Massachusetts Institute of Technology

Naval Construction and Engineering Program
Center for Ocean Engineering
Department of Mechanical Engineering

Li-Ion Battery Component Testing

in Support of MIT Battery Consortium Research

Kyle Miller
LT USN

Involvement of Navy Students

LT Rich Hill- *Development of a Representative Volume Element of Lithium-Ion Batteries for Thermo-Mechanical Integrity (2010-11)*

CDR John Campbell- *Development of a Constitutive Model Defining the Point of Short Circuit Within Lithium-Ion Battery Cells (2011-12)*

LCDR Joseph Meier- *Material Characterization of High-Voltage Lithium-Ion Battery Models for Crashworthiness Analysis (2012-13)*

LT Kyle Miller- *Mechanical Characterization of Lithium-Ion Battery Micro Components for Development of Homogenized and Multilayer Material Models* (2013-14)

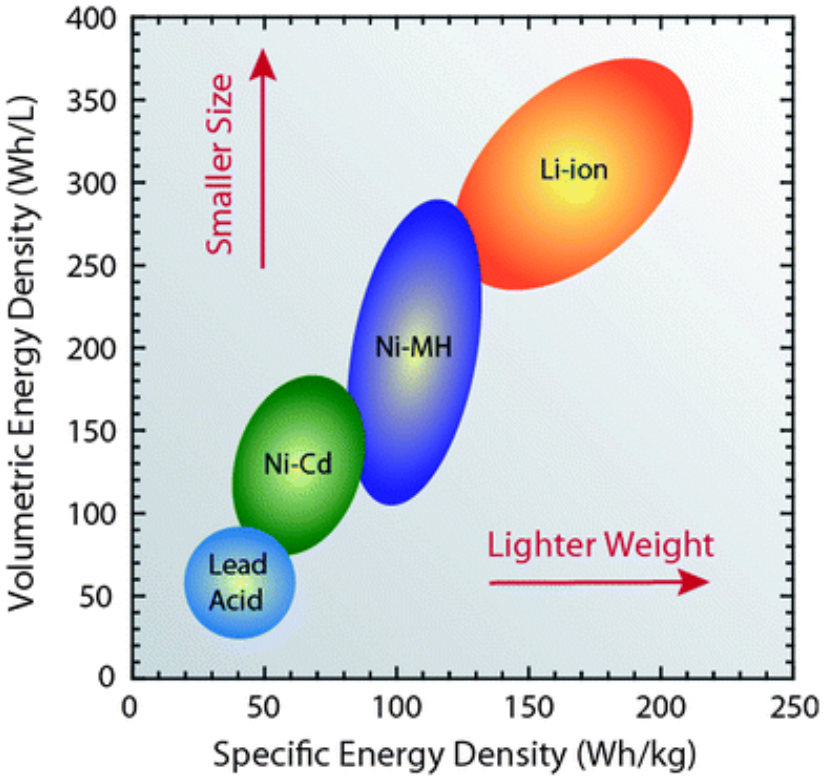
LT Brandy Dixon- Biaxial component testing (2014-15)

Li-Ion Battery Component Testing

Overview:

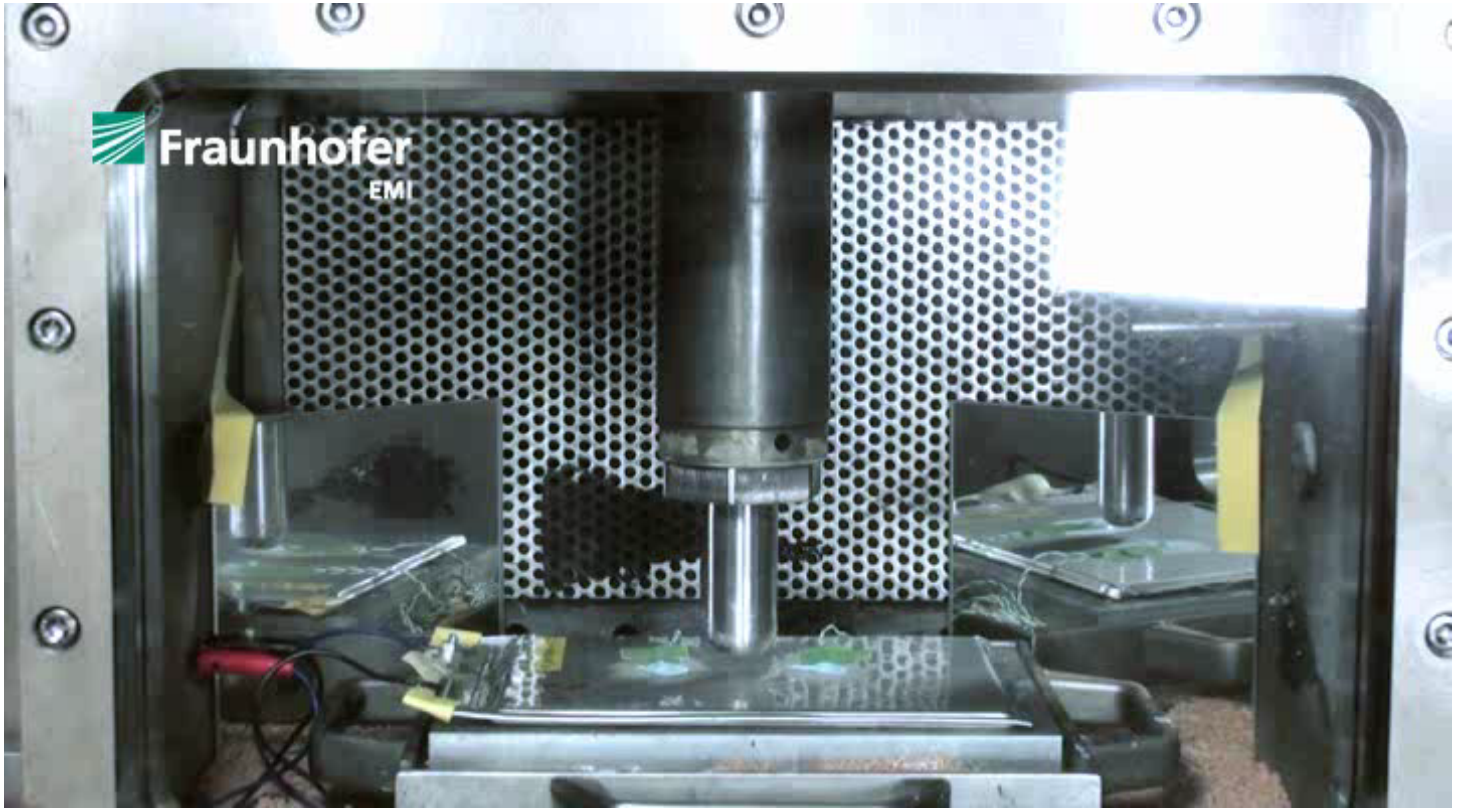
1. Li-Ion battery overview
2. MIT consortium research overview
3. Component Testing Procedures
4. Separator case study
5. Aluminum Cathode case study
6. Short circuit detection case study
7. Conclusions

