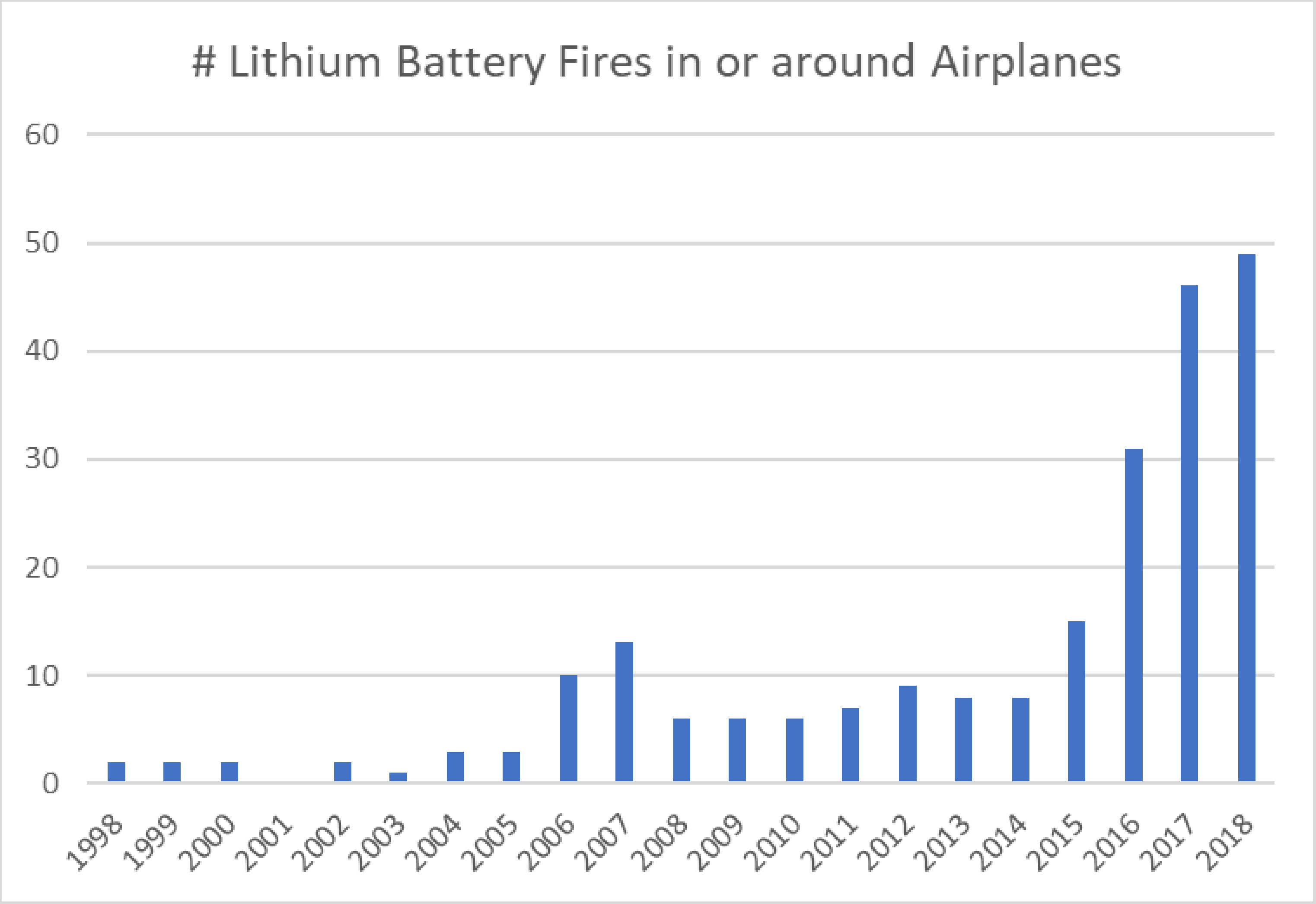
Soteria™

Soteria Battery Innovation Group

Ending Lithium-ion Battery Fires Through Technology

Lithium Ion Battery Thermal Runaway

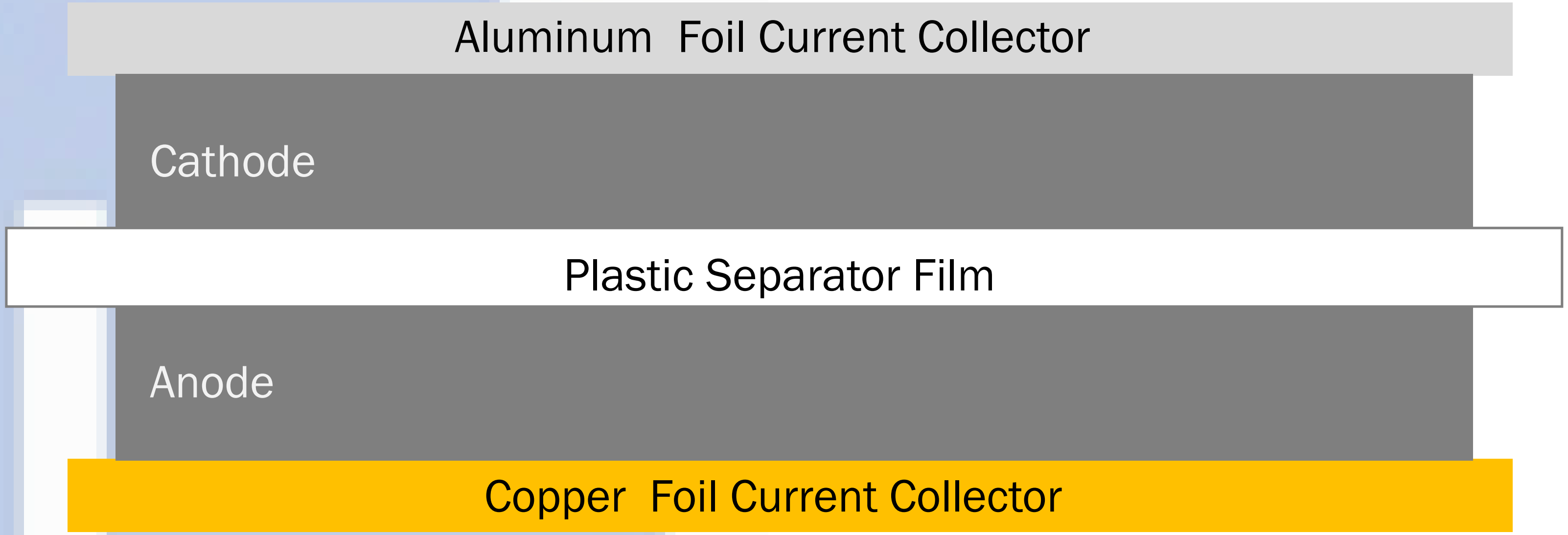
A Worsening Problem



The Soteria Technologies

Mechanism of Eliminating Thermal Runaway

Conventional Architecture



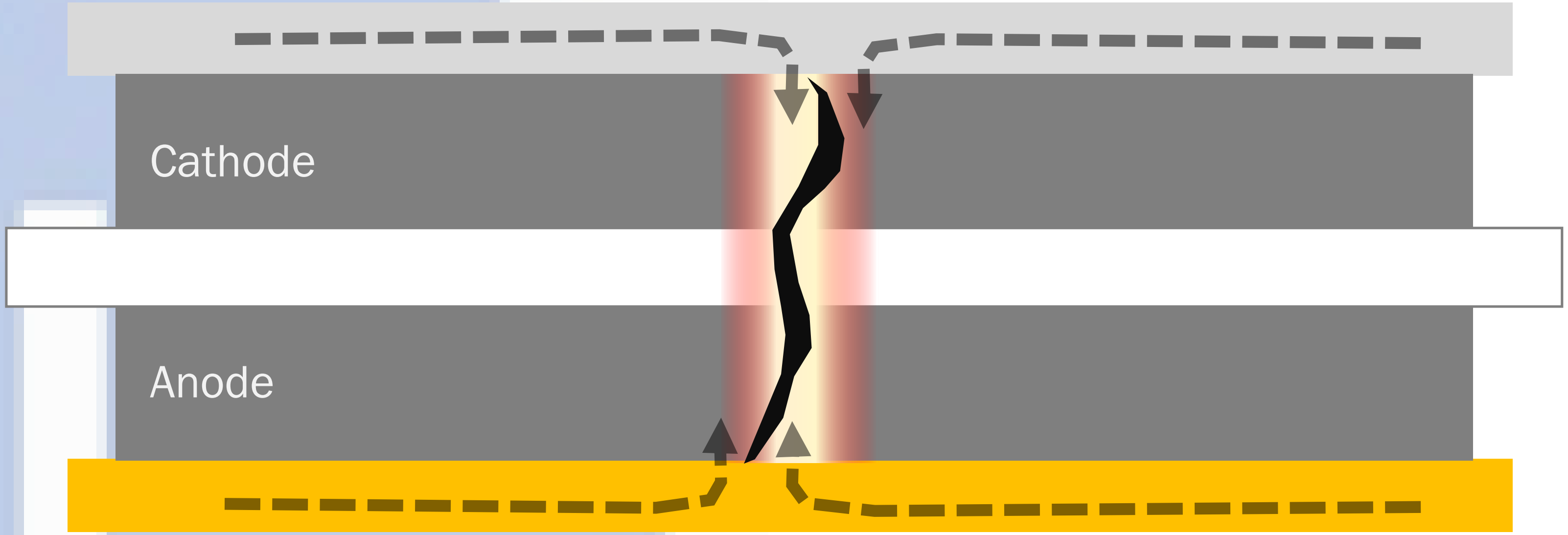
The Soteria Technologies

Mechanism of Eliminating Thermal Runaway

1) A Short Occurs

2) Foils Direct Energy Into Short

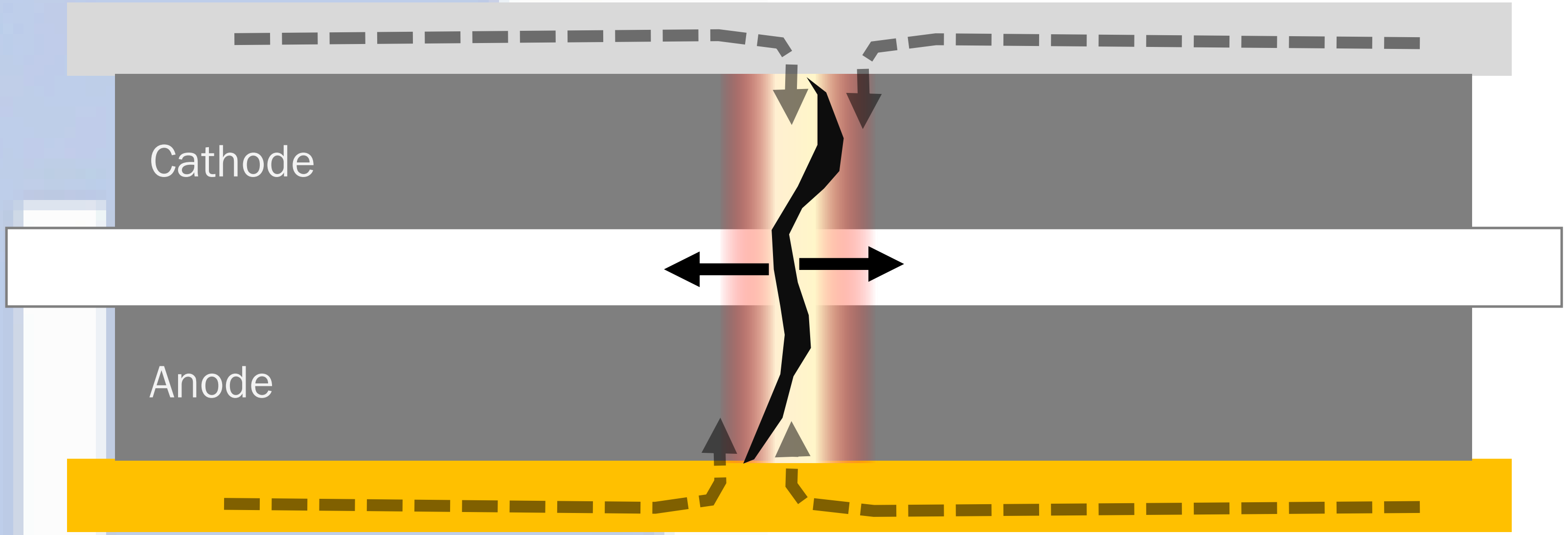
3) High Current Causes High Temperature



The Soteria Technologies

Mechanism of Eliminating Thermal Runaway

4) Separator Retreats from Short



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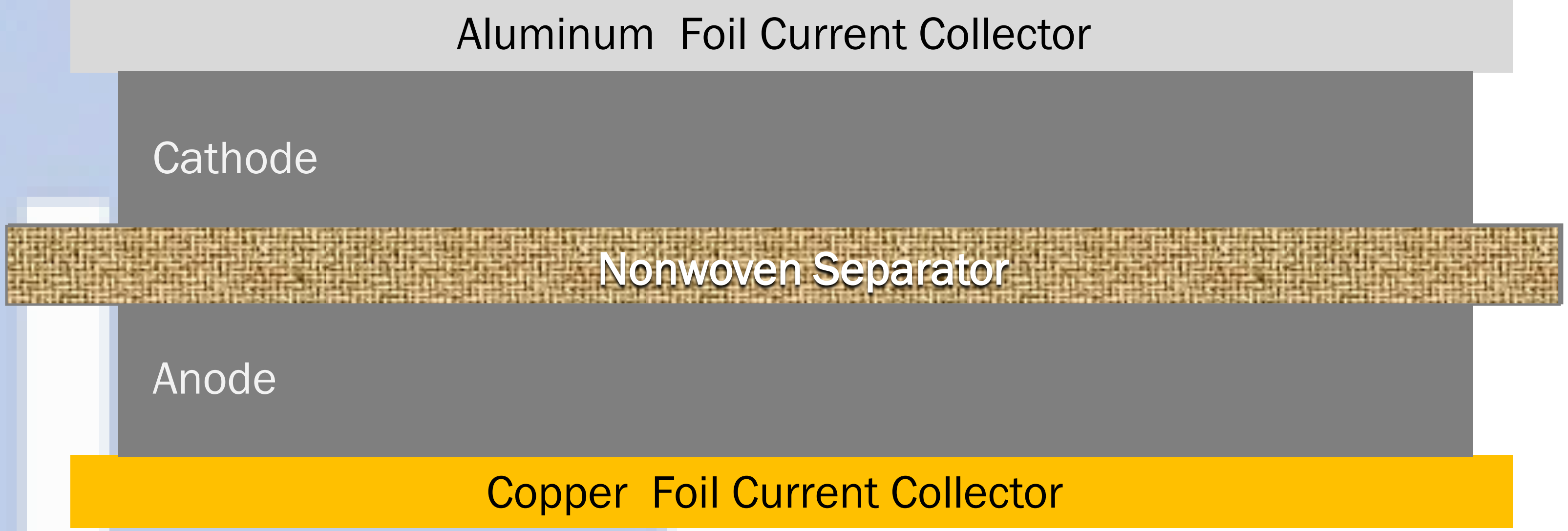
Mechanism of Eliminating Thermal Runaway

1) PET
2) Lyocell
