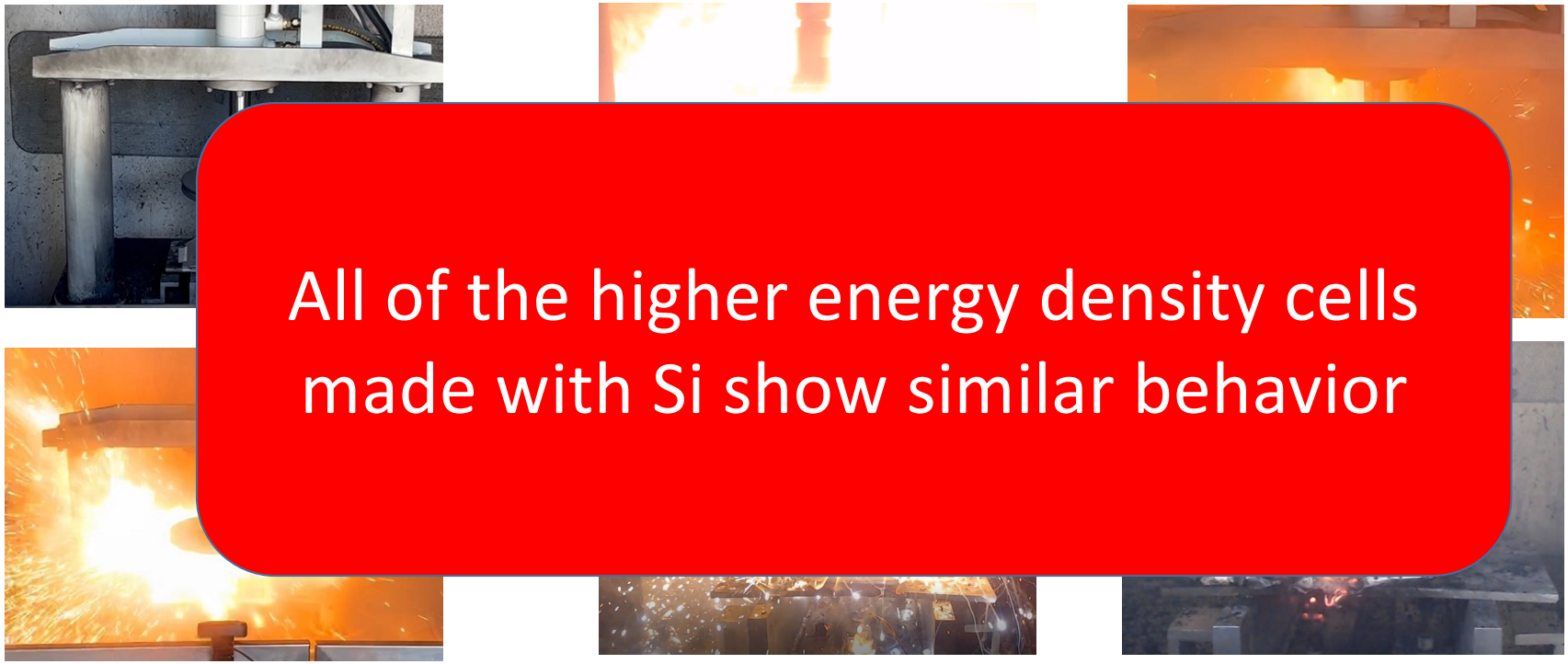
High Capacity Cell NMC/Gr+20%Si

- 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 1085ºC

NMC/Gr+20%Si



All of the higher energy density cells made with Si show similar behavior

What can you do to make these batteries SAFE?

