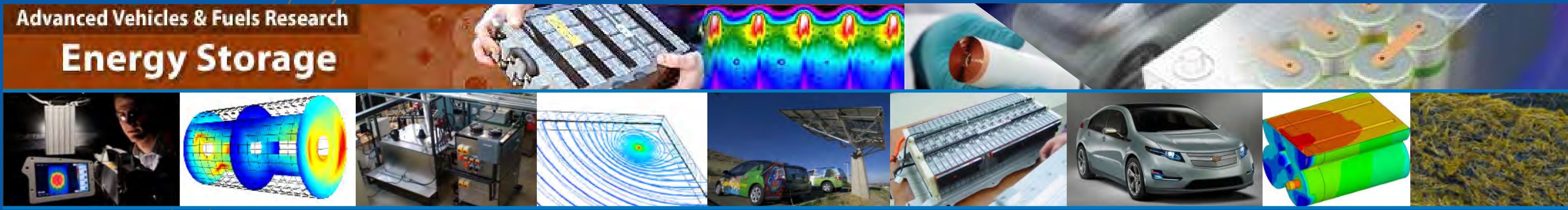
NREL/NASA Internal Short-Circuit Instigator in Lithium Ion Cells



JRC Lithium Ion Safety Workshop

Petten, Netherlands

March 8-9,2018

Matt Keyser, National Renewable Energy Laboratory

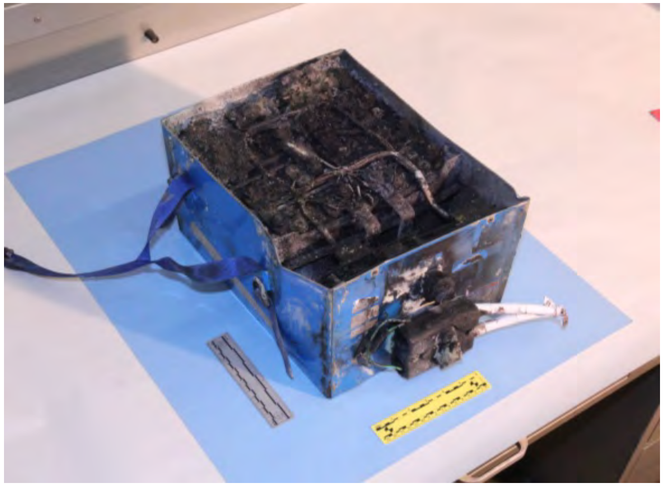
Eric Darcy, NASA - JSC

Presentation Outline

- Background
- Motivation
- Objectives
- NREL/NASA ISC Approach
- ISC Studies
  - Pouch Cell – Flammable vs. Non-flammable Electrolyte
  - 18650 Cylindrical Cell – Shutdown Separator Study
  - Synchrotron Testing with ISC
- Conclusions and Summary

Background: Li-Ion Cell Internal Short, a Major Concern

Aftermath of the Boeing Dreamliner 787 Battery



Laptop Battery Fire

Aftermath of a Hoverboard Battery Fire

Samsung Galaxy Note 7 Fire/Recall

- Li-ion cells provide the highest energy density of all rechargeable batteries to date with the longest life.
- Many safety incidents that take place in the field originate due to an internal short that was not detectable or predictable at the point of manufacture.

Motivation

Lithium Ion Battery Field Failures - Mechanisms

- Latent defect gradually moves into position to create an internal short while the battery is in use.
- Inadequate design and/or off-limits operation (cycling) causes Li surface plating on anode, eventually stressing the separator

Both mechanisms are rare enough that catching one in the act or even inducing a cell with a benign short into a hard short is inefficient.

Current internal short abuse test methods may not be relevant to field failures

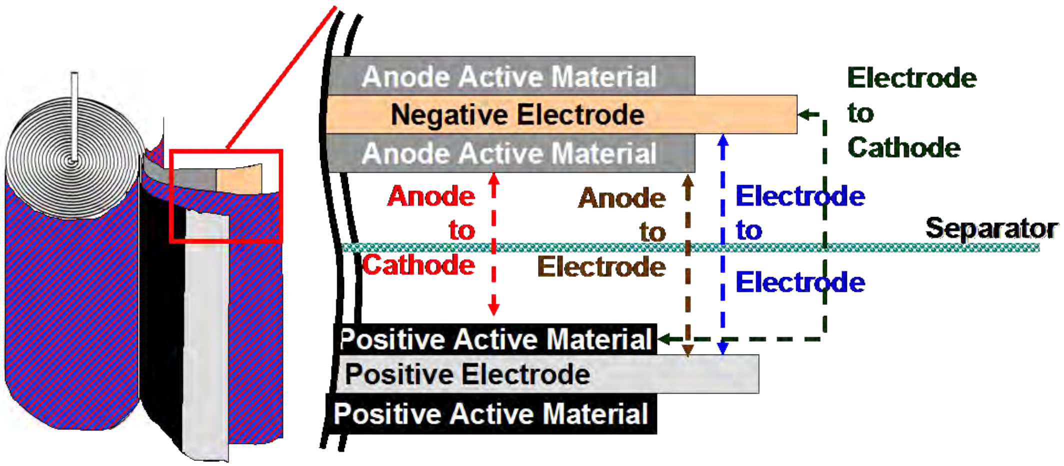
- Mechanical (crush, nail penetration, etc.)
- Thermal (heat to vent, thermal cycling, etc.)
- Electrical (overcharge, off-limits cycling, etc.)

To date, no reliable and practical method exists to create on-demand internal shorts in Li-ion cells that produce a response that is relevant to the ones produced by field failures.

NREL/NASA Objectives

Establish an improved ISC cell-level test method that:

- Simulates an emergent internal short circuit.
  - Capable of triggering the **four** types of cell internal shorts



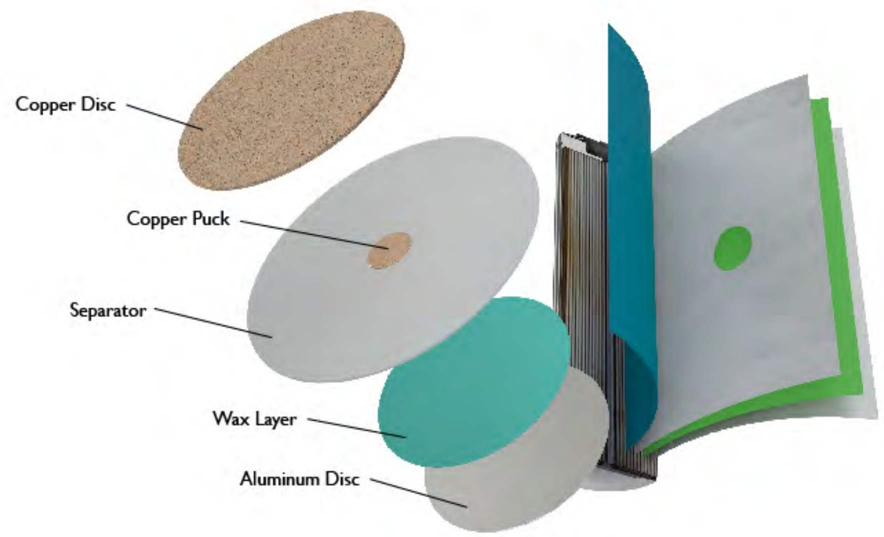
Spiral wound battery shown – can also be applied to prismatic batteries.

- Produces consistent and reproducible results
- Cell behaves normally until the short is activated – age cell before activation.
- We can establish the test conditions for the cell – SOC, temperature, power, etc…
- Provides relevant data to validate ISC models

NREL/NASA Cell Internal Short Circuit Development

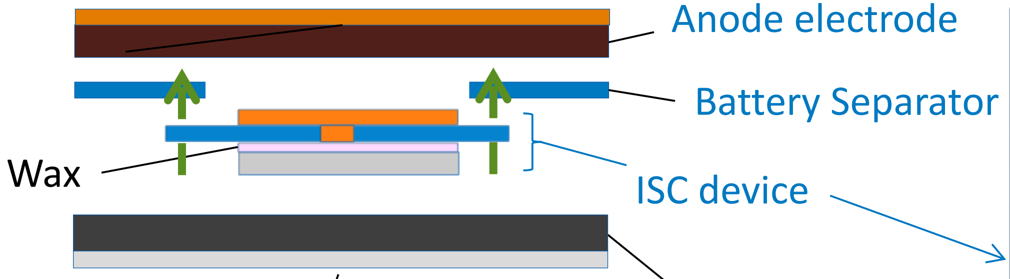
Internal short circuit device design

- Small, low-profile and implantable into Li-ion cells, preferably during assembly
- Key component is an electrolyte-compatible phase change material (PCM)
- Triggered by heating the cell above PCM melting temperature (presently 40°C – 60°C)
    - NREL has developed an ISC that triggers at 47°C and 57°C.