3) Aramid

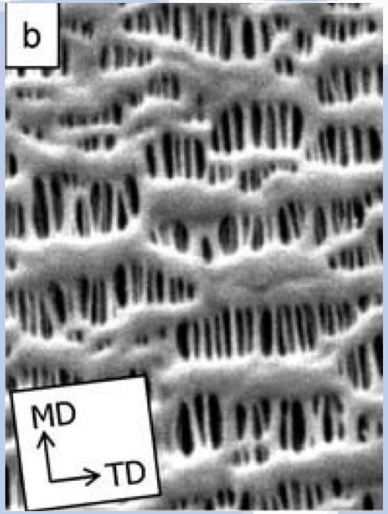
Soteria Architecture Part 1: Nonwoven Separator

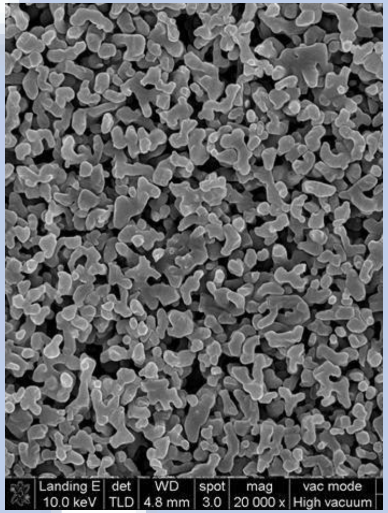


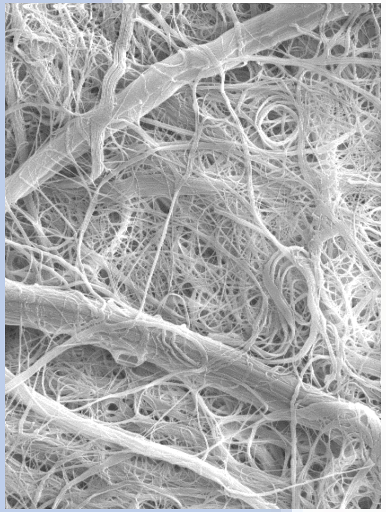
Dreamweaver Separator Material Performance

1st, 2nd and 3rd Generation Separators

1st Generation Biaxially Stretched Polyolefin	2nd Generation Ceramic Coating Added	3rd Generation Dreamweaver Nonwoven



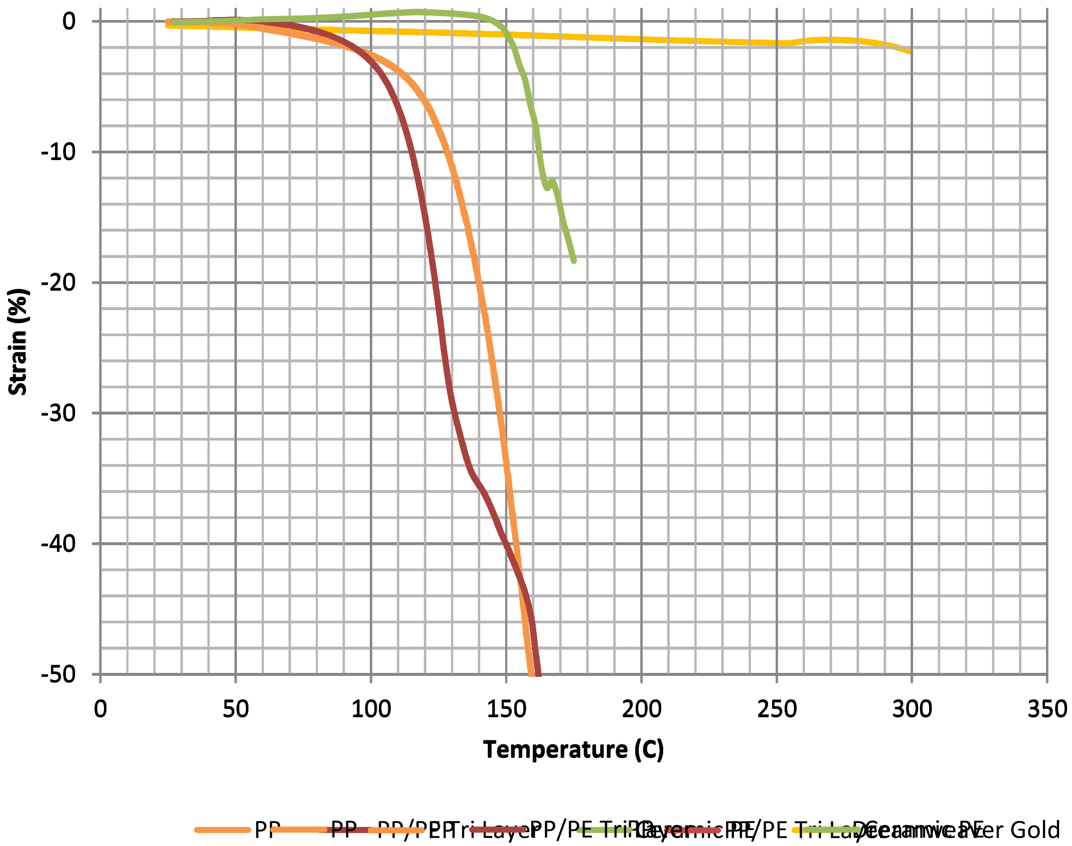




Shrink @ 130C	Shrink @ 175C	No Shrink To 300C

- No unstable polymer component
- High temperature materials incorporated in homogenous composite
- Often stable to 500 C

Thermo Mechanical Analysis*



*Measurement of shrinkage as a function of temperature

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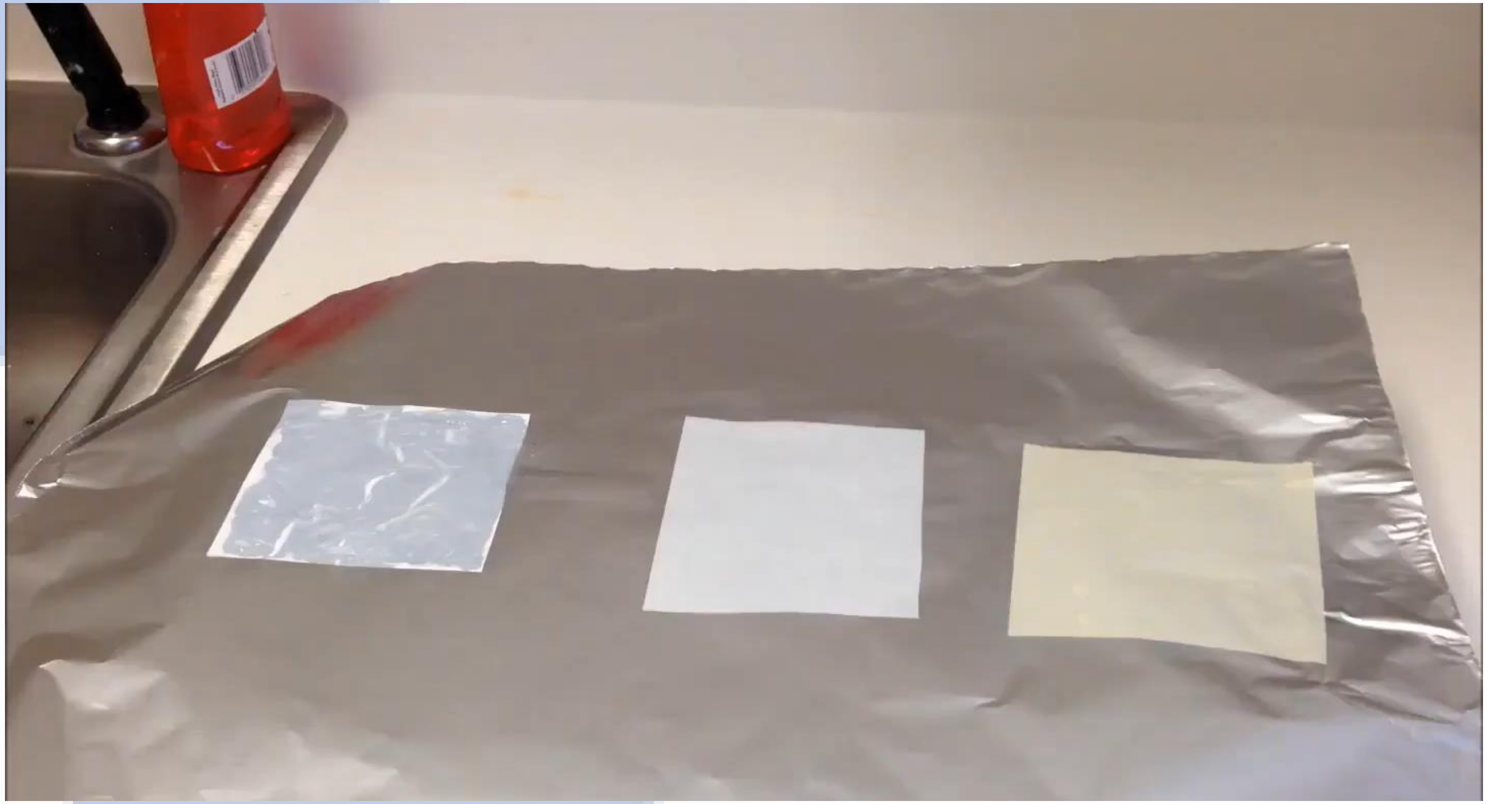
Dreamweaver Separator Material Performance