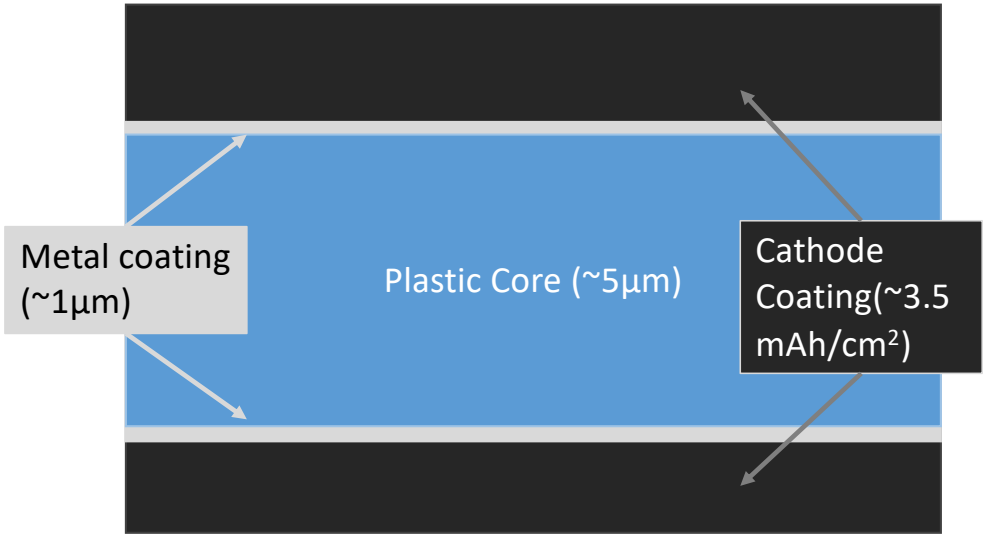
- **New separator?**
  - +All ceramic or coated separator films
  - +Higher temperature resistance
  - +Better able to separate anode / cathode

New Separator
High Capacity NMC622

- EUCAR 7

What can you do?

- Metalized Current Collectors?



Metalized CC
High Capacity NMC622

- EUCAR 2!!

Metalized CC (TAKE 2) High Capacity NMC622

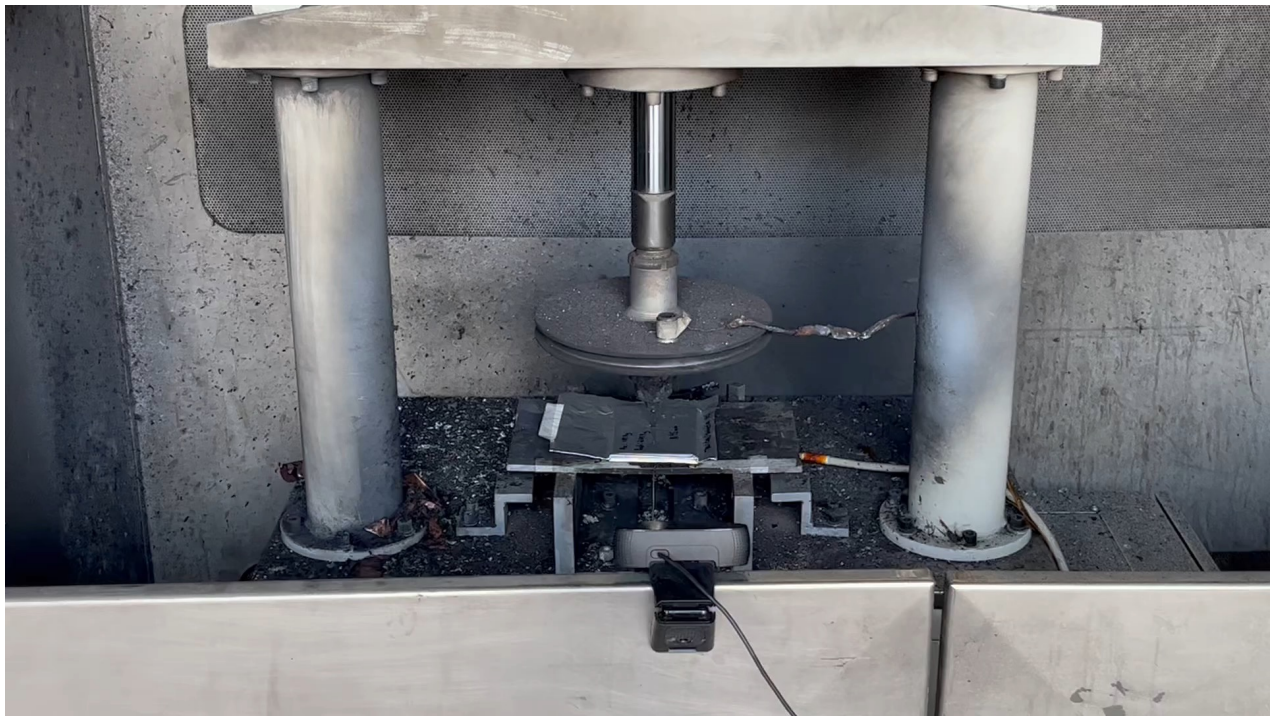
- EUCAR 2
- AGAIN!

