Soteria™

Battery Innovation Group

Soteria and Battery Safety

www.darwinAwards.com

All humans who meet the following criteria are eligible to win:

*** Reproduction ***

Out of the gene pool: dead or sterile.

*** Self-Selection ***

Cause one's own demise.

*** Excellence ***

Sublimely idiotic misapplication of judgment.

*** Maturity ***

Capable of sound judgment.

*** Veracity ***

The event must be true.

Every Battery Fire Hurts

80 TON BATTERY FIRE IN CHICAGO

SOME FIRE STATISTICS

Waste Management: 245 fires, $1.2 B/a

Energy Storage: 28 fires in Korea

Hybrid EVs: 3,474 fires per 100k sales

- (EV is lower, but they have not been on the road as long.)

Air/airports: 350 fires

Vapes: 2,035 fire injuries

Consumer Products: 138 fire recalls

E-bike: battery fires double in NYC

Battery-related: 78,926 hospitalizations 2016 – 2020 in USA

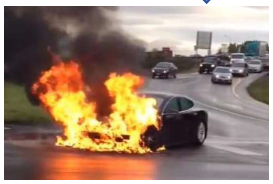
Lithium-ion fires: a drumbeat of public events

2014

Boeing 787 Grounded
~$1 billion loss

2014

Tesla recall, adds titanium plate to all Model S, X



2015

Amazon & Target stop selling hoverboards due to fires.

2016

Samsung Galaxy Note 7 Recall. $17 billion lost revenue

2020

Ford recalls 20,000 vehicles, stops production & US launch

2020

BMW EV recall.
26,700 vehicles

2021

Tesla S Plaid production stopped for battery fires.

2021

Hyundai Kona EV recall
$900 million

2021

Chevrolet Bolt recall
$2 billion

2022

EV container ship sinks
$440 million

How lithium-ion batteries catch fire

Contain flammable materials

- Electrolytes
- Lithium metal

Ignition caused by release of electrical energy

- Manufacturing defects
- Charging
- Accidents
- Physical damage
- Heat

Once put out, electrical energy can reignite batteries

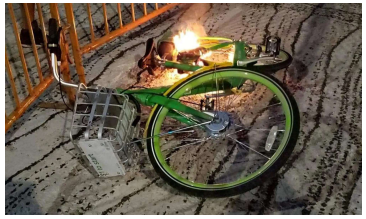
- Average 30,000 gallons of water to put out EV fire, vs. 300 gallons for gasoline fire

After an accident

While charging

Driving

While parked



Pedaling

Playing golf

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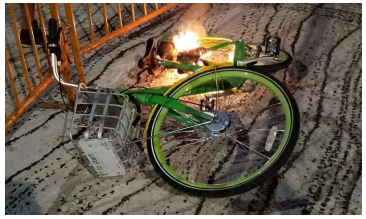


Pedaling

Playing golf

Soteria™

Current solution is heavy, expensive and inadequate

>30% weight and cost burden

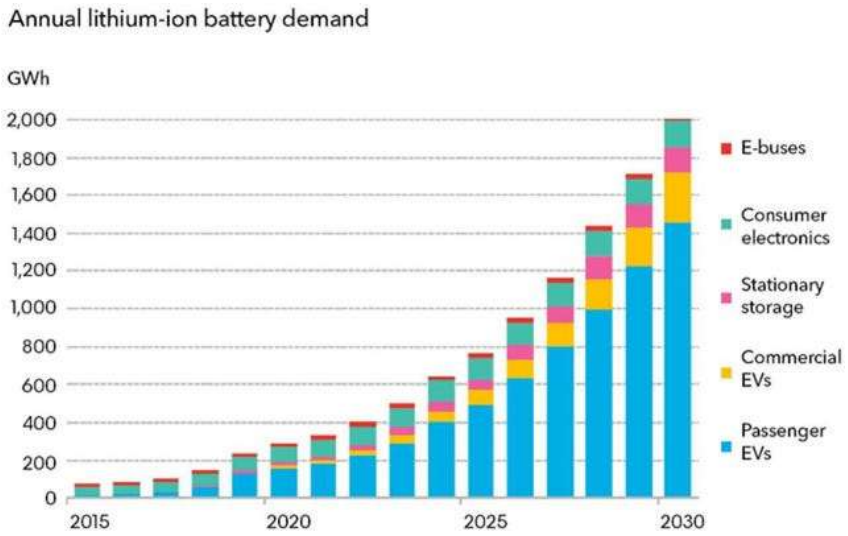
- Steel / aluminum box
- Titanium plates
- Spacers / dividers
- Sensors
- Fuses / switches