Flammability With Electrolyte



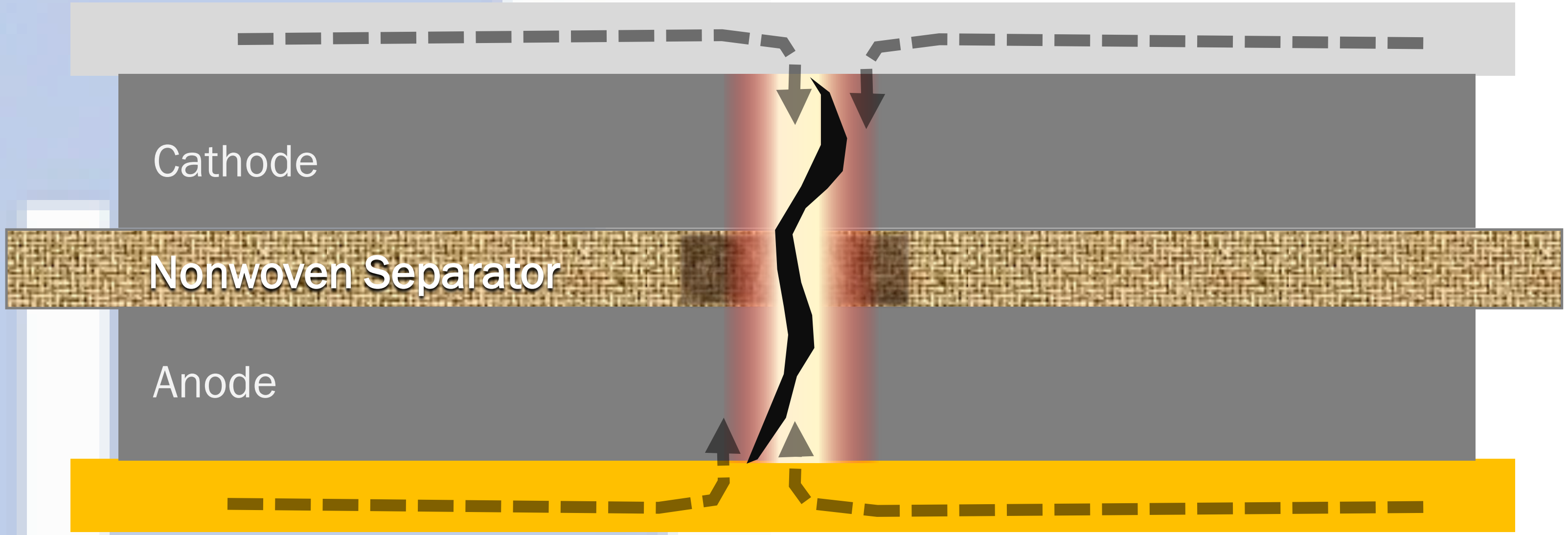
WATCH THE VIDEO

https://youtu.be/j9XWJgTlT1w

The Soteria Technologies

Mechanism of Eliminating Thermal Runaway

Soteria Architecture Part 1: Nonwoven Separator

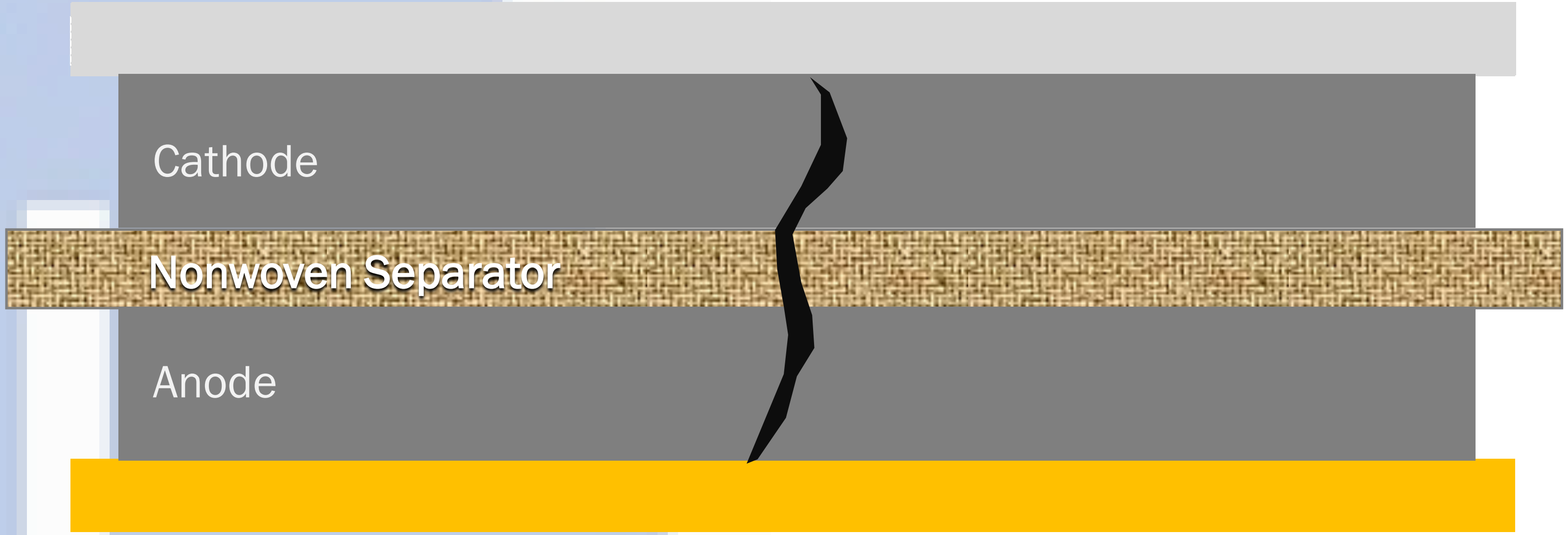


Dreamweaver Separator will char but not retreat from a short.

The Soteria Technologies

Mechanism of Eliminating Thermal Runaway

Soteria Architecture Part 2: Metallized Film Current Collector

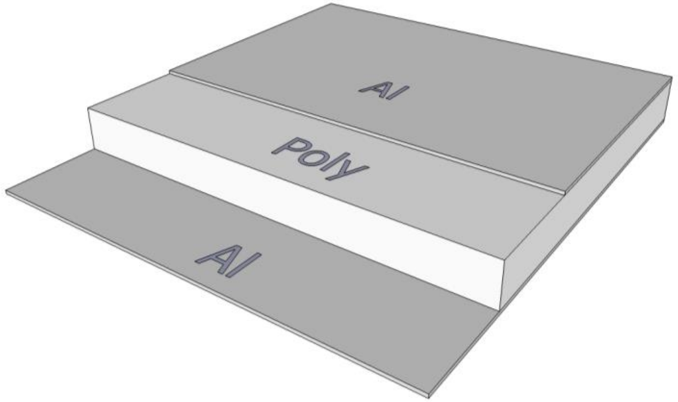


Soteria Metallized Current Collector

Prototype Properties

	Copper Foil	Soteria Copper Film	Aluminum Foil	Soteria Aluminum Film
Thickness	10um	11um	15um	11um
Metal Thickness	10um	500nm per side	15um	500nm per side
Weight	90 g/m^2	21.5 g/m^2	43 g/m^2	16.4 g/m^2
Tensile	400 N/mm^2	120N/mm^2	150 N/mm^2	126 N/mm^2

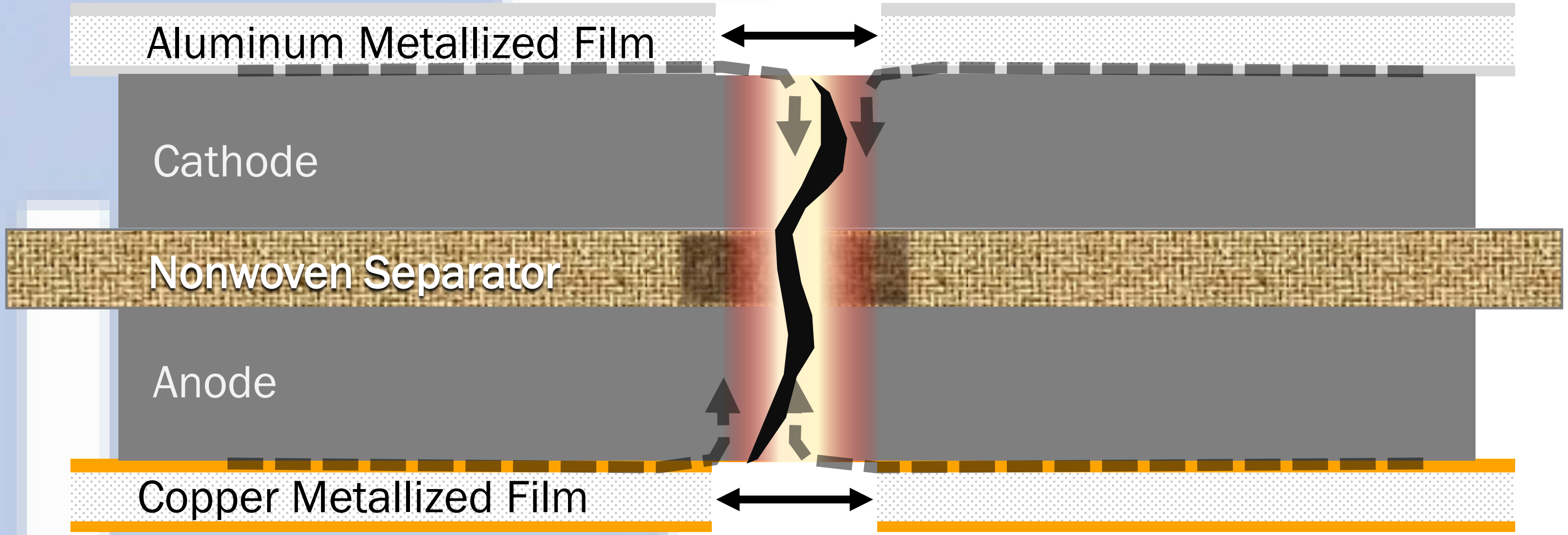
- Initial base film: 10 um, 13.7 g/m2, PET
- Developing metallized films down to 4.5um
- Substrate and metallization thickness engineerable



The Soteria Technologies

Mechanism of Eliminating Thermal Runaway

Soteria Architecture Part 2: Metallized Film Current Collector

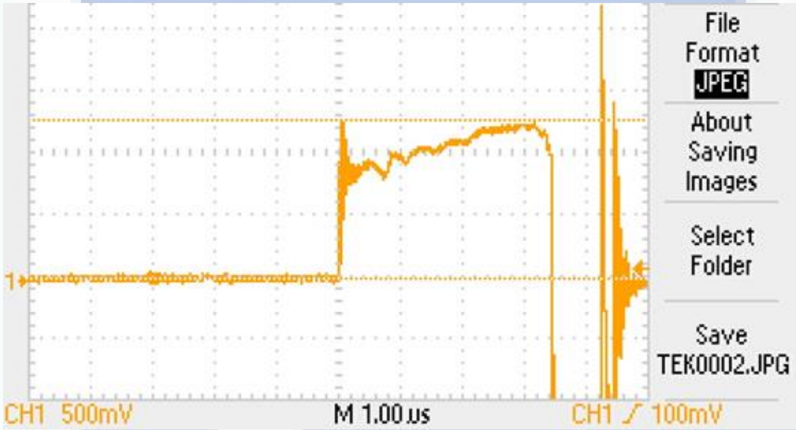


Soteria separators oxidize and retreat from short, acting as an internal fuse.