Li-Ion Battery Pros and Cons



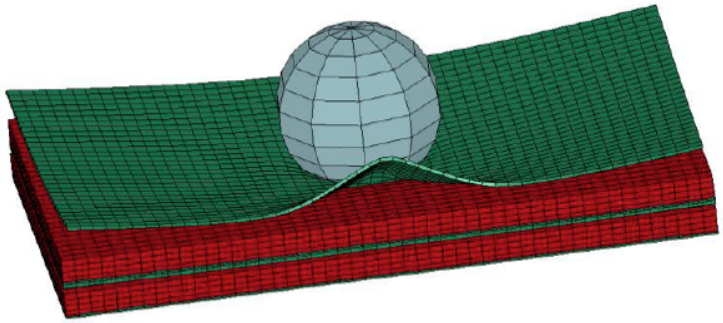
Photos courtesy: Meier, Sahrei, Wierzbicki

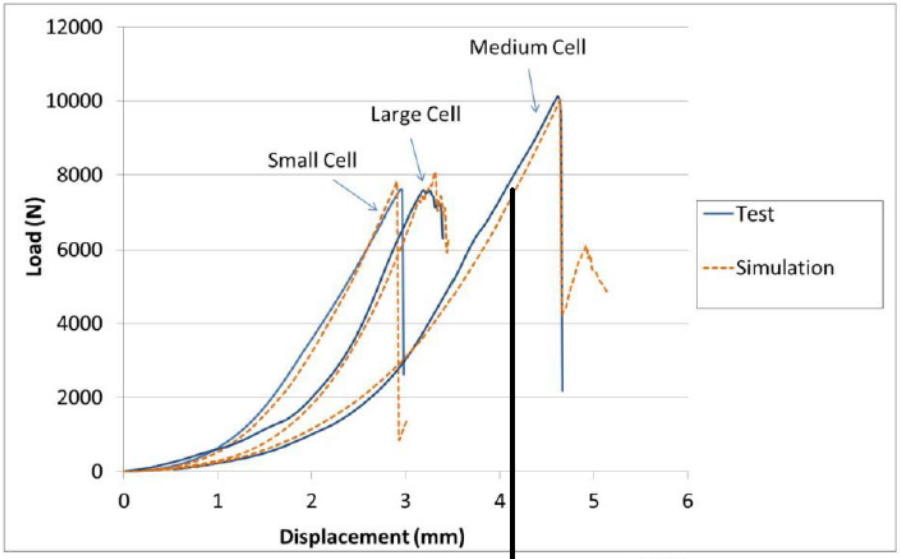
ICL Battery Consortium Research History

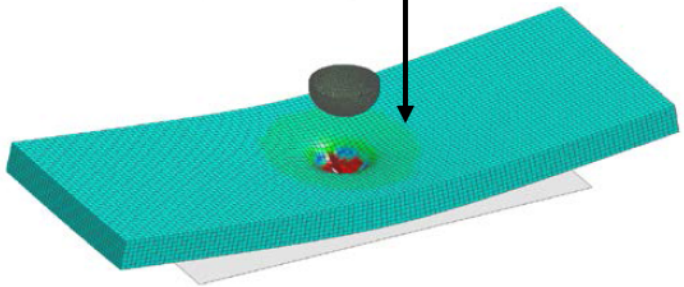


Video courtesy: Meier, Sahrei, Wierzbicki

ICL Battery Consortium Research History







Photos courtesy: Meier, Sahrei, Wierzbicki

Typical Li-ion Battery Layout

- Aluminum sheet coated on both sides with $LiCoO_2$ (cathode)
- Polymer sheet with micro-porous holes to allow Li-ions to pass from anode-cathode or vice versa
- Copper sheet coated on both sides with graphite (anode)