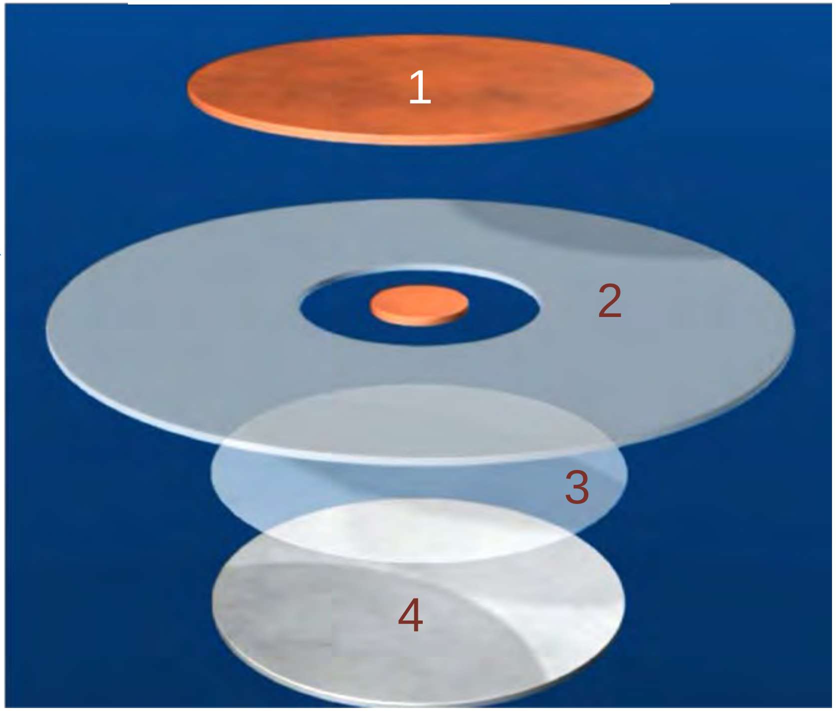


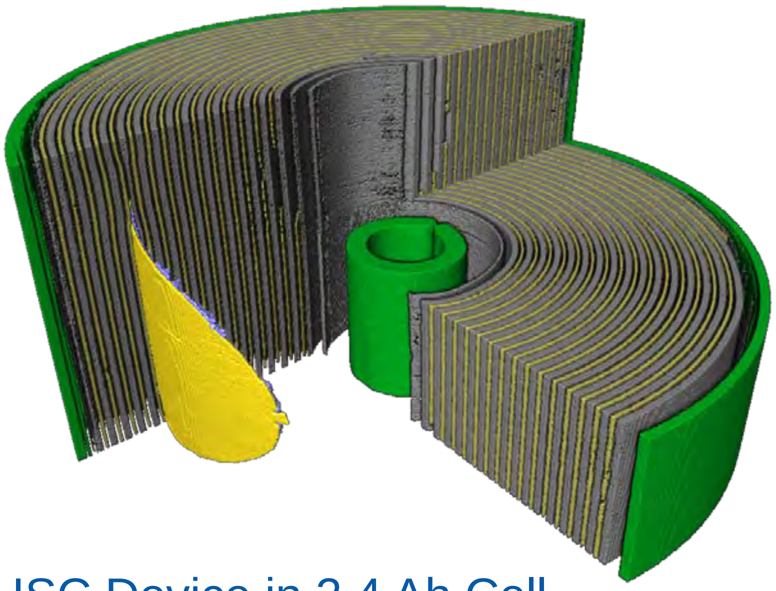
ISC in spiral wound cell

NREL/NASA Internal Short Design



US Patent #: 9,142,189





ISC Device in 2.4 Ah Cell

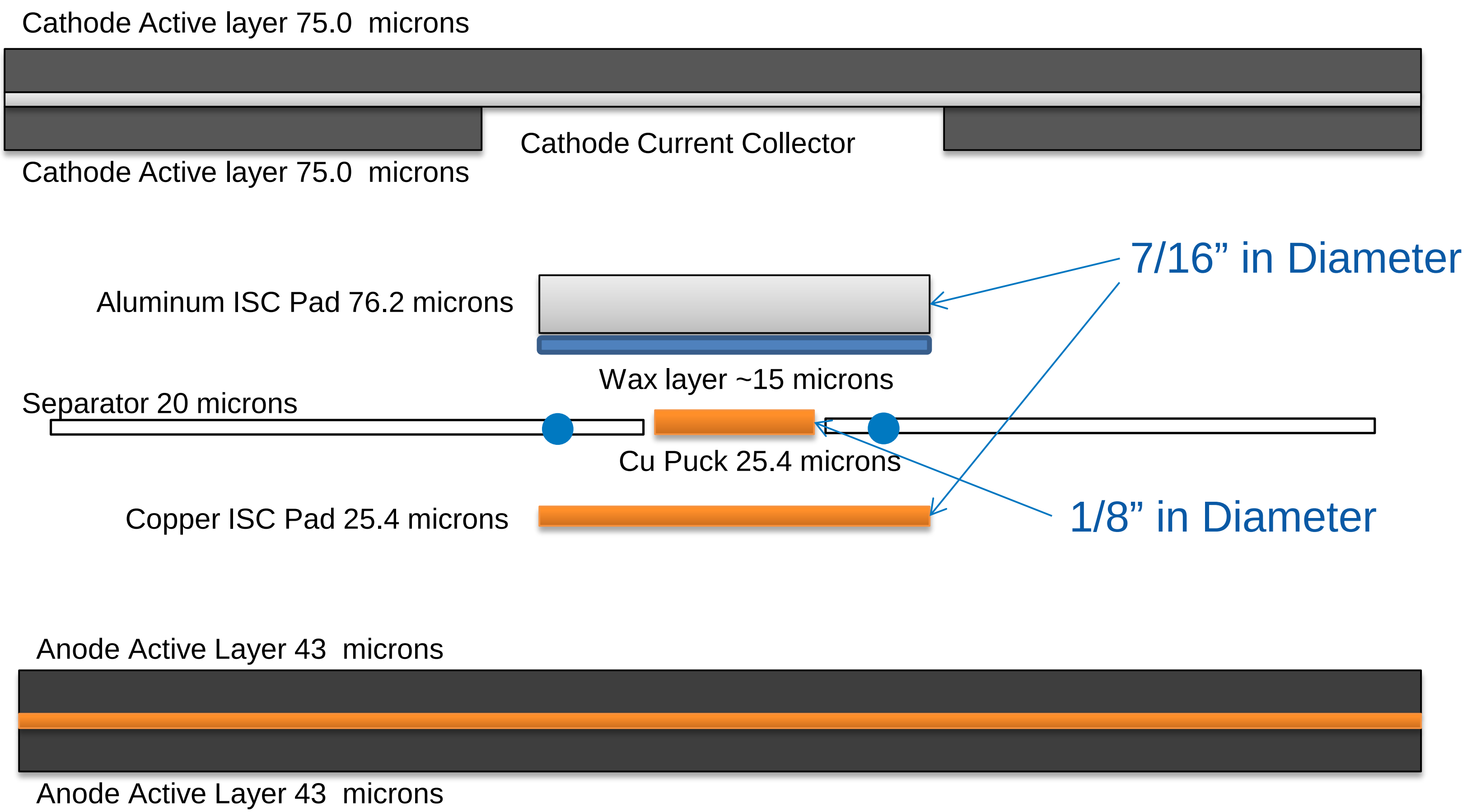
Top to Bottom:
1. Copper Pad
2. Battery Separator with Copper Puck
3. Wax – Phase Change Material
4. Aluminum Pad

Four Types of ISC

Type	ISC Device Description
1	Cathode – Anode
2	Collector – Anode
3	Cathode – Collector
4	Collector – Collector

ISC Device Example for a Type 2 Short

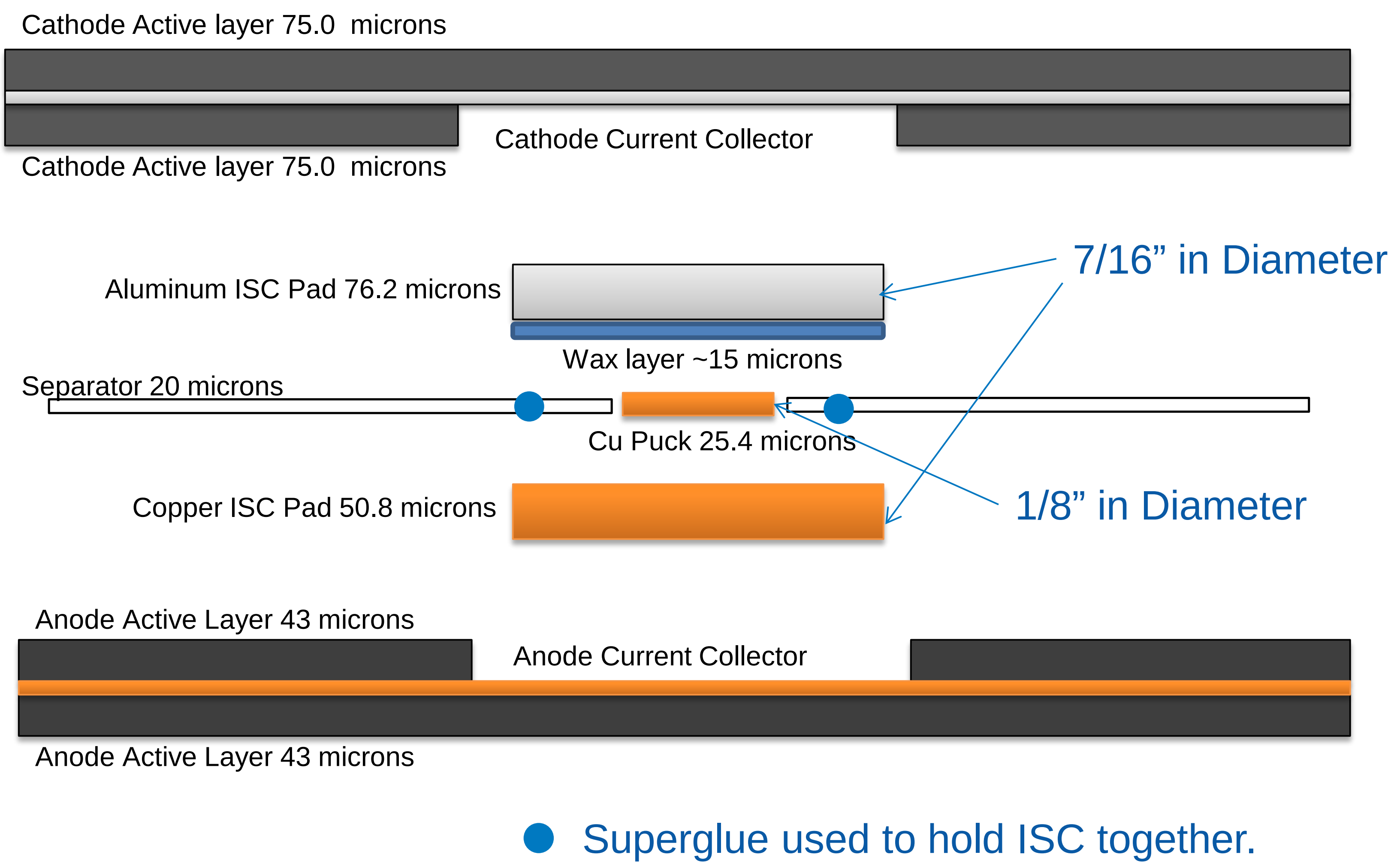
Cathode current collector to Anode active material