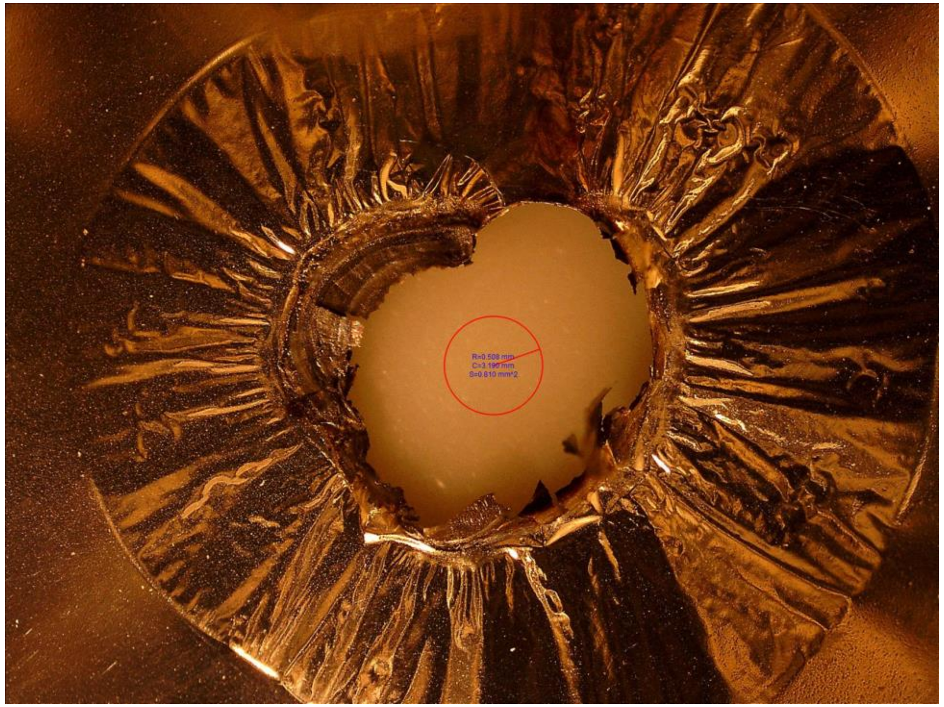
Soteria Current Collector Material Performance

Response Dynamics During a Short

Property	Aluminum	Copper
Time before broken	5 μs	28 μs
Joules generated	4×10^{-6} J	4×10^{-5} J



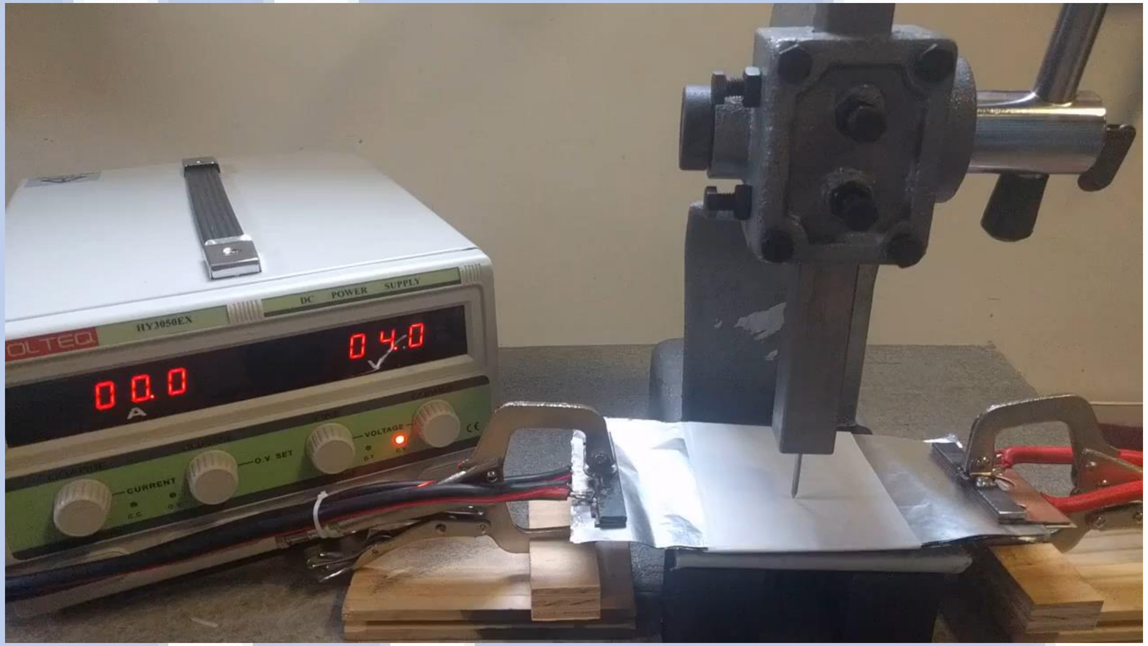
Once a short is created, the time before it is broken is so short that almost no energy is generated.