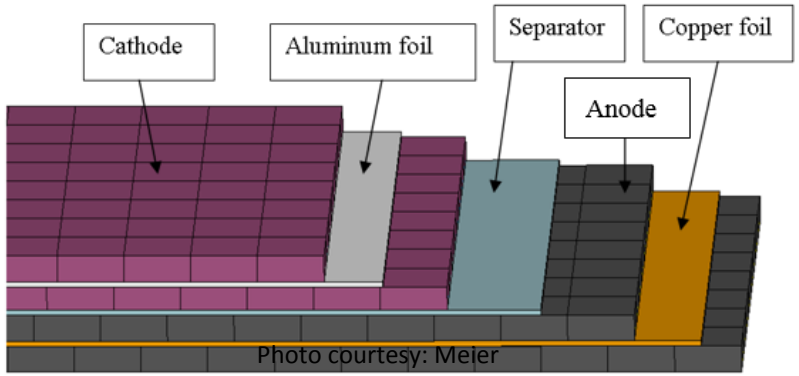
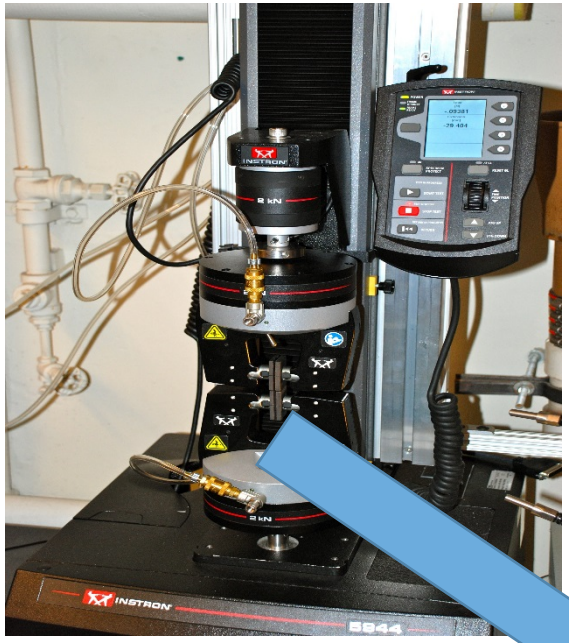
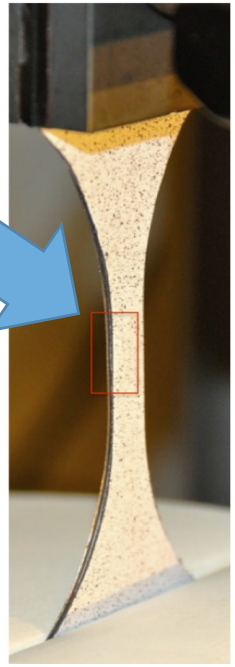
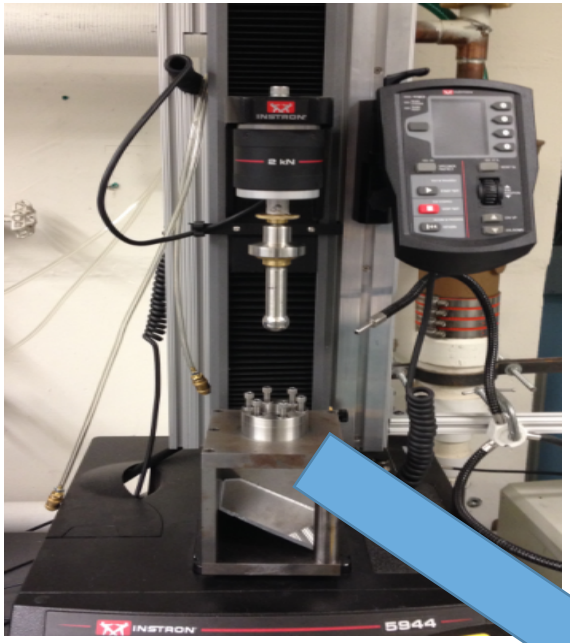


Photo courtesy: Meier

Uniaxial and Biaxial Testing







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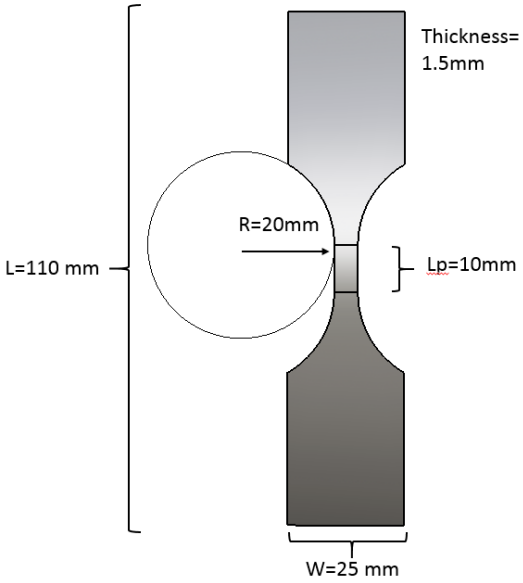
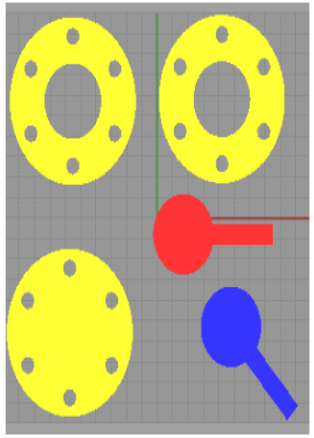
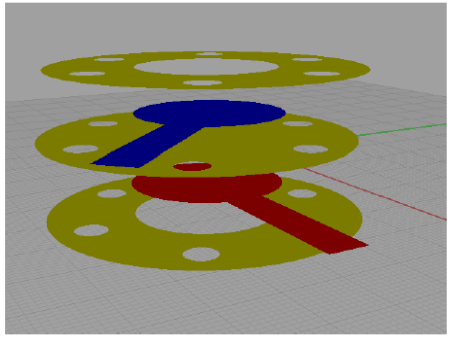
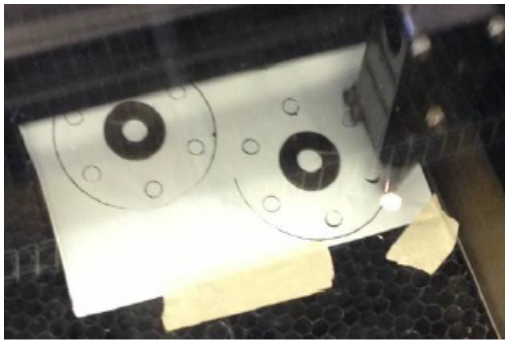
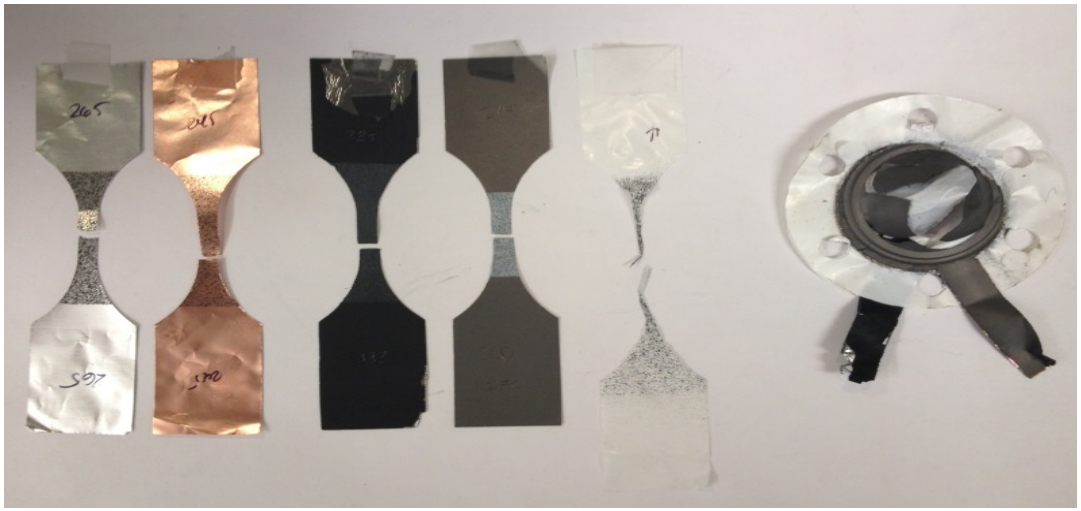