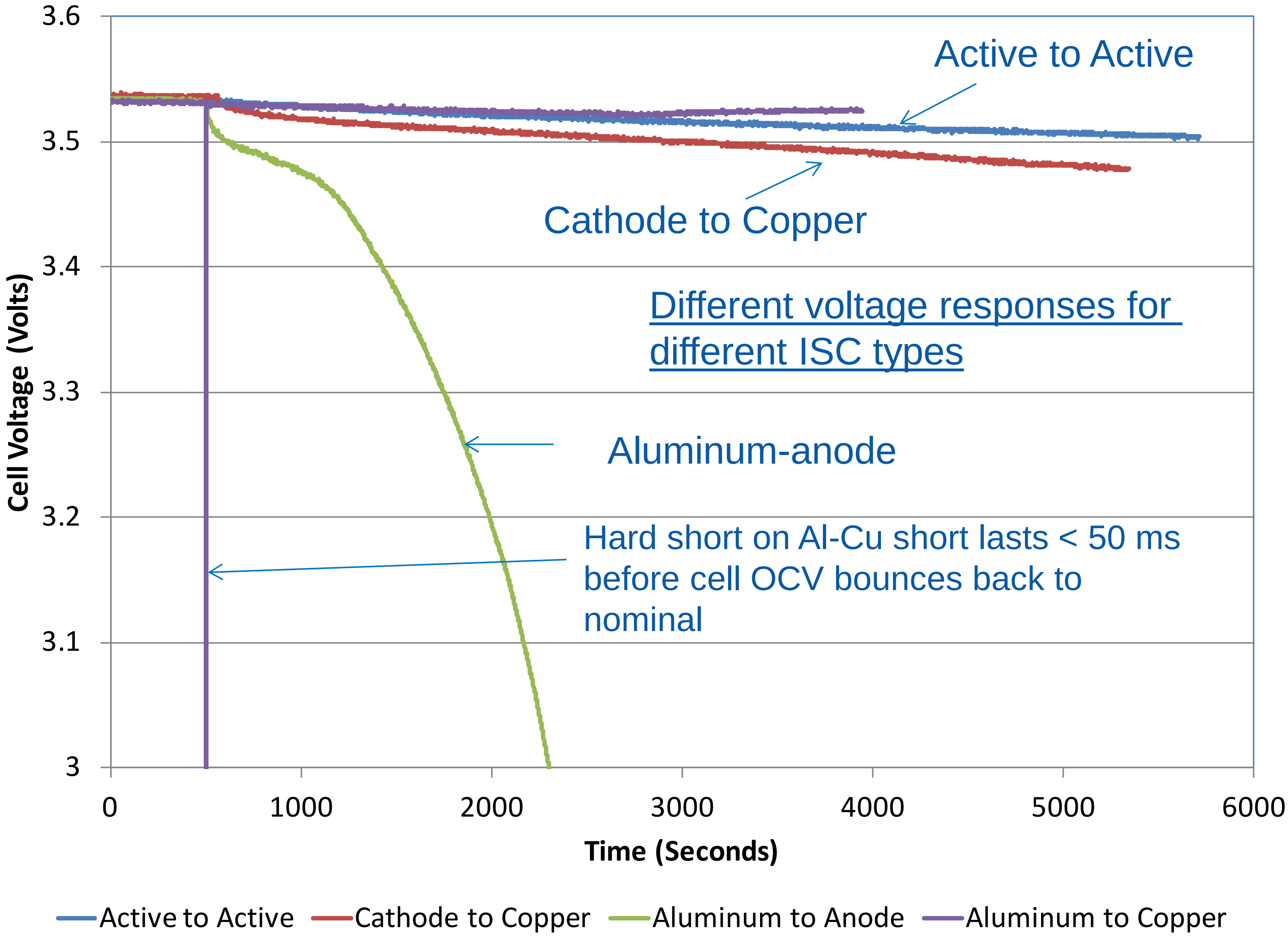
- Superglue used to hold ISC together.

ISC Device Example for a Type 4 Short

Cathode current collector to Anode current collector

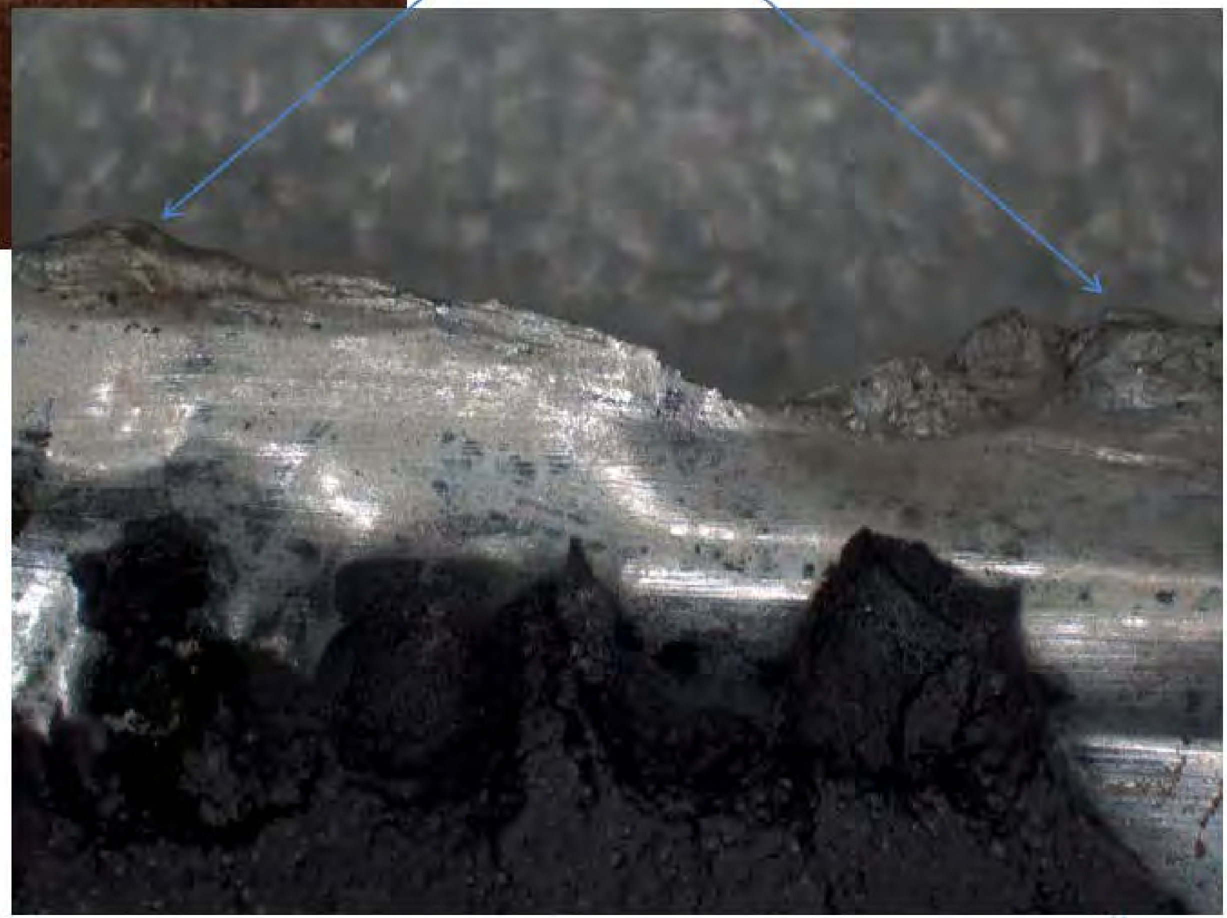


Dow Kokam 8 Ah Cell Activation at 10% SOC



Macro Image of Cathode DK Cell Tab – Al to Cu ISC

Molten Al is evident several places



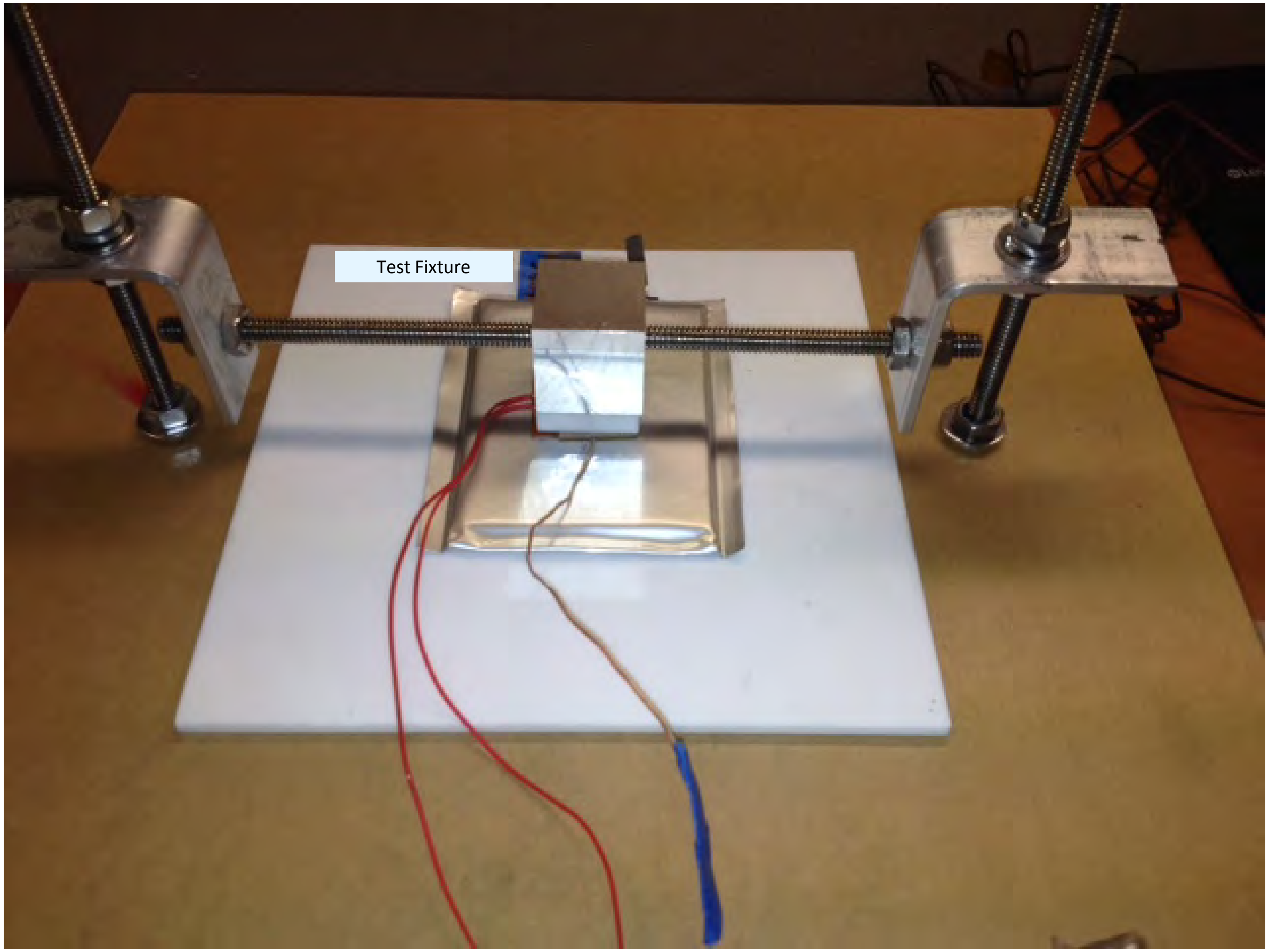
Tab was thermally overstressed, fused open during the hard short incident