Soteria Current Collector Material Performance

Dry Stack Nail Penetration – Voltage and Current

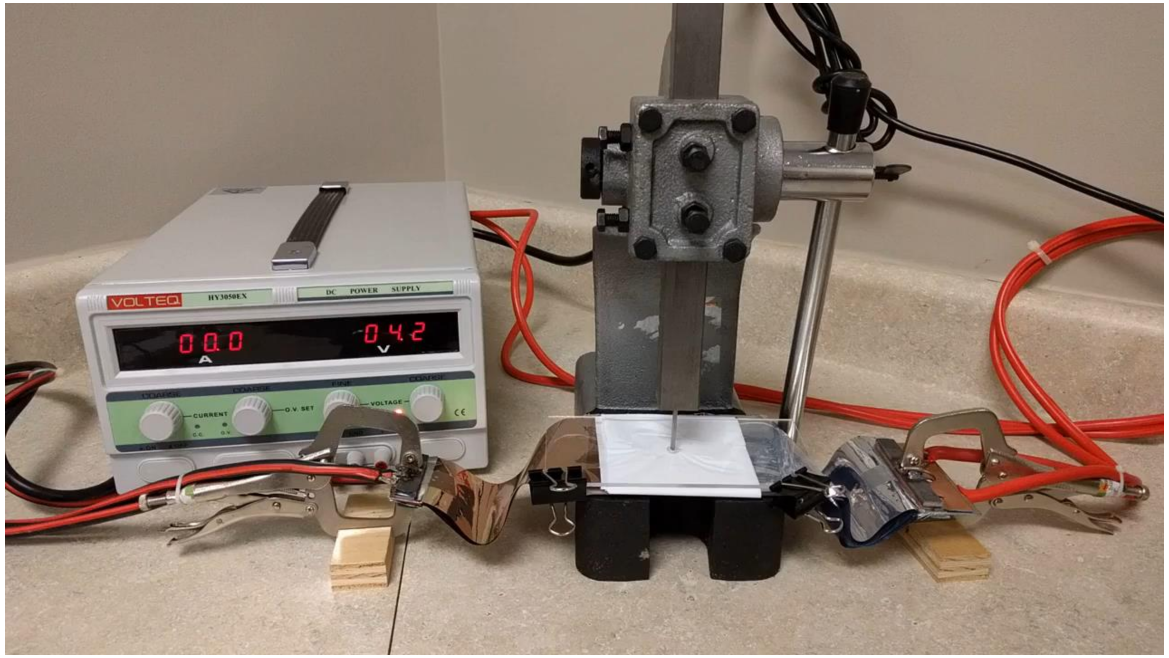
Conventional Material



Nail allows current to flow between layers

V = 0.5 V, I = 50 A

Soteria Architecture



Metallized current collector does not allow current to flow between layers

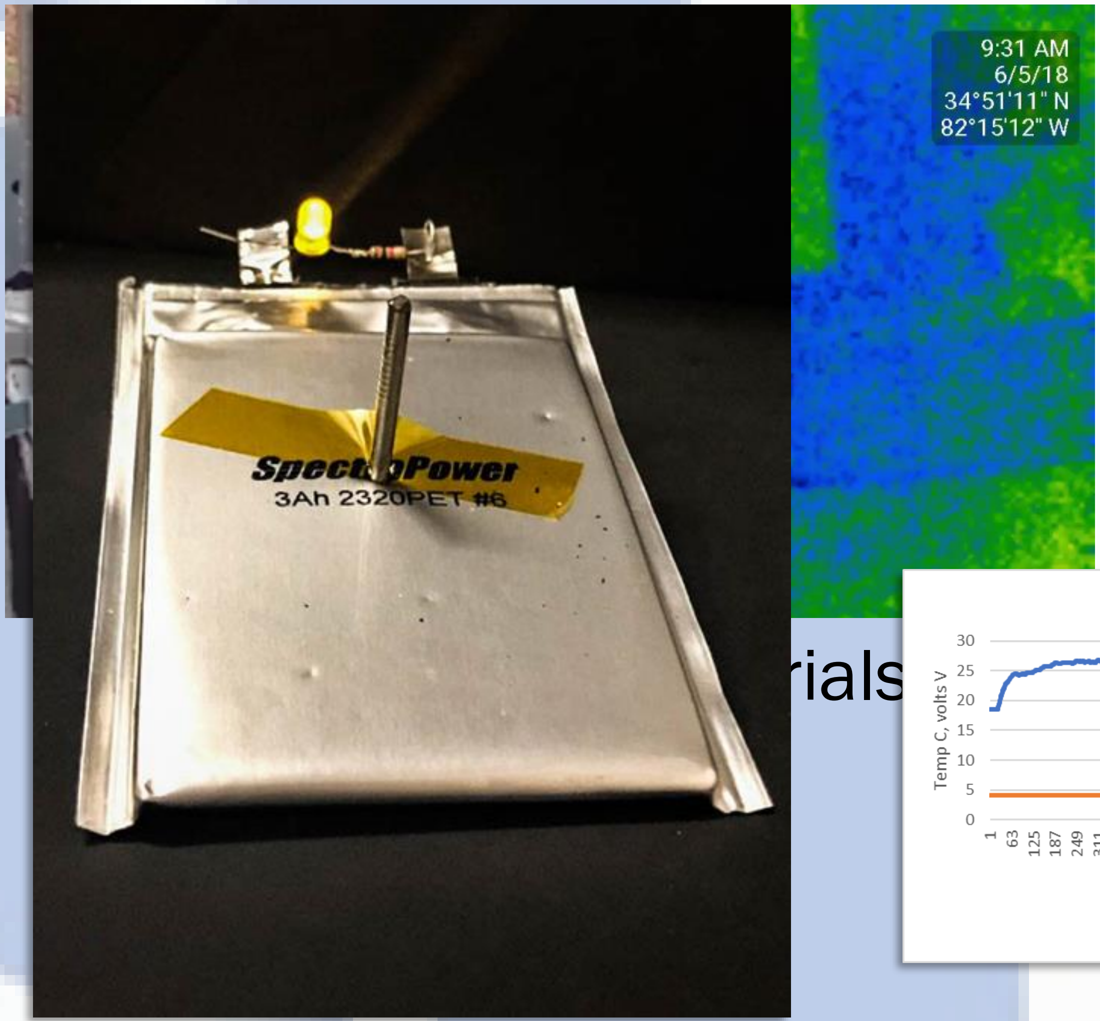
V = 4.0 V, I = 0 A

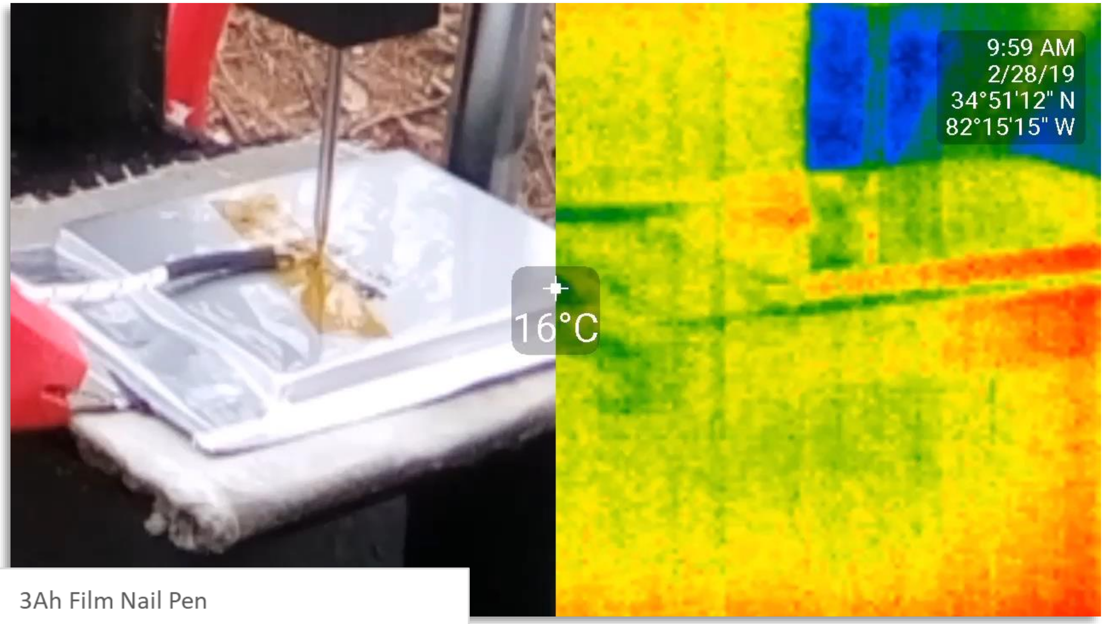
Watch Video: https://youtu.be/4uKyOb0PxaE

Watch Video: https://youtu.be/Bdt2MsWdltE

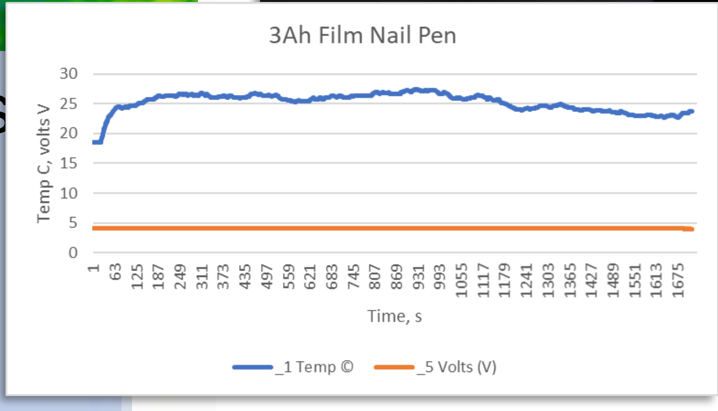
Soteria Cell-Level Performance (3 Ah Pouch)

Nail Penetration Response





rials



Materials

- Maximum surface temp near penetration point = 26C
- No detected voltage perturbation

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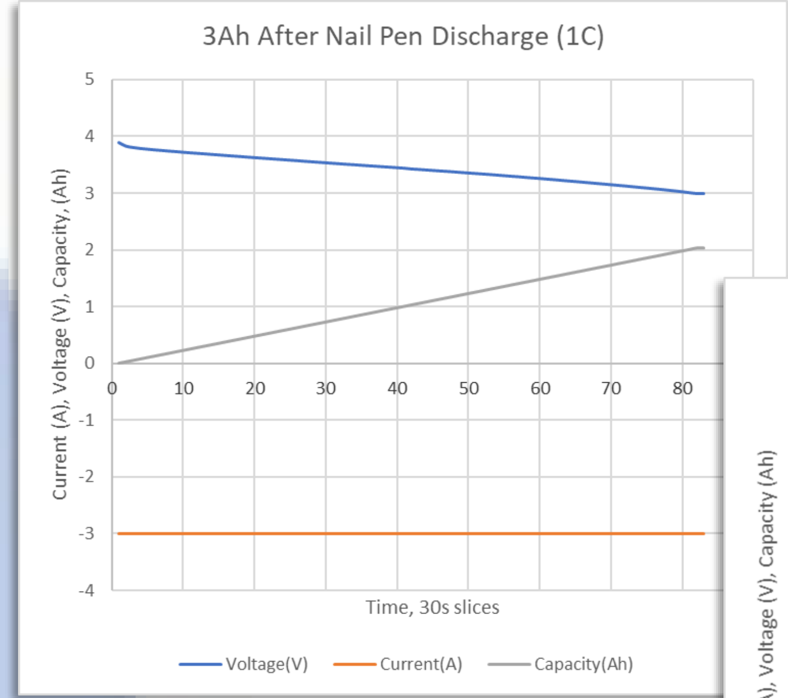
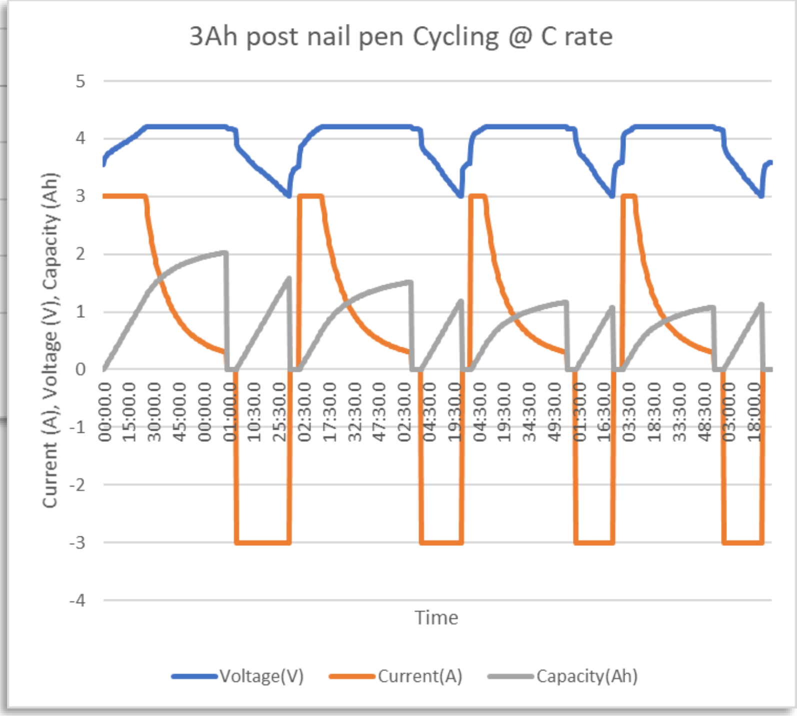
Soteria Cell-Level Performance (3 Ah Pouch)

Post-Nail Penetration Cell Cycling

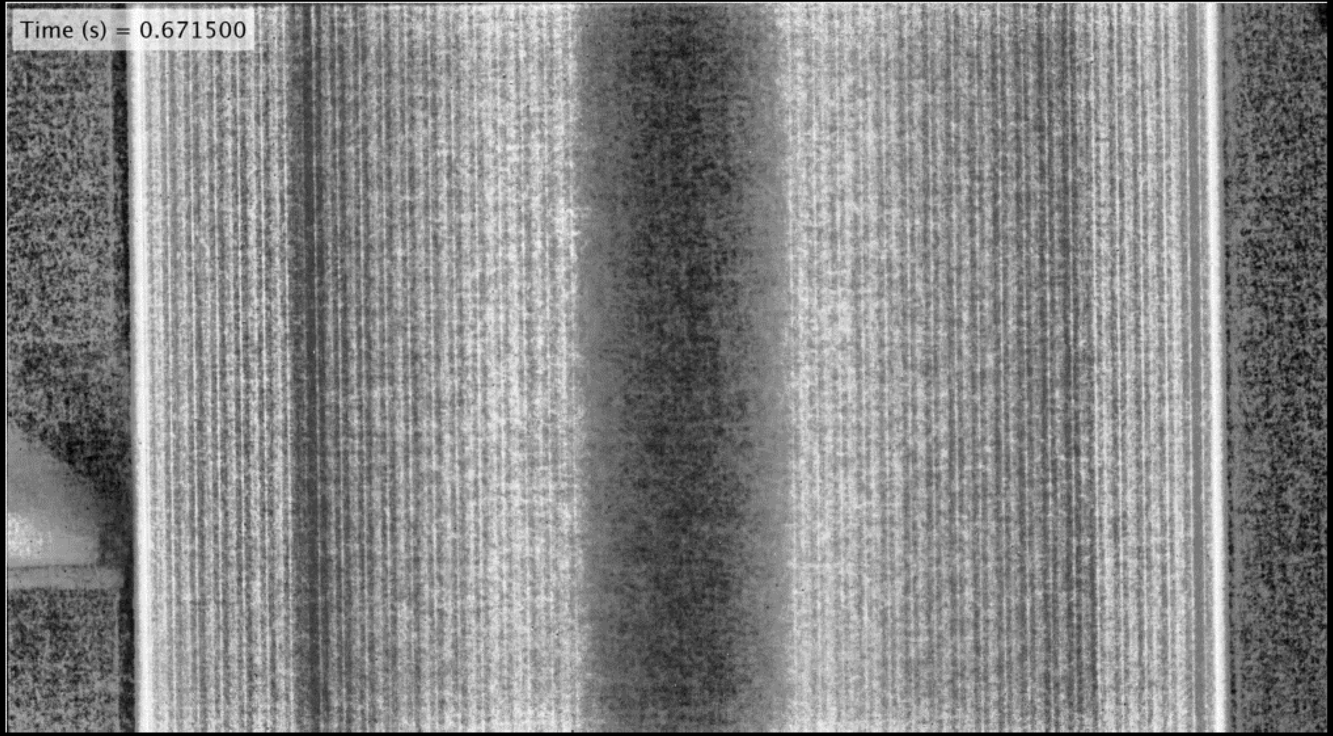
- Nail removed, cell discharged at C rate (3A)
- Total capacity remaining: 2025mAh
- Achieved 2Ah/3Ah - ~66% remaining capacity at 1C.
- After capacity check discharge, cell cycled at C rate (3A)
- Capacity decreased on each subsequent charge/discharge from 2028mAh to 1125mAh