Yellow=Separator
Red=Copper Anode
Blue=Aluminum Cathode



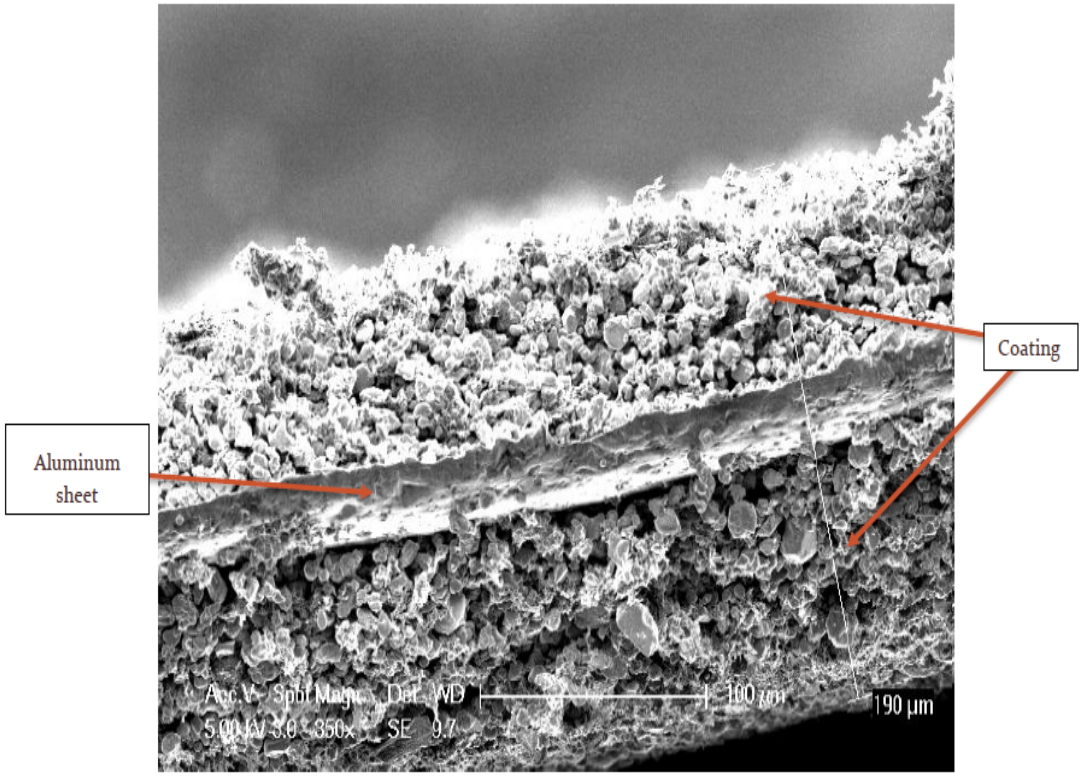






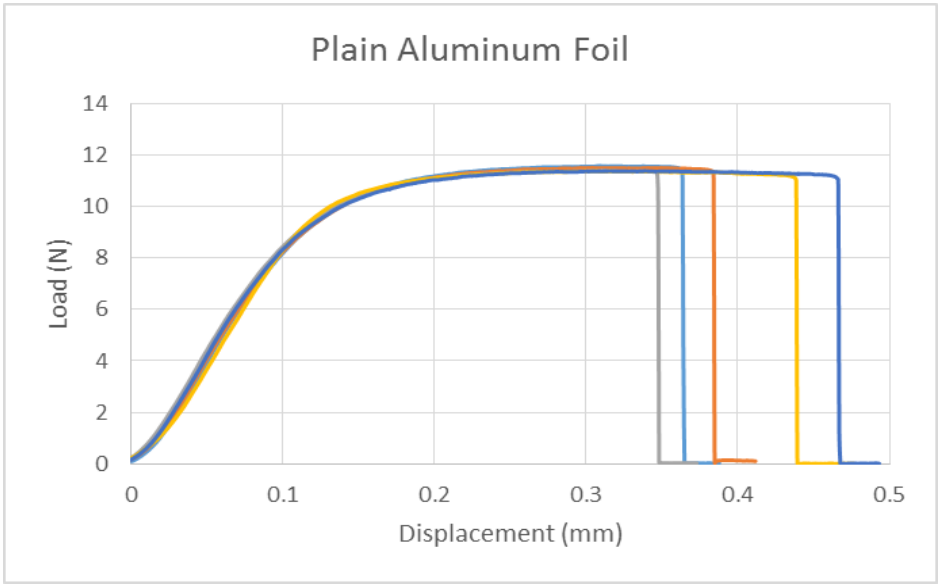
Scanning Electron Microscope Photographs