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!



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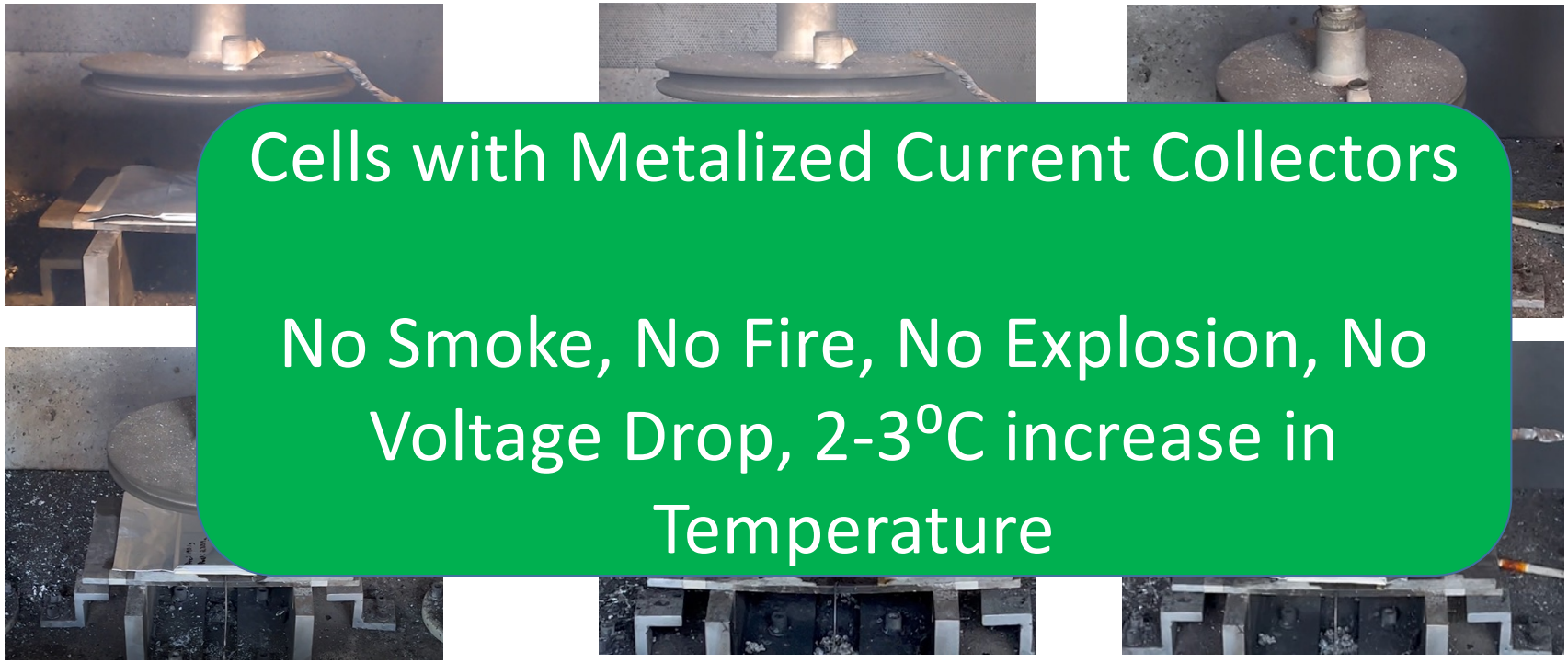
Improvement from a 7 to a 3 with only changing the current collector!

Fig. 3: Various hazard levels defined by EUCAR members for the use of a cell level safety performance in EV

#3 Metalized Current Other Repeat Cells



Cells with Metalized Current Collectors

No Smoke, No Fire, No Explosion, No Voltage Drop, 2-3^{o}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