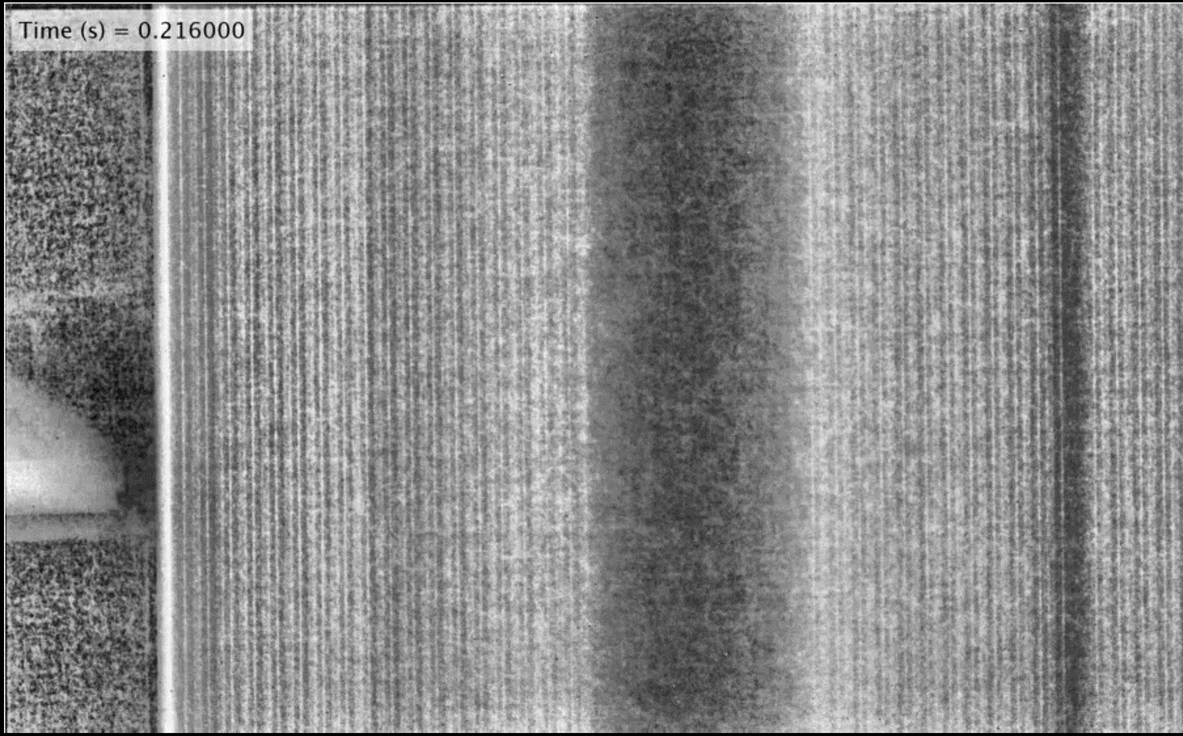
Soteria Cell-Level Performance (18650)

NASA Full-Scale Safety Validation



2.1 Ah Cell – 100 % SOC (4.2 V)
Standard materials
Without ISC device

Watch Video: https://youtu.be/LhlaHTKIgqc

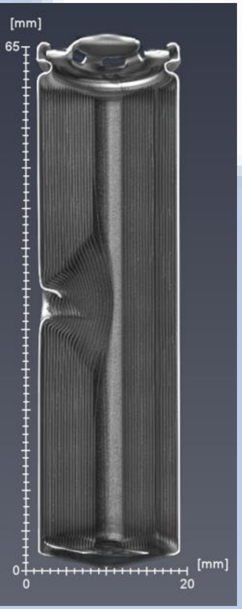


2.1 Ah Cell – 100 % SOC (4.2 V)
Al coated polymer current collector
Without ISC device

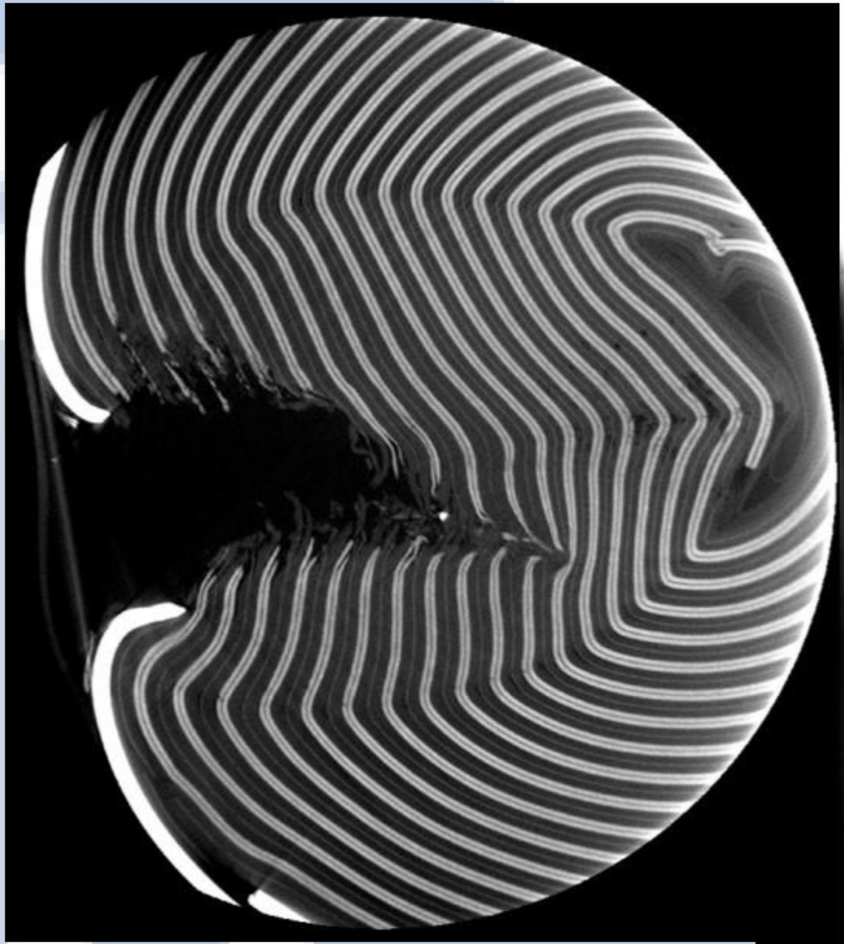
Watch Video: https://youtu.be/uIAPoho44tM

Soteria Cell-Level Performance (18650)

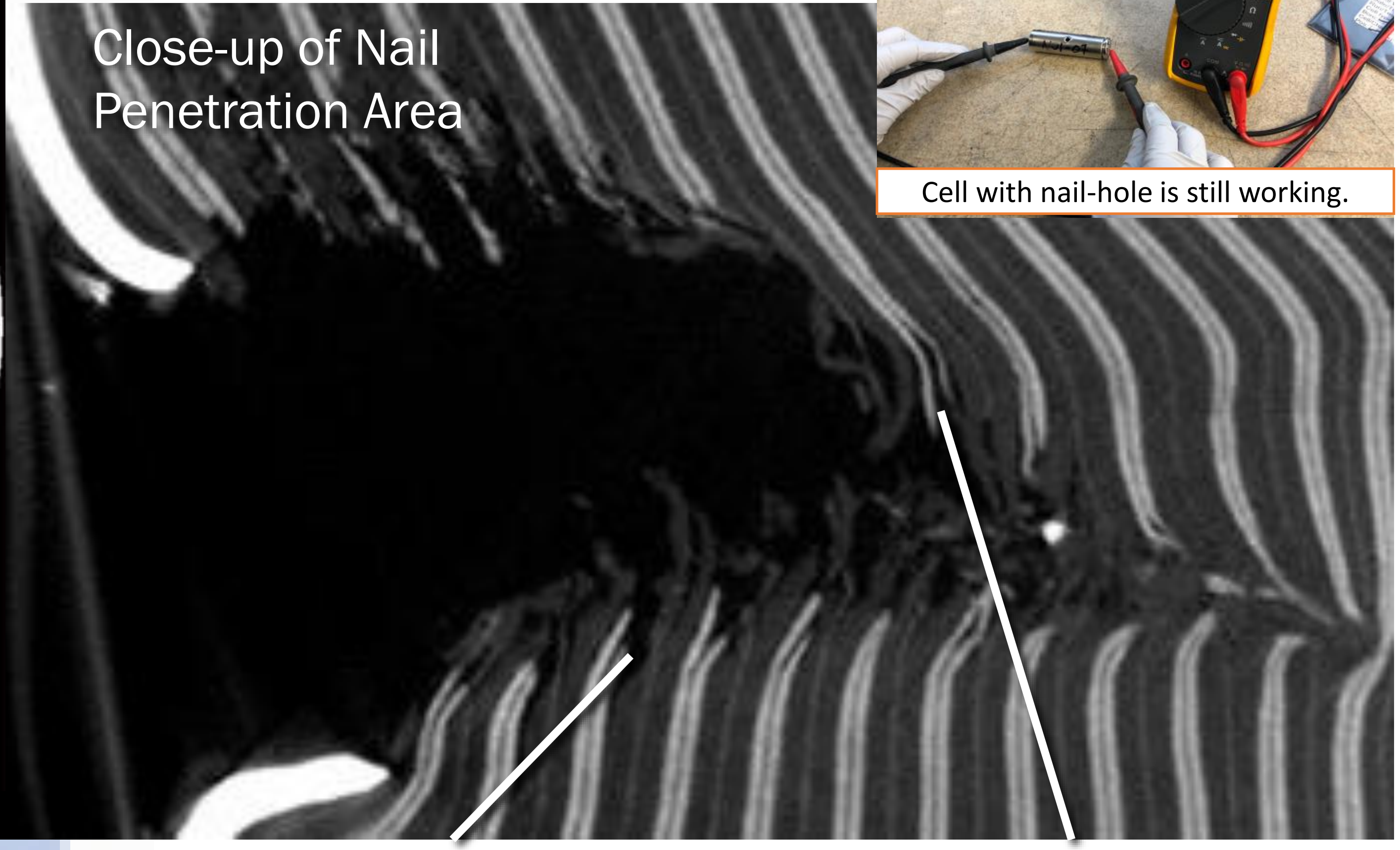
NASA Full-Scale Safety Validation



18650 cell with nail entry hole



High resolution CT scan of nail entry area. Light grey is cathode with Al Soteria films; dark grey is anode with Cu Soteria films.