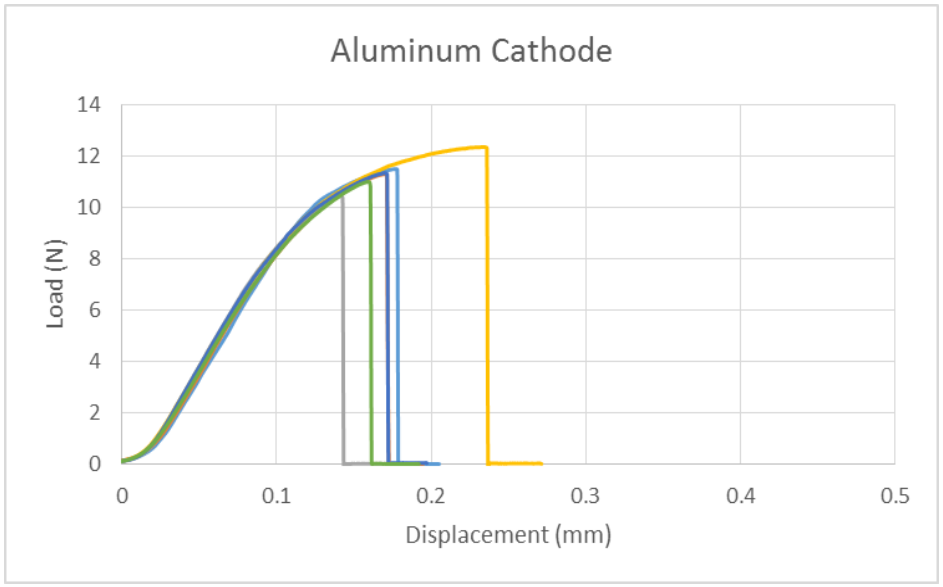
- Better interpret experimental results
- Determine path forward for testing
- Measure component thicknesses



Coated Aluminum

Case Study #1: Aluminum Cathode

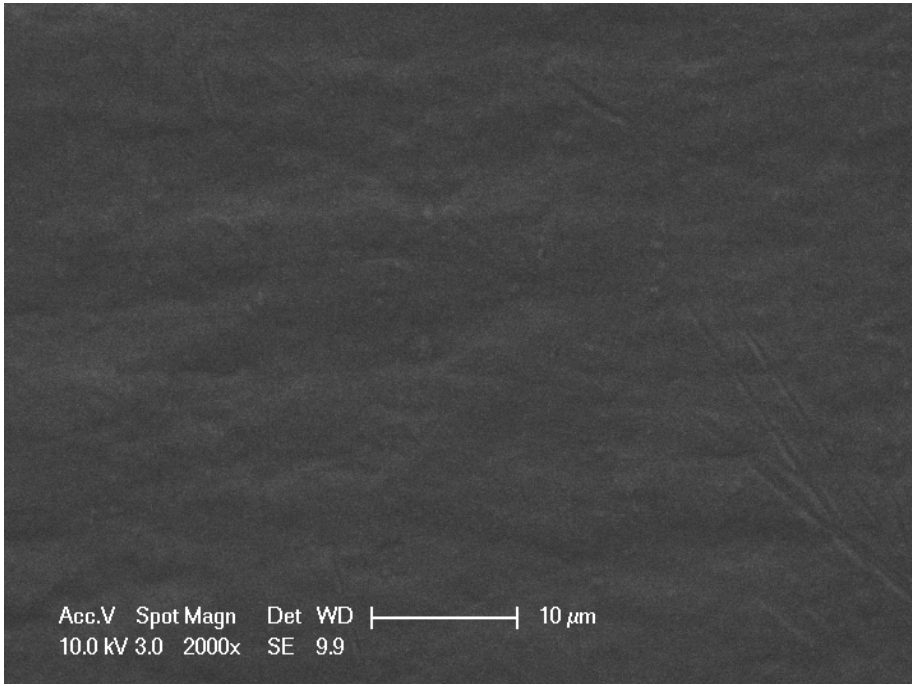




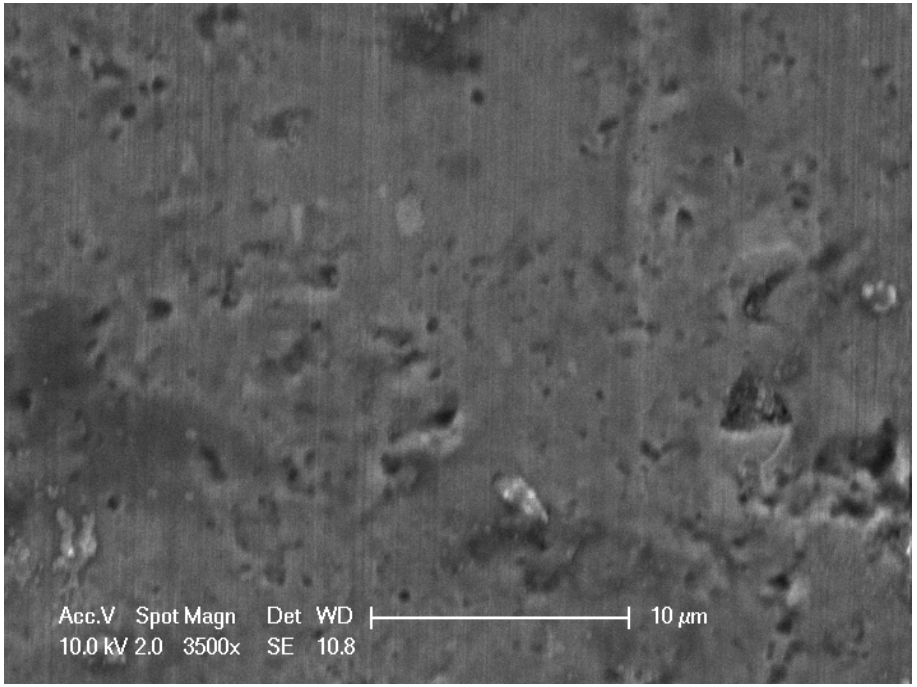
*Each individual line represents a different test