Photo Credits: Eric Darcy, NASA

ISC Device Implantation and Test Results

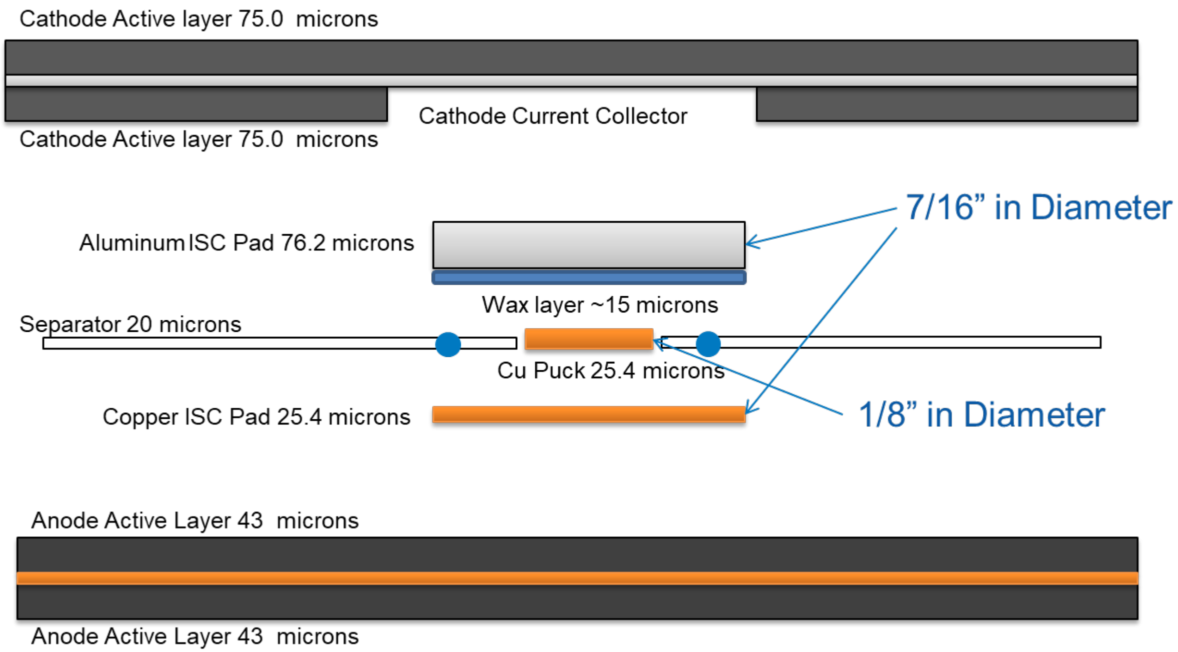
- **Pouch Cell – Non-flammable (NF) electrolyte**
- 18650 Cylindrical Cell – Shutdown Separator Study
- Synchrotron Testing with ISC Trigger

Test Fixture

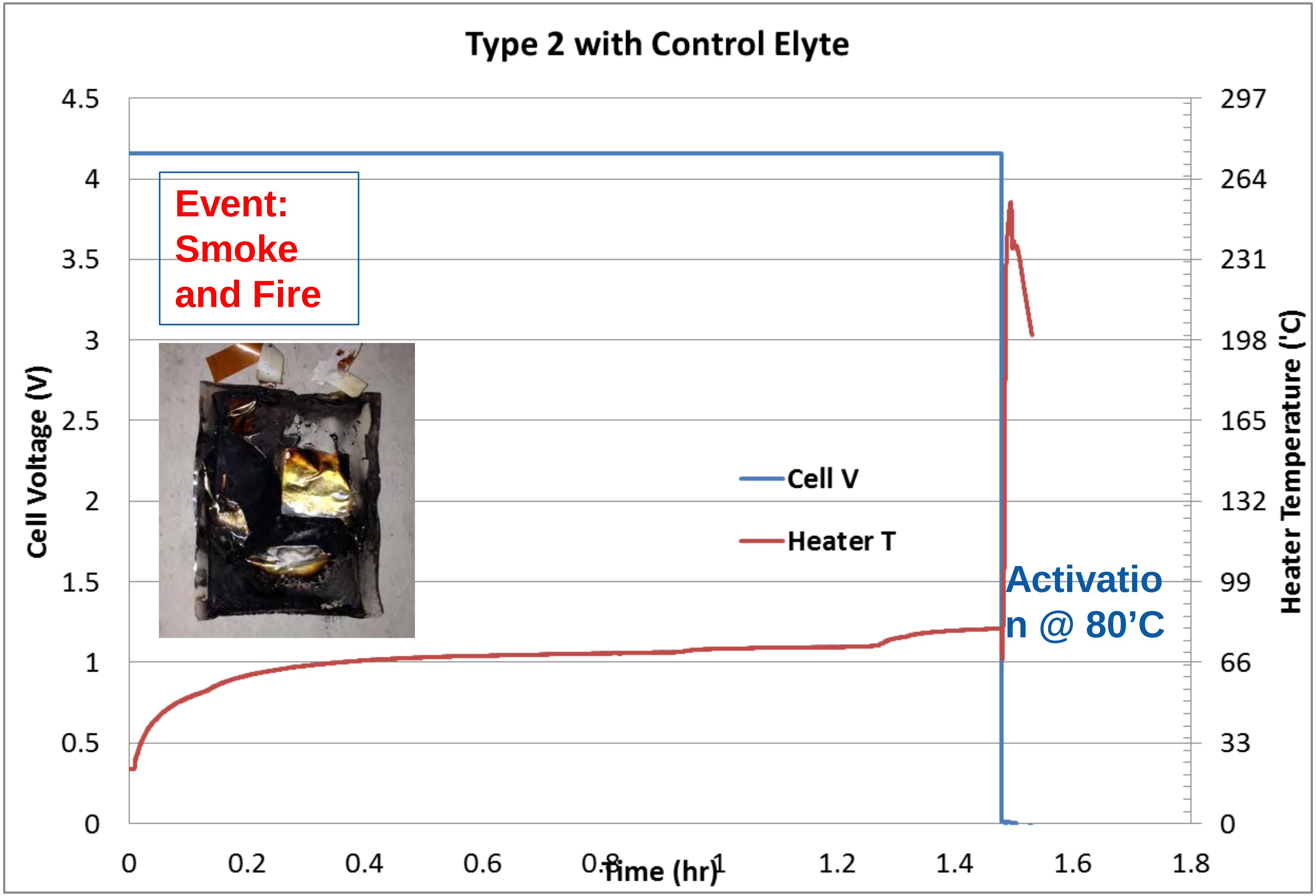


~20 Ah cells were testing with two types electrolytes and with a Type 2 ISC – Al to Anode.