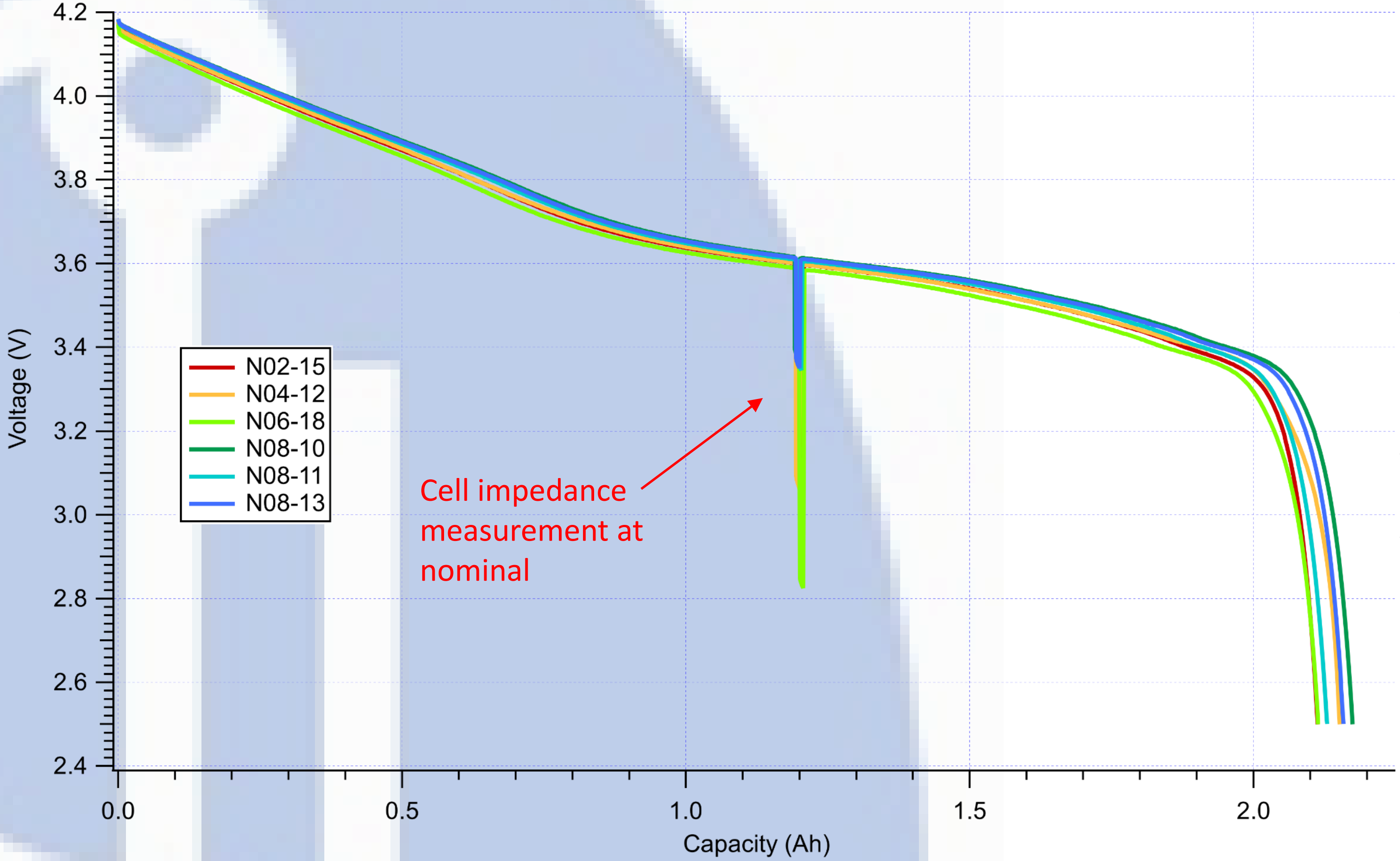
Light cathode layers have retreated below grey anode, preventing short through nail.

Open “alligator jaws” show residual electrode after collector retreated.

Cell with nail-hole is still working.

Soteria Cell-Level Performance (18650)

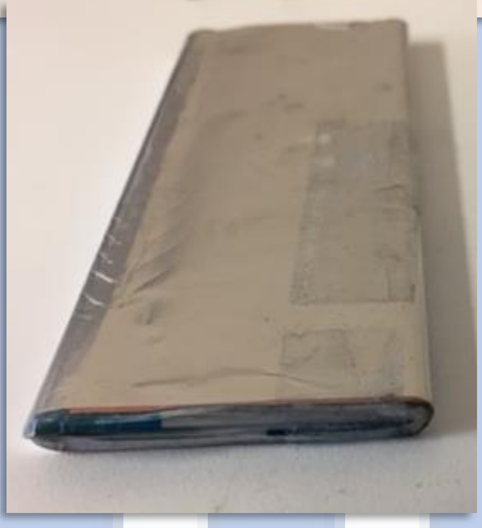
Cell Discharge Curves

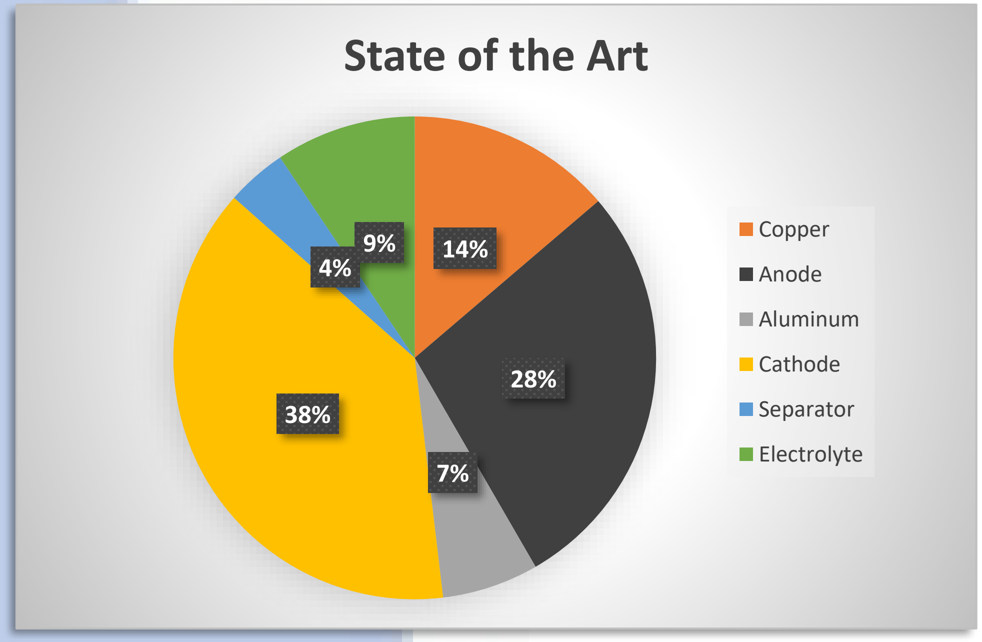


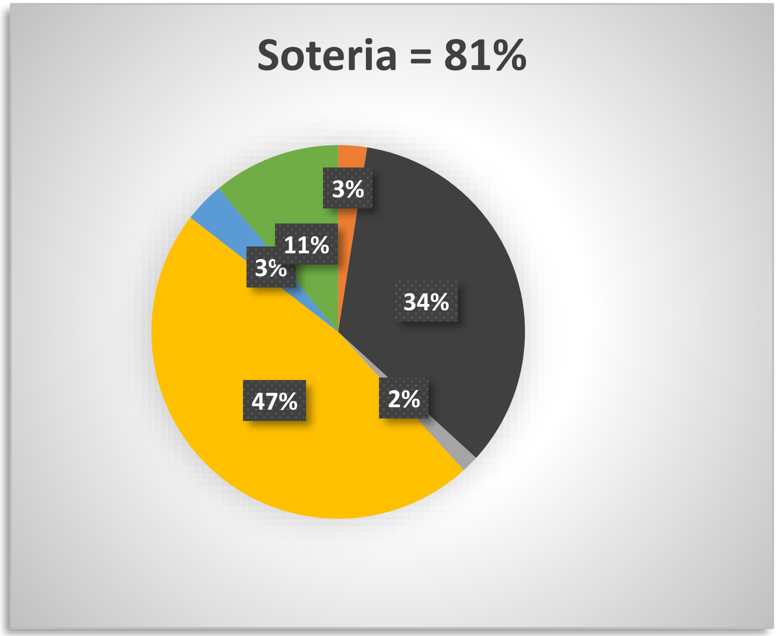
- Data is combination of cells with:
  - conventional foils
  - copper Soteria films only
  - aluminum Soteria foils only
  - Soteria copper and aluminum foils
- Negligible difference in discharge curves
- Data is at low C discharge rates
- Higher C rates may require manipulating:
  - Metal thickness
  - Electrode layer thickness
  - # of layers

Effect of Soteria Materials on Weight

Samsung Galaxy Note 7 Comparison







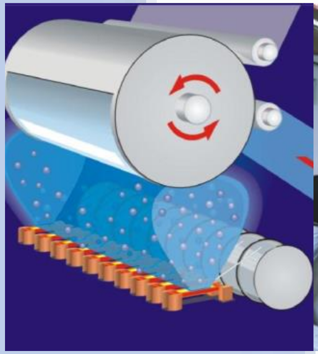
Soteria materials can reduce copper/aluminum/separator from 25% of the weight to 8%.

Effect of Soteria Materials on Process

Minimal Change in Equipment or Process

Material Production

- Current Collector
  - Vacuum deposition
  - Similar to food pkg



- Separator

Refining

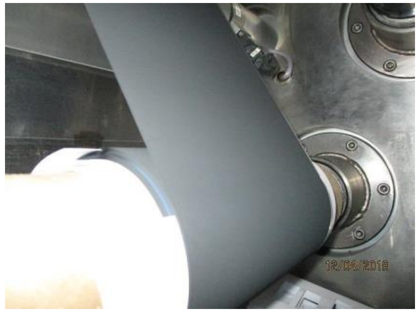
Papermaking

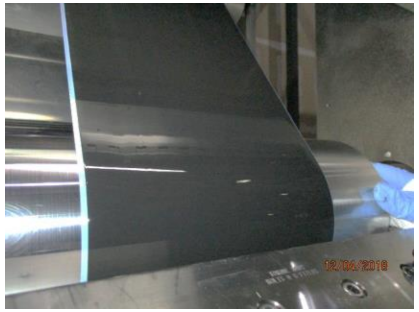
Calendering

Both materials made on existing robust manufacturing processes adopted from other industries.

Battery Production

- Coating





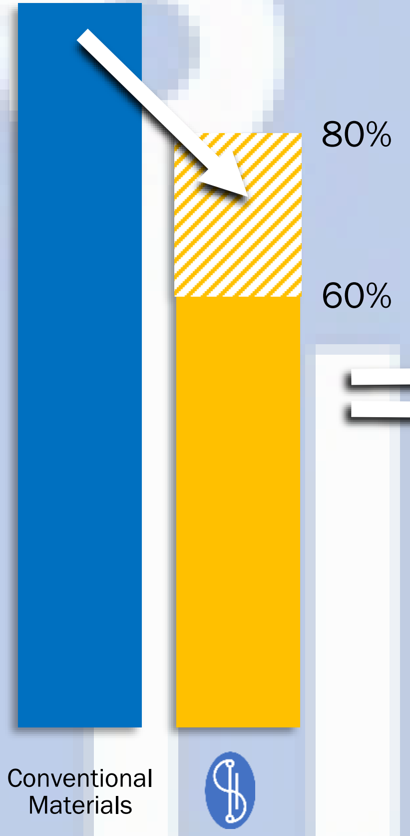
- Stacking and Winding

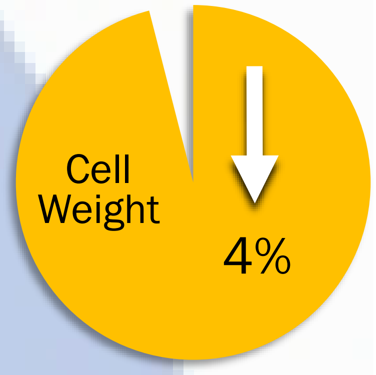
Both materials are drop in replacements to existing materials in normal lithium ion battery production.