- The aluminum foil is stronger than the coated aluminum foil

Case Study #1: Aluminum Cathode



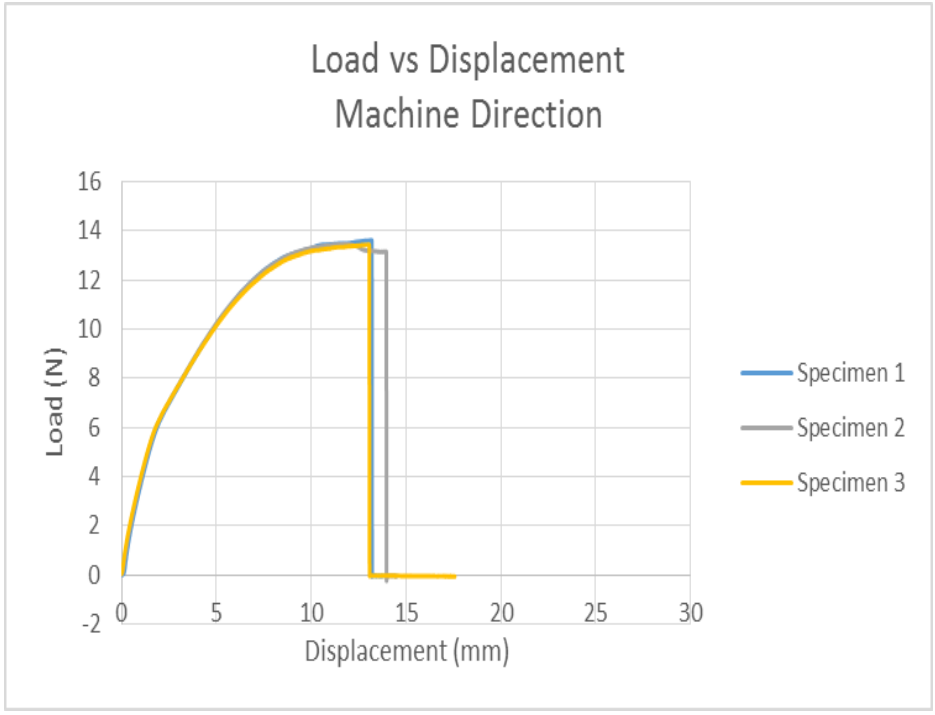
Uncoated Aluminum

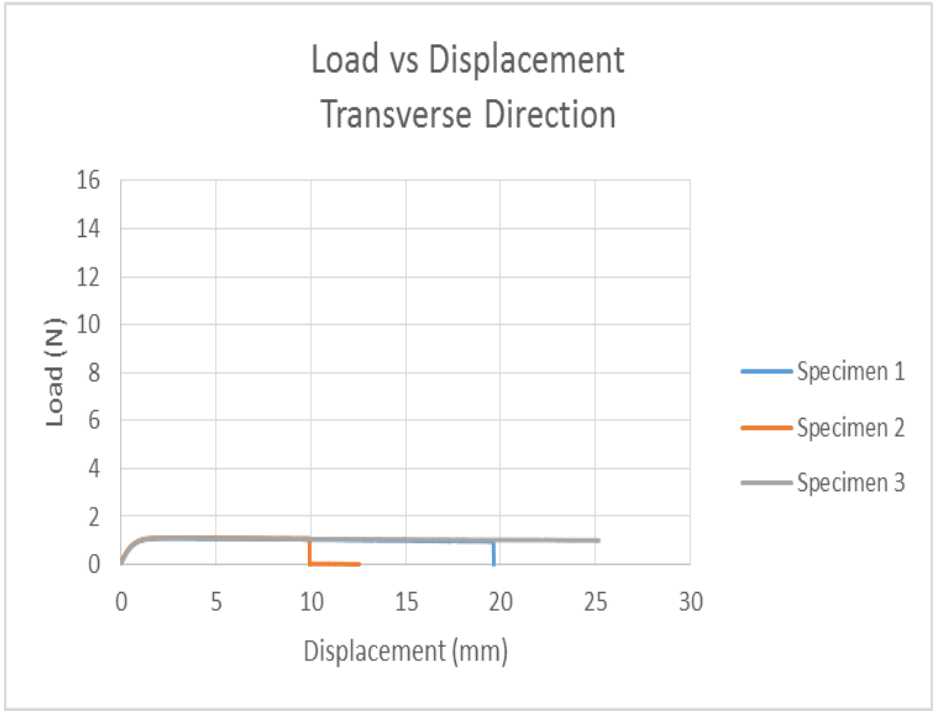


Previously Coated Aluminum

- The aluminum sheet appears to have been damaged in the cathode coating process

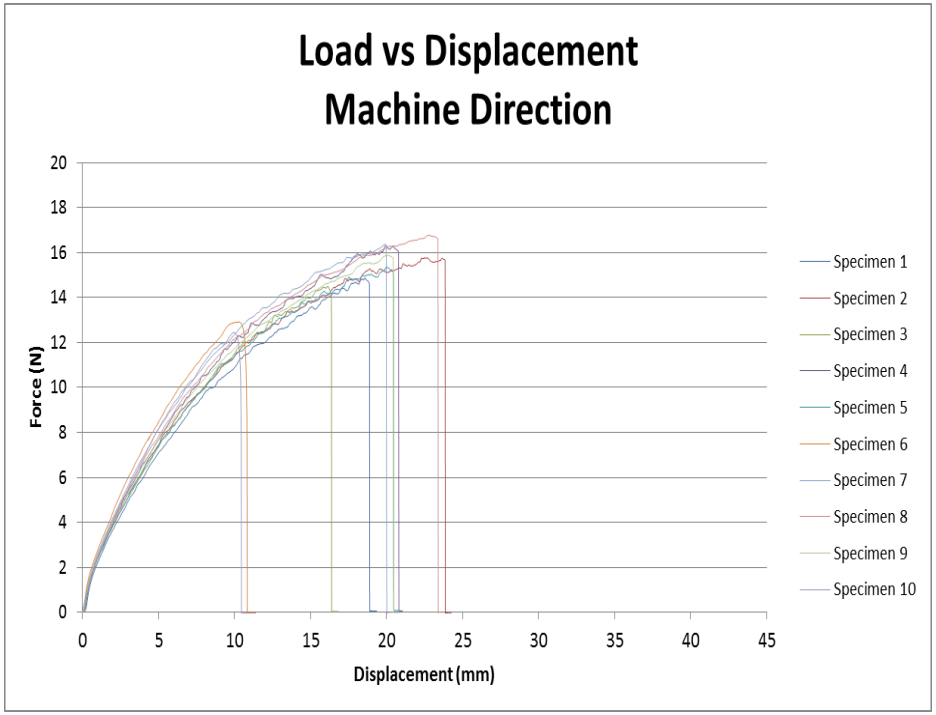