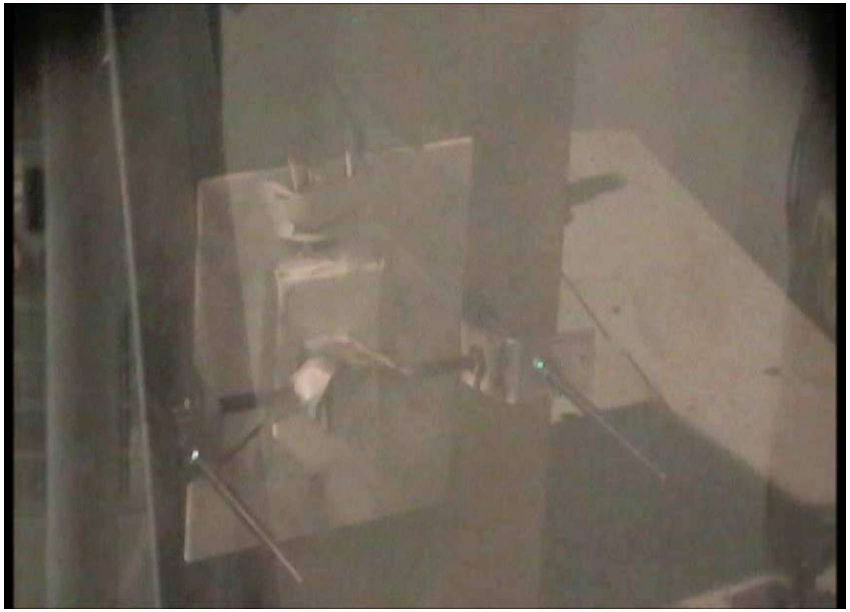
Type 2 ISC – Aluminum to Anode ISC

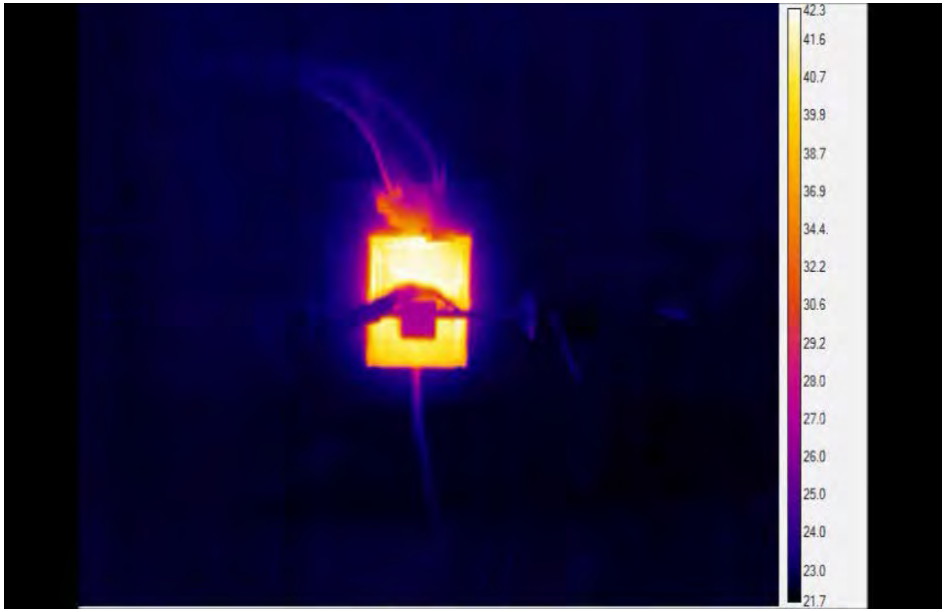


Type 2, Control Electrolyte

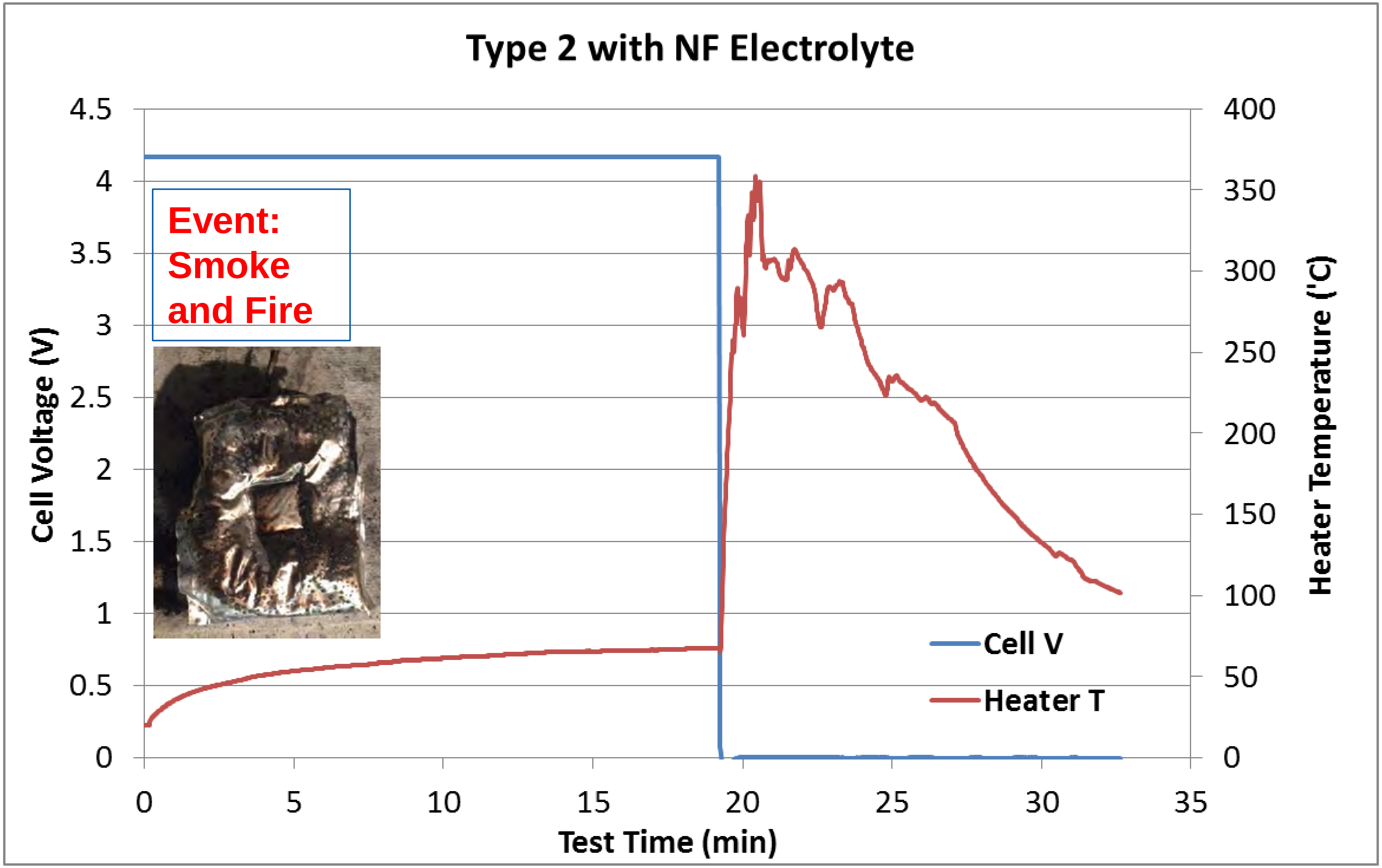


Type 2, Control Electrolyte

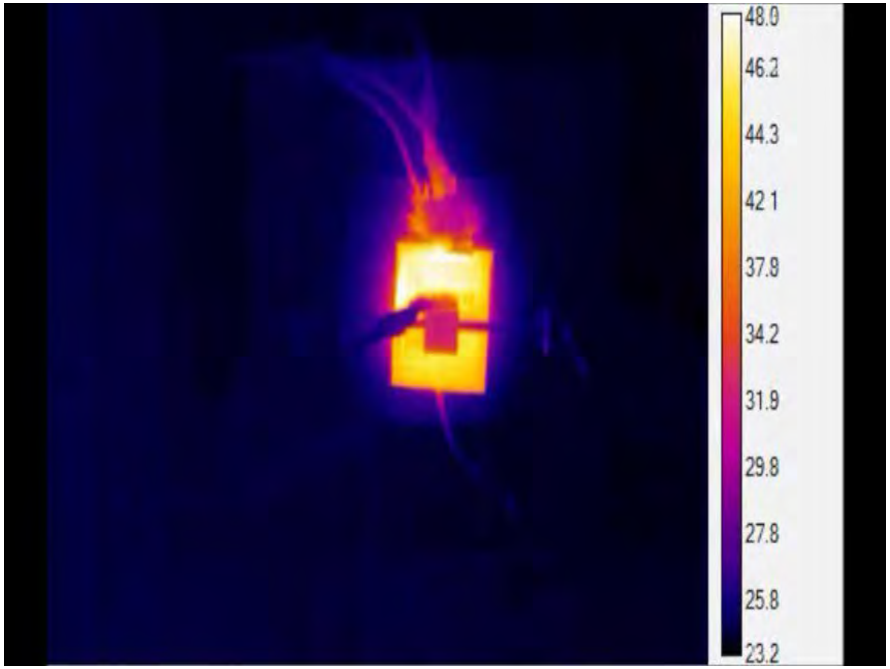




Type 2, Non-flammable (NF) Electrolyte



Type 2, NF Electrolyte



ISC Device Implantation and Test Results

- **Pouch Cell – Non-flammable (NF) electrolyte**
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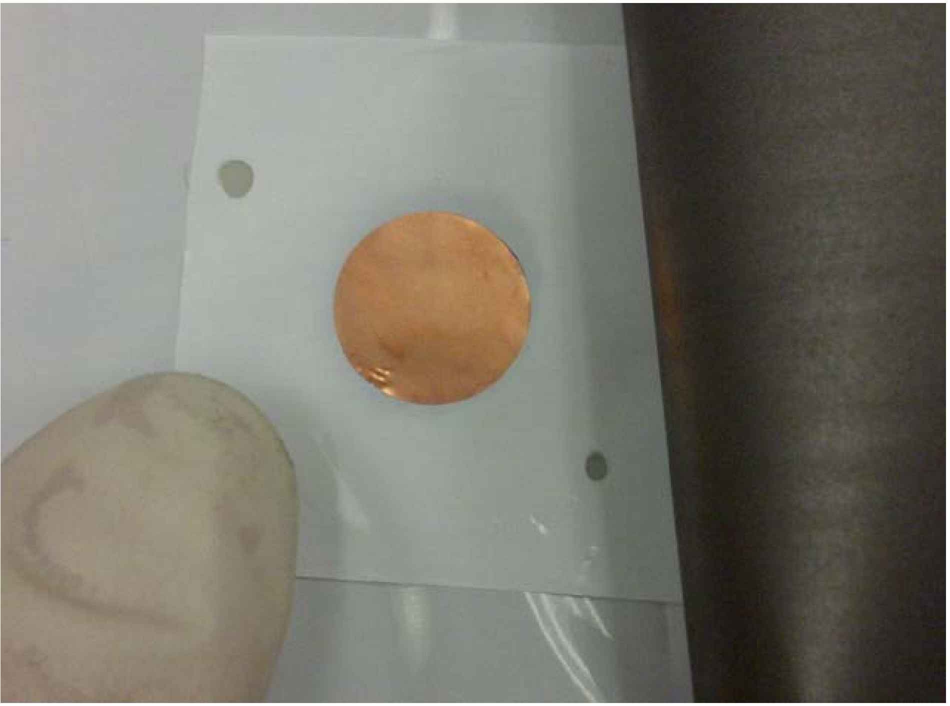
ISC Implantation – Active to Active



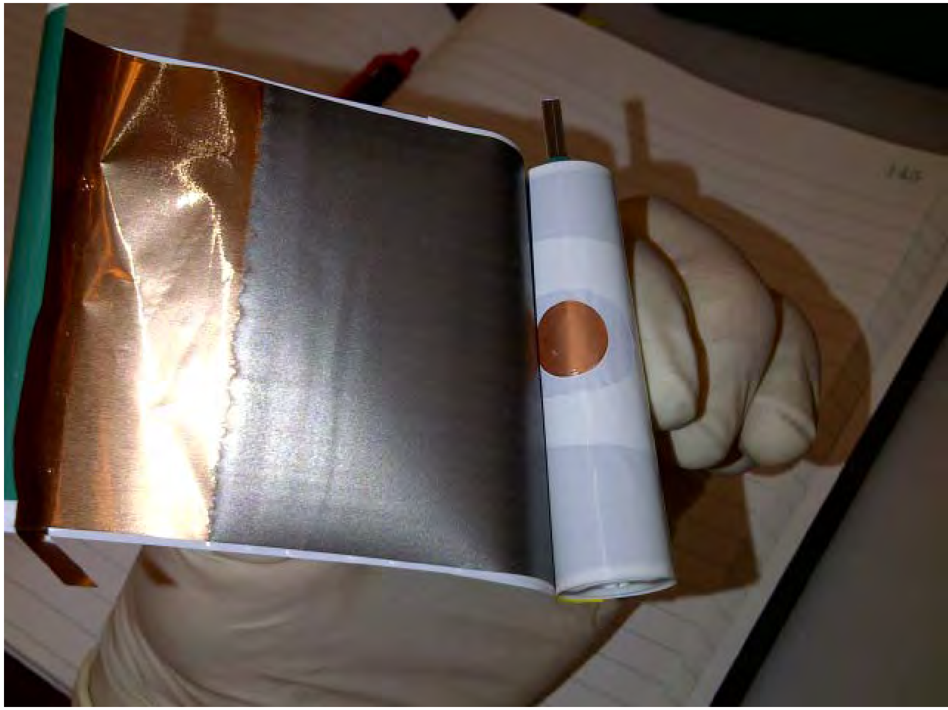


Photo Credits: Mark Shoesmith, E-One Moli

CT Scan of ISC in E-One Moli Cell

Click on Image to see video – approximately 10 seconds into video the ISC will appear in the lower left hand corner of the cell.