Effect of Soteria Materials on Cost

Cost Comparison & Effect on Cell Costs

Material Cost Effect

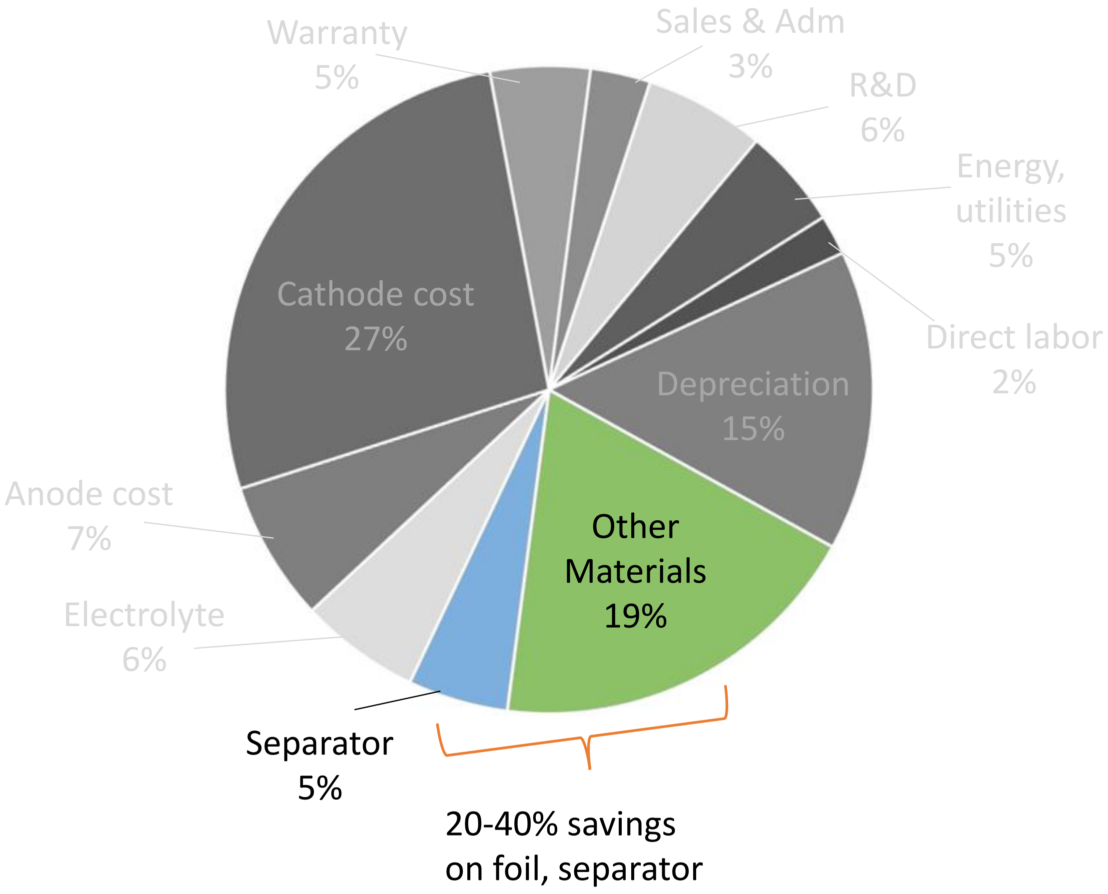




*100kg per EV

Potential elimination of auxiliary safety materials

Lithium Ion Cell Cost Structure



The Soteria Business Model

Connecting Technology with Entire Supply Chain

Soteria™

DNV·GL

SVOLT 蜂巢能源

Lionano®

BOSCH

REVISION®

TEIJIN

BÜHLER

APPLIED MATERIALS®

Lenzing
Innovative by nature

K2 ENERGY®

POLY JOULE

Cellergy

nOHMs TECHNOLOGIES

XERGY

SWM
engineered for tomorrow

TELEDYNE TECHNOLOGIES INCORPORATED

inVENTUS™ POWER

FLASH CHARGE Batteries

GDI
graphenix development inc.
enabling energy

Solzen Energy

ingevity

Rolled-Ribbon BATTERY COMPANY

VOITH

Mercedes-Benz
Research & Development North America, Inc.

CDE
ENERGIZING IDEAS

ADA Technologies, Inc.

ONE2MANY

GLATFELTER

Domtar

NanoMets Corp

BIC

CROWN BATTERY SINCE 1926

SpectraPower™

JENAX

CUSTOMCELLS®

LEITAT
managing technologies

NASA

delfort

DUPONT

EMERSON™

AHLSTROM MUNKSJÖ

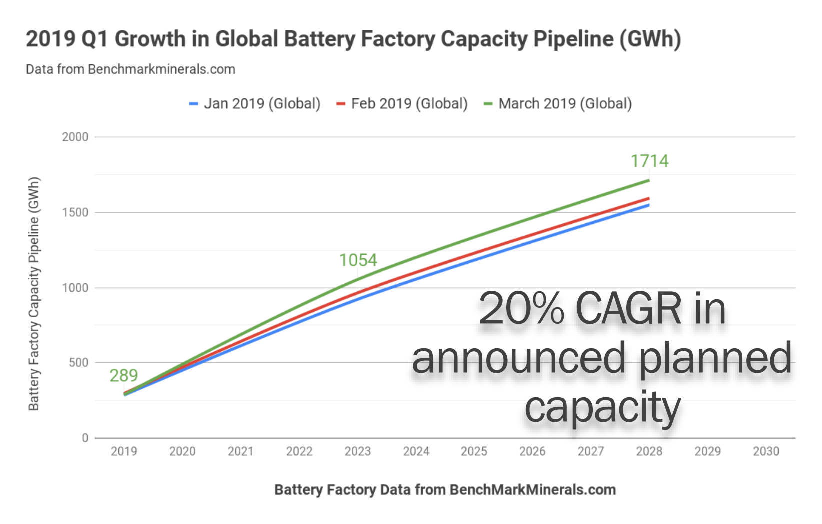
KIER 한국에너지기술연구원
KOREA INSTITUTE OF ENERGY RESEARCH

UC San Diego

ENERDEL™

DuPont Teijin Films™

The Soteria Consortium Model:
The Motivation to Work Together



Goal: 25% market penetration by 2030

<u>Relevant Benchmarks</u>

NMC (2005-17)	30% share
Celgard (2007-17)	35% share

<u>Resulting Market (per year)</u>

5 Billion Square Meters
of current collectors and separators

approx. $5 Billion
of existing materials being replaced

<u>Upstream Market Created (per year)</u>

<u>Specialty Fibers</u>

Polyester	$75M
Lyocell	$90M
Para-aramid	$225M

<u>Paper Machines</u>
$200M*

* after substantial initial investment

<u>Polymer Film</u>
$125M

Copper and <u>Aluminum Wire</u>
$155M (combined)

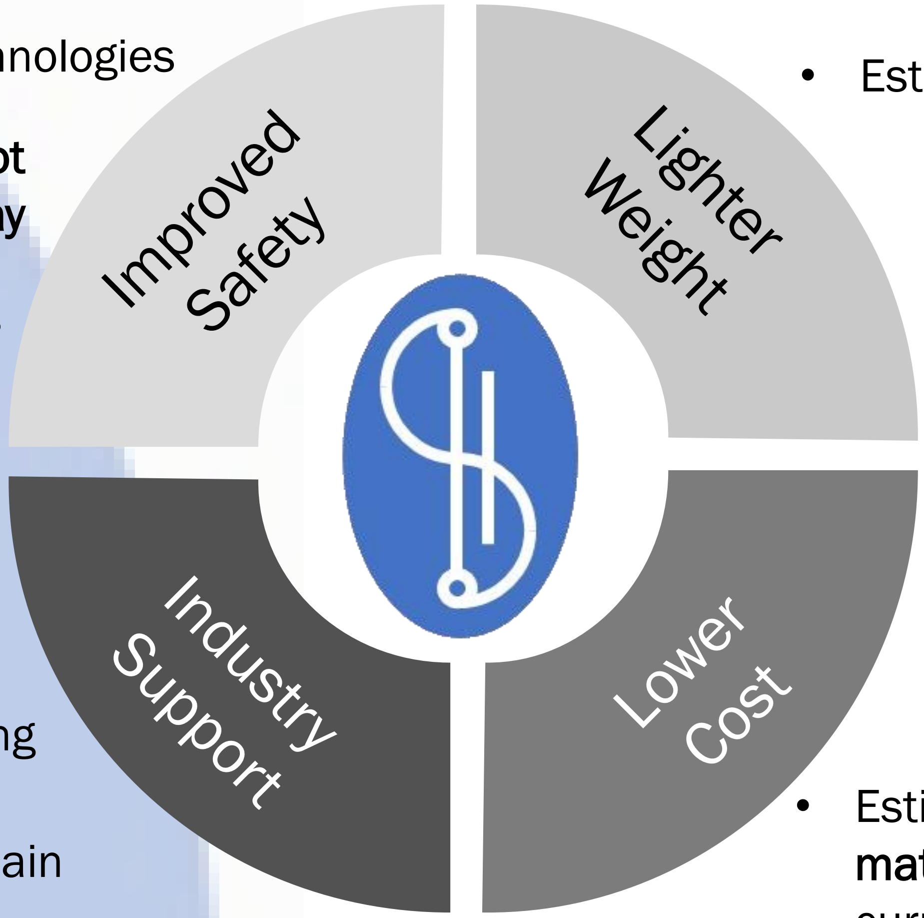
Vacuum Metallization <u>Equipment</u>
$160M*

Soteria™

The Soteria Value Proposition:

Safer, Cheaper, Lighter and Industry Supported

- Currently two licensable technologies
- Technologies address and **eliminate root causes of thermal runaway**
- Technologies enable functioning cells after nail penetration
- Soteria has formed a global consortium of 39 member companies throughout battery supply chain
- Open innovation model with FRAND licensing
- Consortium enables broad technology development support and robust supply chain required by industry



- Estimated **20% reduction in weight** at the cell level
- Potential to remove cost and weight of protective materials & systems
- Replace 90% of current collector metal with commodity film
- **Drop-in replacements** to existing materials
- Estimated **30% reduction in material costs** for separator and current collector

Award-Winning Technology

Recognized by Industry

#1 Advanced Materials

InnoSTARS

Soteria Battery Innovation Group

recognized by CIOReview *magazine as*

10 MOST PROMISING ENERGY TECH STARTUPS - 2019

An annual listing of 10 technology startups that are spearheading innovation and transforming the industry

Entrepreneur MAGAZINE

PEPPERDINE GRAZIADIO

IDEA19 MIAMI BEACH
The World's Preeminent Event for Nonwovens & Engineered Fabrics

index17 Awards

US CHINA Innovation Alliance

CIO Review 10 MOST PROMISING ENERGY TECH STARTUPS - 2019

The Soteria Executive Team

Experience and Vision

- 3rd startup
- PhD Physics Ohio State
- 200 patents
- $1 billion in product sales from patents

- MS EE Michigan Tech
- 27 years auto & automotive
- Director of Engineering at two lithium ion battery companies
- Author of book on electric vehicles

- PhD Chemical Engineering University of Illinois
- CEO of publicly-listed chemical company
- 15 years at Miliken

Thank you!