Case Study #2: Separator Material

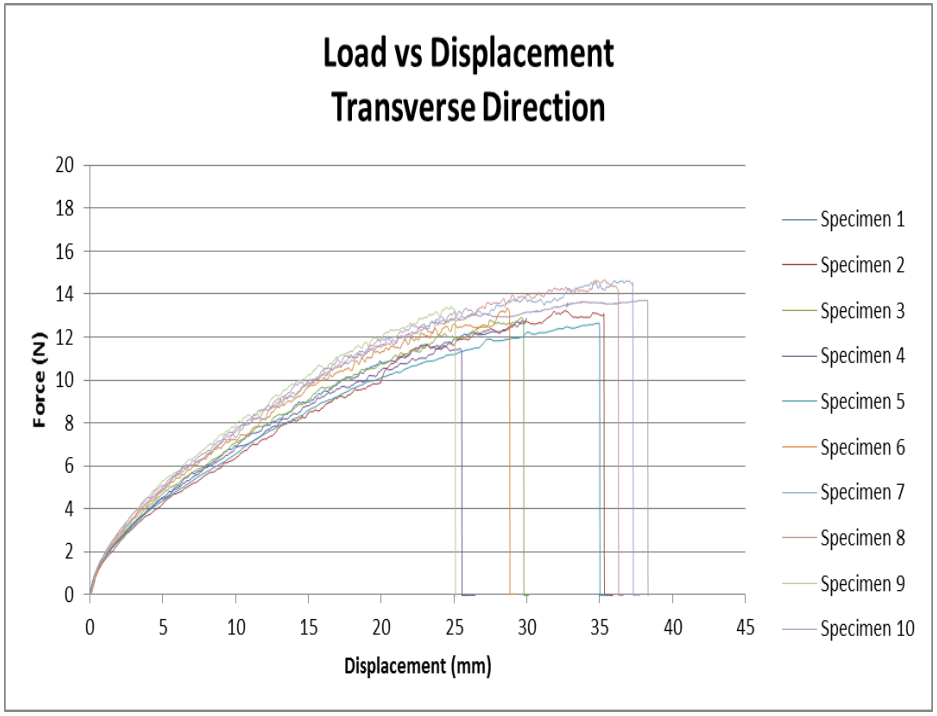




- Type “A” Separator Material: severe anisotropic properties

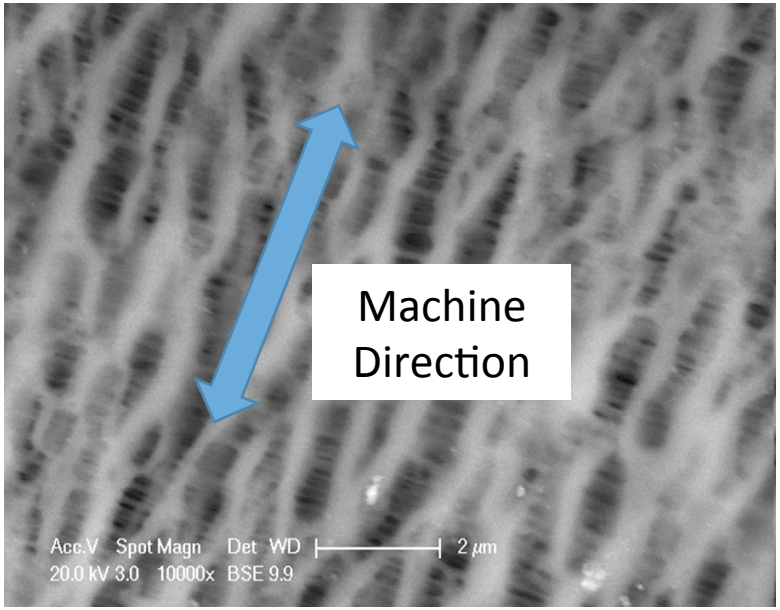
Case Study #2: Separator Material

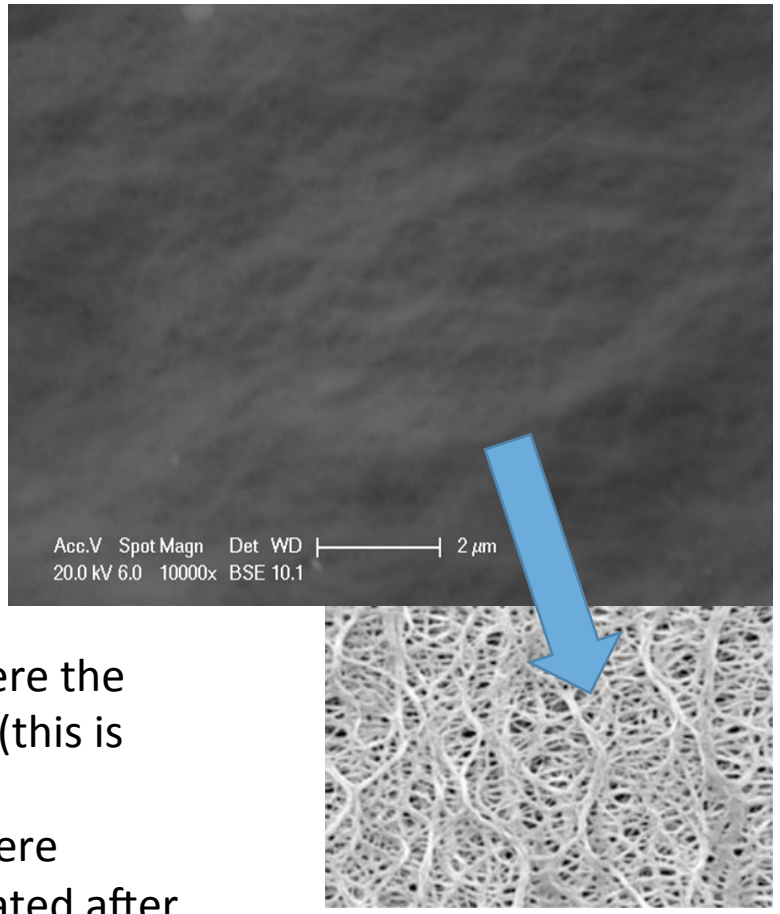




- Type “B” Separator Material: still anisotropic, but much less than type “A”