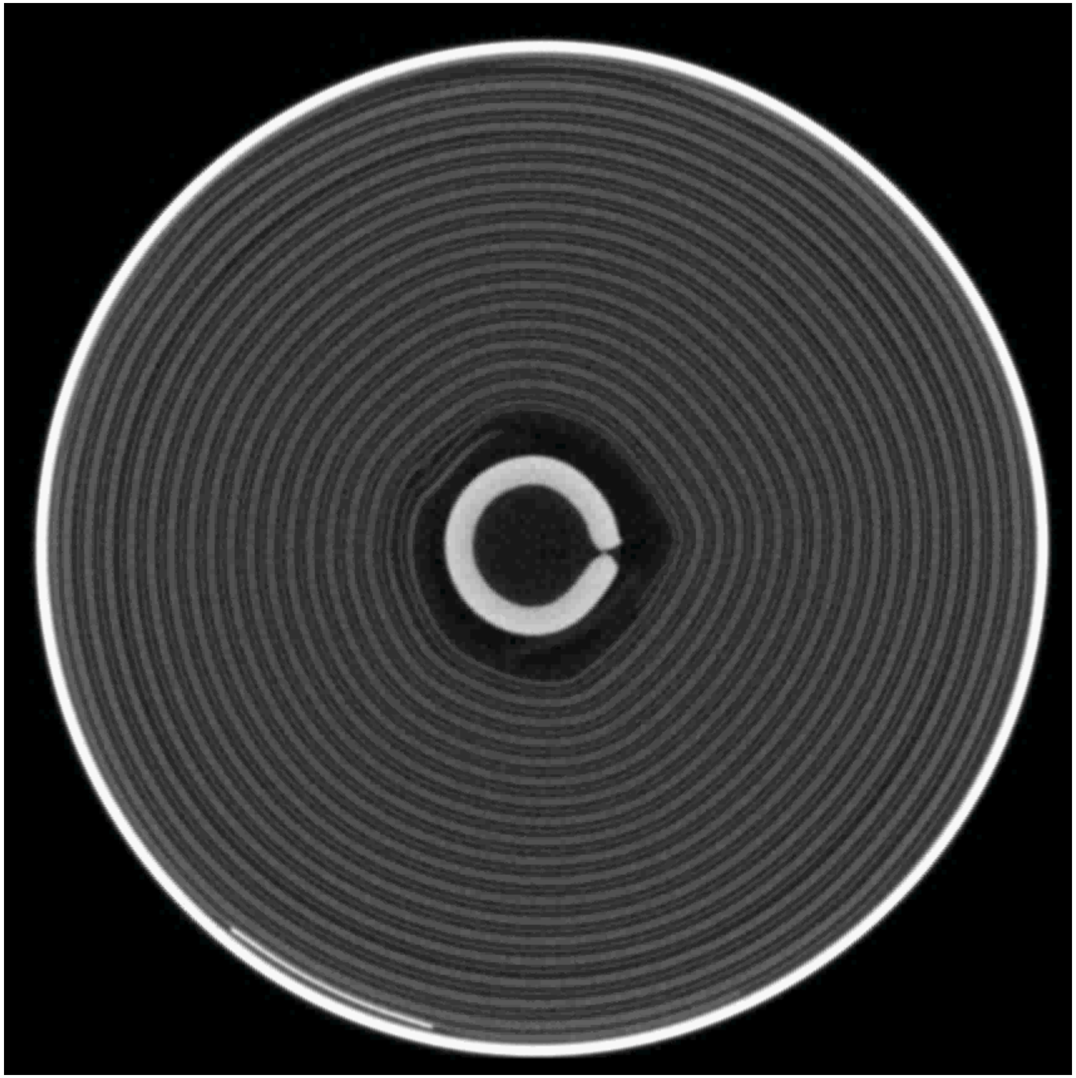
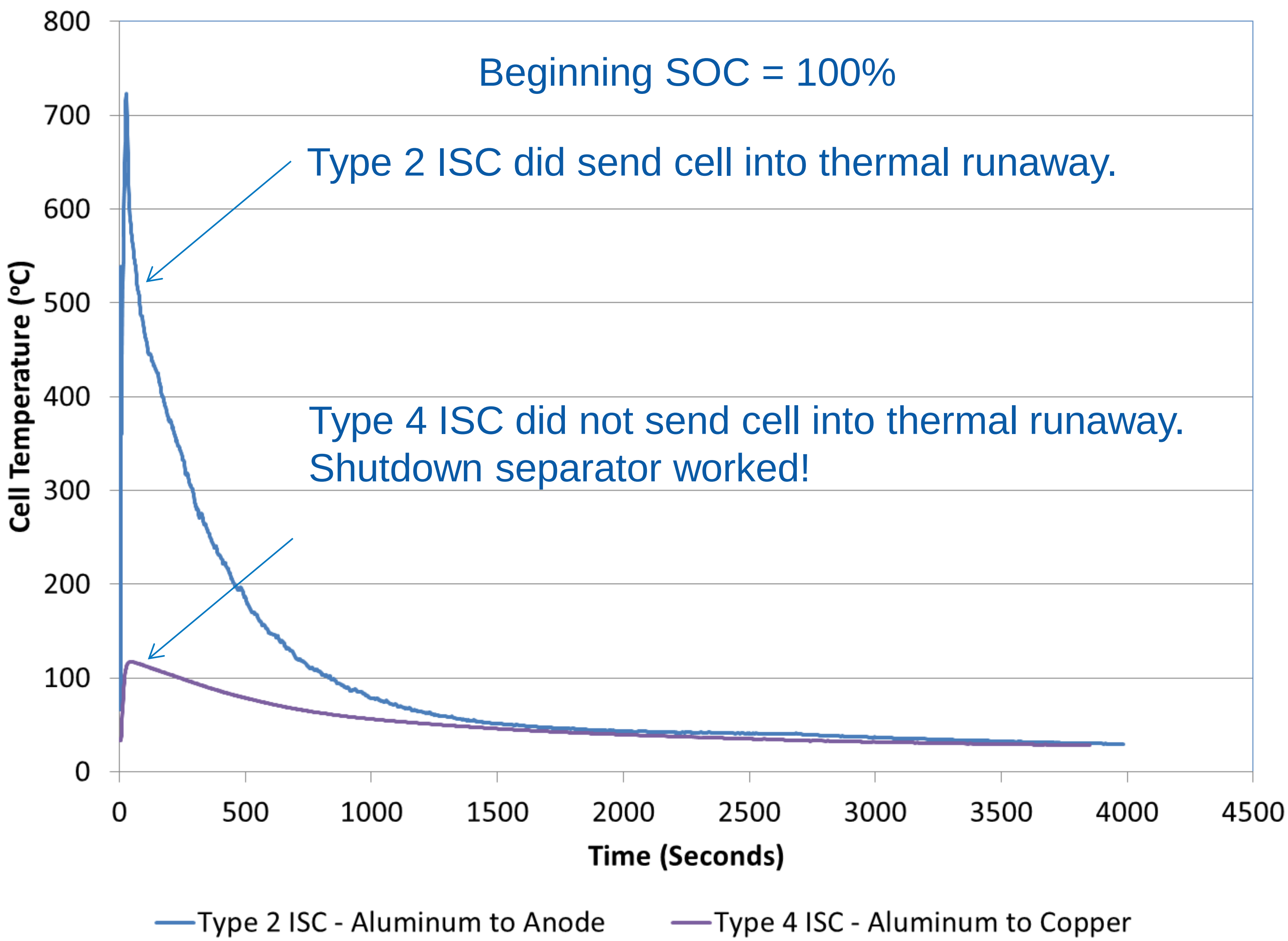