Case Study #2: Separator Material

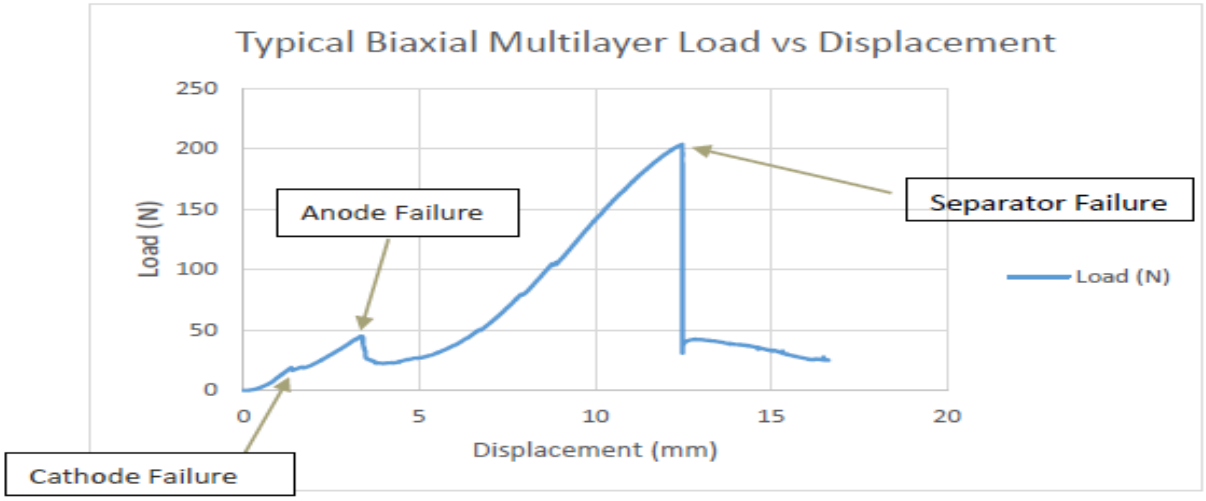


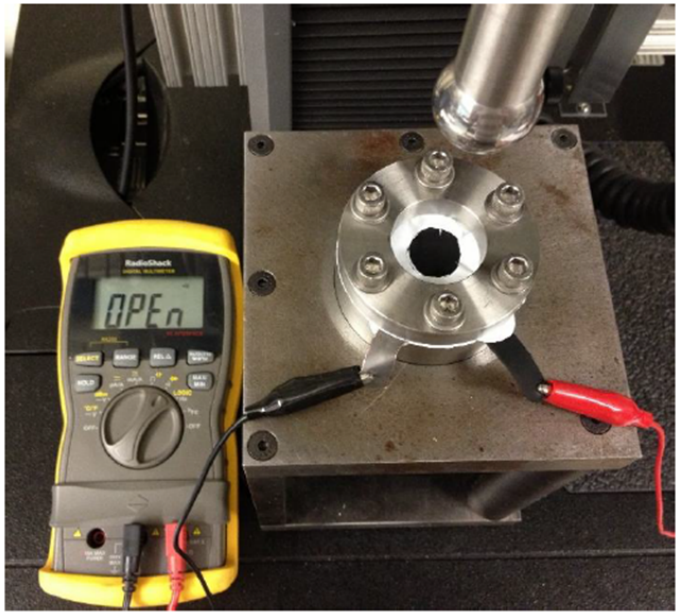


- Type “A” is manufactured using a dry process where the sheet is created and then it is stretched in the TD (this is called crazing)
- Type “B” is manufactured using a wet process where additives are put in the material and then evaporated after the sheet is created

Bottom photo courtesy: Celgard

Case Study #3: Short circuit detection using components





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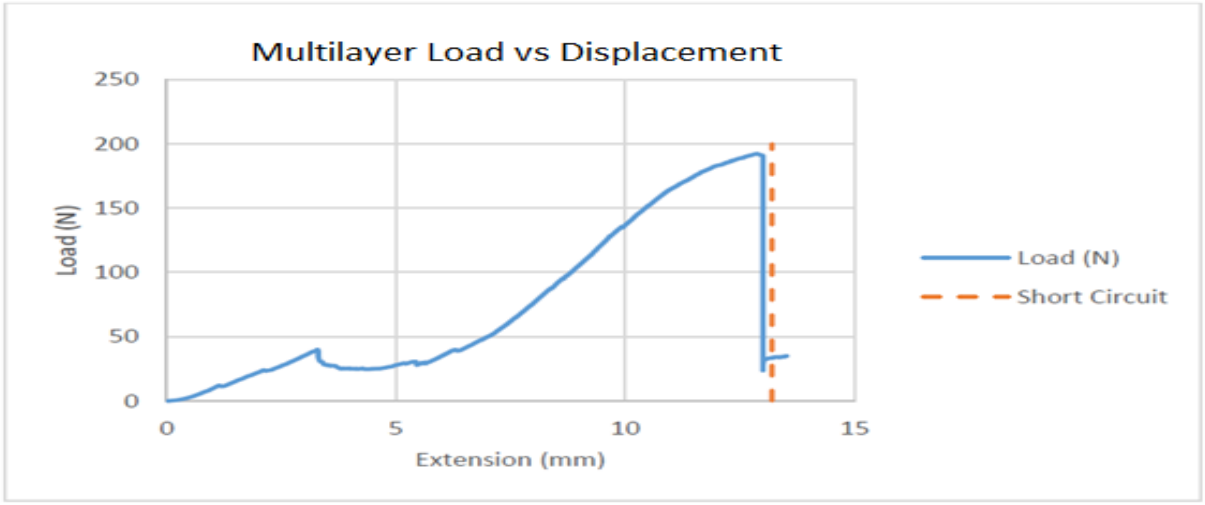

- No toxic gas release
- No need to buy full batteries
- No hazmat disposal
- Results still need to be validated with full sized battery models

Conclusions and Future Work

- Anode/Cathode are damaged during coating and have less desirable mechanical properties
- Separator manufacturing methods are crucial to mechanical properties
- Short circuit can be detected through single multilayer specimen
- Results to be used to further refine a robust computational tool to predict strength, energy absorption, and the onset of electric short circuit of batteries
- Cell deformation models will enable optimization of the battery pack/vehicle combination with respect to tolerance of battery crush intrusion behavior
- Models will contribute to the reduction of prototyping cost and shorted the development cycle of any electric powered vehicle/vessel

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