Photo Credits: Mark Shoesmith, E-One Moli

Type 2 ISC vs. Type 4 ISC with Shutdown Separator



Aluminum to Anode ISC Activation – 18650 Cell Activation – 100% SOC

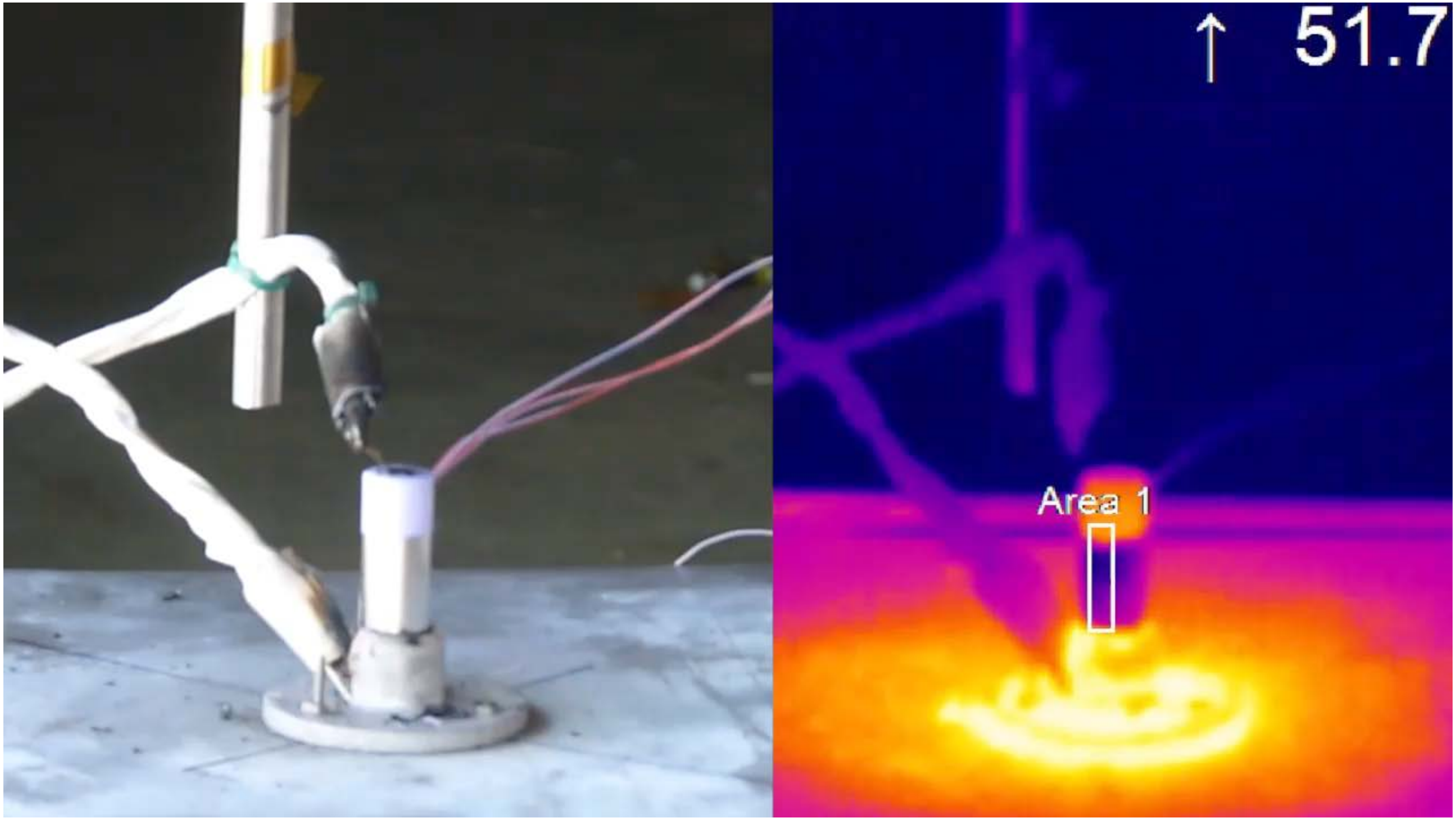


Photo Credit: Mark Shoesmith, E-One Moli

PP Separator Used - Non-Standard Separator

ISC Device Implantation and Test Results

- **Pouch Cell – Non-flammable (NF) electrolyte**
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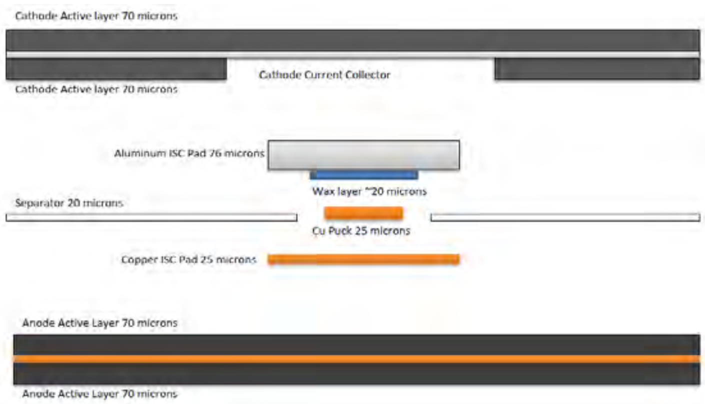
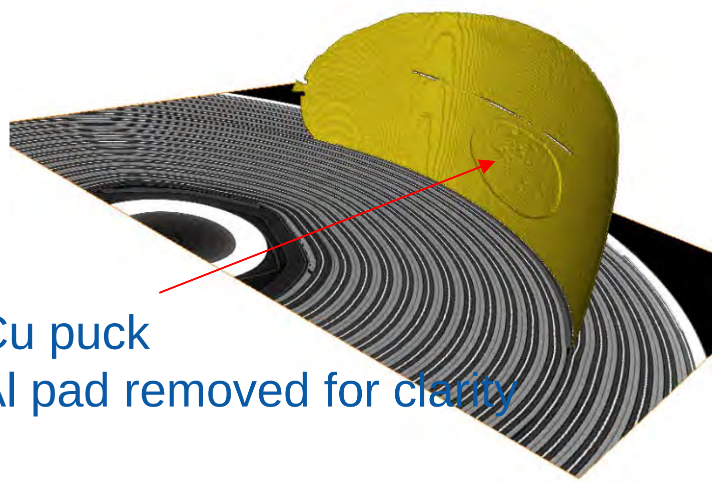
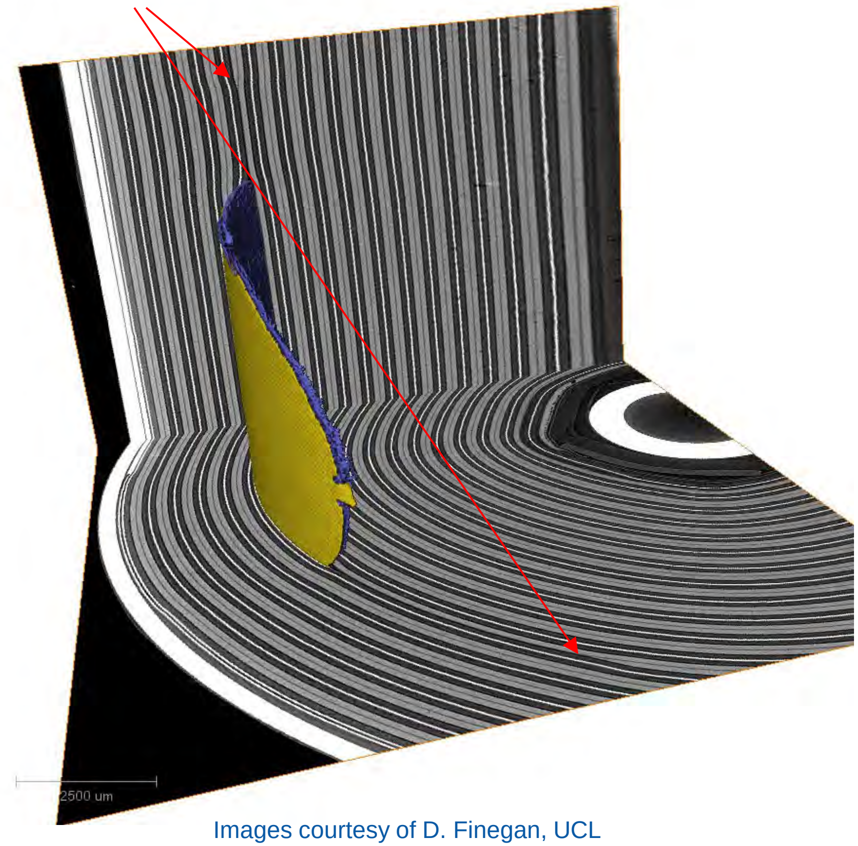
CT Images of ISC Device



Clearly shows that active material hole boundaries are much wider than the device

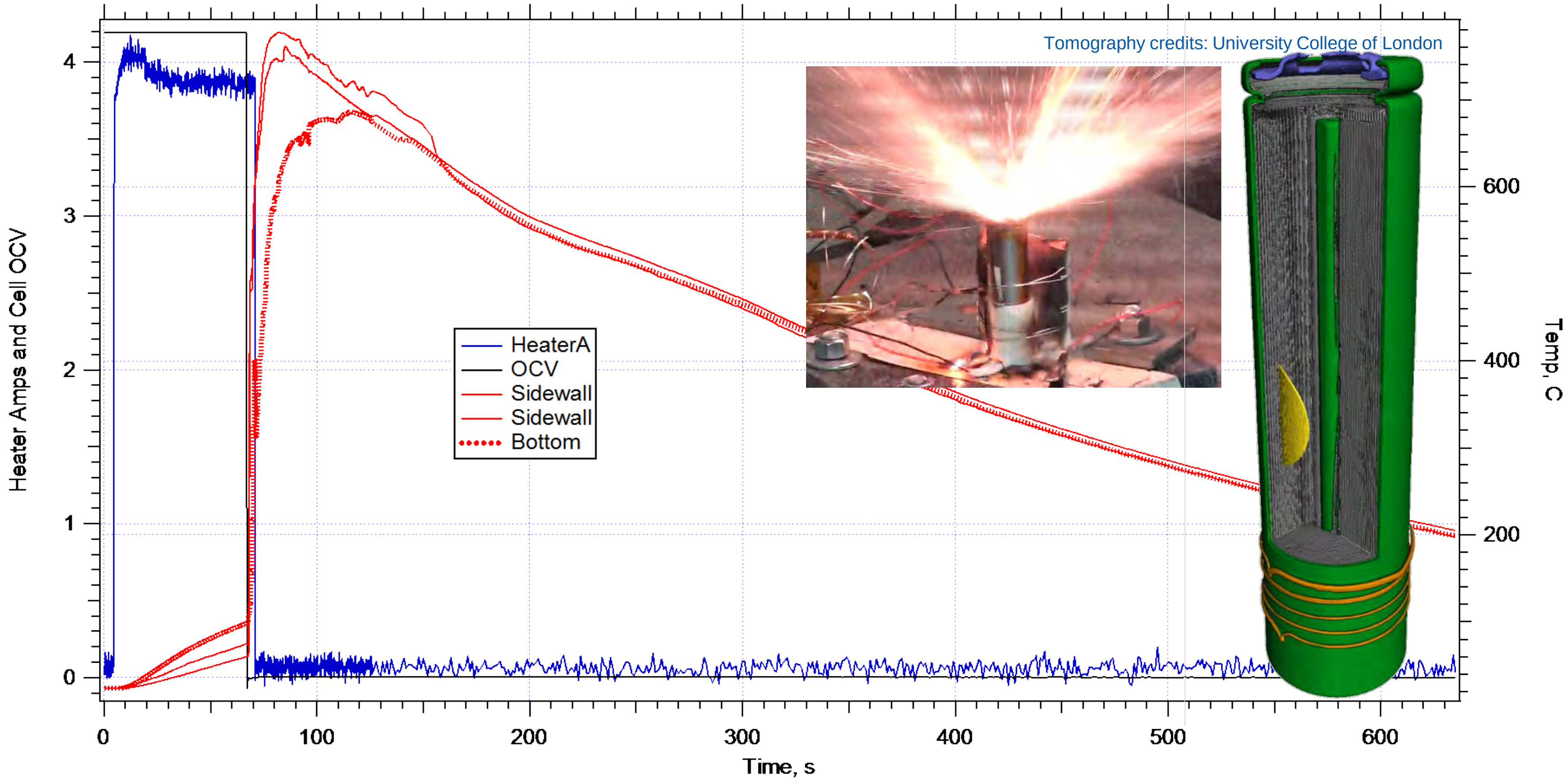


Cu puck
Al pad removed for clarity



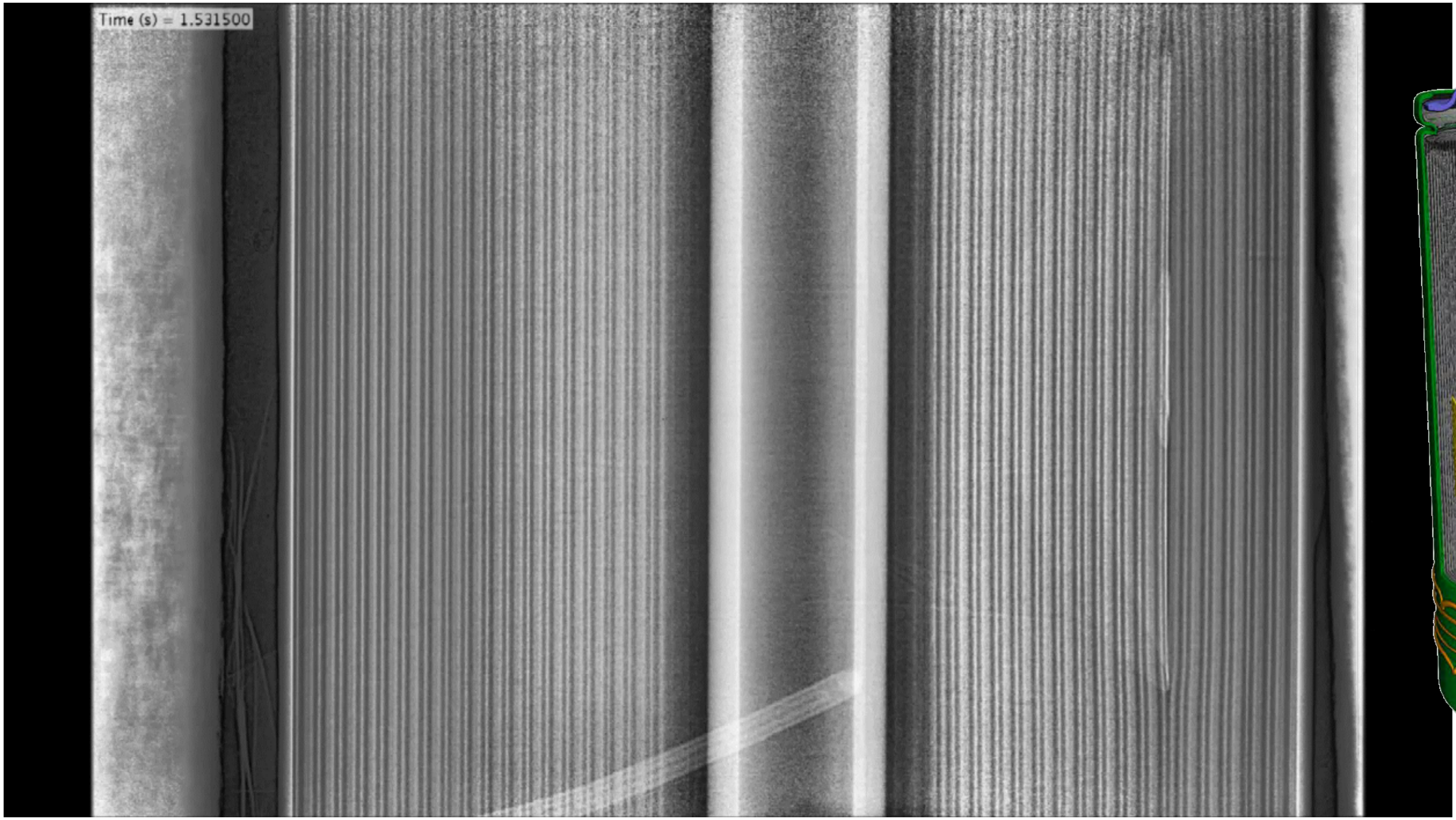
Images courtesy of D. Finegan, UCL

Single Cell TR – Moli 2.4Ah with ISC Device



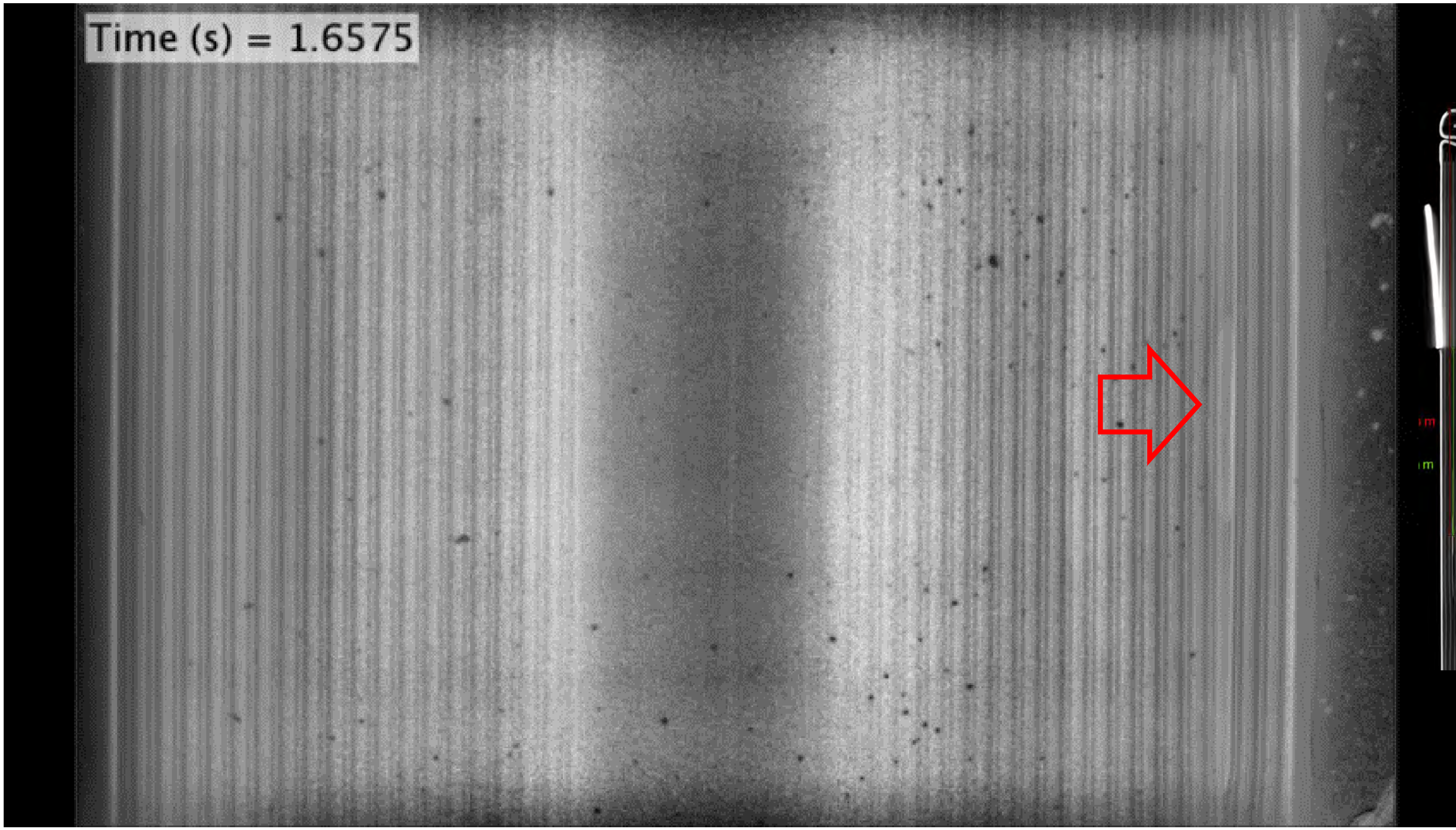
Open air test with cell charged to 4.2V and with TCs welded to cell side wall (2) and bottom (1)

2.4Ah Cell with ISC Device – JR Ejection



video courtesy of D. Finegan, UCL

3.5Ah Cell #21 with ISC Device Video



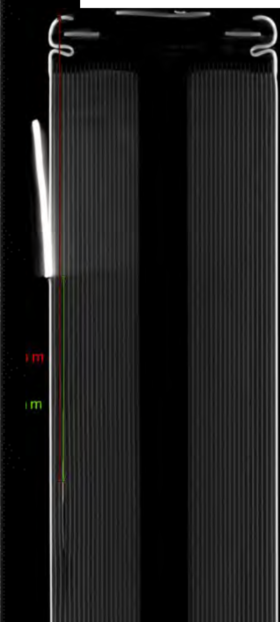


Image and video courtesy of D. Finegan, University College of London

3.5Ah Cell #21 with ISC Device

- JR ejected
- Top edge of crimp shows reflow steel
- Side wall breach in neck of crimp is clocked with ISC device
- Smaller breach in can wall is slightly off the ISC device clocking and above it

Summary and Conclusions

- Used to Study
  - Type of Separators
  - Non-flammable electrolytes
  - Electrolyte Additives
  - Fusible Tabs
  - Propagation Studies
  - Top and bottom vents
  - Gas generation within a cell
  - Much more…
- Being used to make batteries safer.

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