Fires still occur

- **Current solution does not protect against defects**
- Inadequate protection against physical damage

Vehicle Battery Pack

But today, demand is outstripping supply



Toyota, lagging rivals, outlines plans to expand sales of electric vehicles.

FORD TO LEAD AMERICA'S SHIFT TO ELECTRIC VEHICLES WITH NEW MEGA CAMPUS IN TENNESSEE AND TWIN BATTERY PLANTS IN KENTUCKY; $11.4B INVESTMENT TO CREATE 11,000 JOBS AND POWER NEW LINEUP OF ADVANCED EVS

Rivian, an E.V. maker with big ambitions but few sales, will build a new factory in Georgia.

AUTOS

GM plans investments to expand electric vehicle production

Elon Musk: Tesla plans to invest over $10 billion in Gigafactory Texas, employ 20,000 workers

Fred Lambert - Dec. 16th 2021 1:47 pm PT @FredericLambert

VW Expands EV Offensive with Plans for Six Battery Factories

At its Power Day event, Volkswagen said it plans to have all the factories operating in Europe by 2030 and will also be expanding its global charging networks.

BUSINESS

Stellantis Plans to Go Big on EVs. Here's What's in Store.

PSA-Fiat Chrysler tie-up makes electrified cars a priority, as CEO Carlos Tavares gets ready to take on General Motors and Volkswagen

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Today's Electric Vehicle

3% of car industry
50% of battery industry
100 – 300-mile range
40 – 100 kWh battery
$40 – 120,000
1 – 8h charge
Safety – Spontaneous fires
– Damage induced fires

Gigafactories: 250 GWh or 0.25 TWh
~7 Tesla Gigafactories

200-mile range: 3 hrs of driving time
200,000 mile battery

60 kWh battery: 400 kg

$40 – 100,000: Total cost of ownership ~200% of ICE

1h charge: 250 kW

Safety: some spontaneous fires
many/most collisions fire

Soteria™

Today's Electric Vehicle

3% of car industry
50% of battery industry
100 – 300-mile range
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Tomorrow's Electric Vehicle

80% of car industry
75% of battery industry
600-mile range
200 kWh battery
$20 – 50,000
0.5h charge
Safety – no fire after 75 mph collision

Tomorrow's Electric Vehicle

80% of car industry
75% of battery industry
600-mile range
200 kWh battery
$20 – 50,000
0.5h charge
Safety – no fire after 75 mph collision

Gigafactories: 16,000 GWh or 16 TWh
~400 Tesla Gigafactories

600-mile range: 8 – 10 hrs of driving time
1.2-million-mile battery

200 kWh battery: today – 1,000 kg
tomorrow < 500 kg

$20 – 50,000: Total cost of ownership ~50% of ICE

0.5h charge: 400 kW, about 3x today's fast charge

Safety: no fire after 75 mph collision
Today—some spontaneous fires
most collisions fire

Reflections

NEAR FUTURE OF EVS

Supply limited market keeps prices high

- ➔EVs will remain premium product

Old guard will fight a rear retreat

- EV sales will not make up for lost market share of ICE

New entrants will succeed

- Rivian, Lucid, Nio, Li Auto
- Once-a-century opportunity for premium brands

DISTANT FUTURE OF EVS

Everything changes

- Cars drive you for 600 miles without charging
- Charging in every parking lot along travel lanes
- Travel is no longer an inconvenience because mobile office, work-from-car
- Auto becomes competitive with air
- Cost per mile traveled goes down
- …but EV prices remain high for a long time

Electric point-to-point air is real

Drone delivery is real

Drivers rarely needed in air, cargo, personal transport

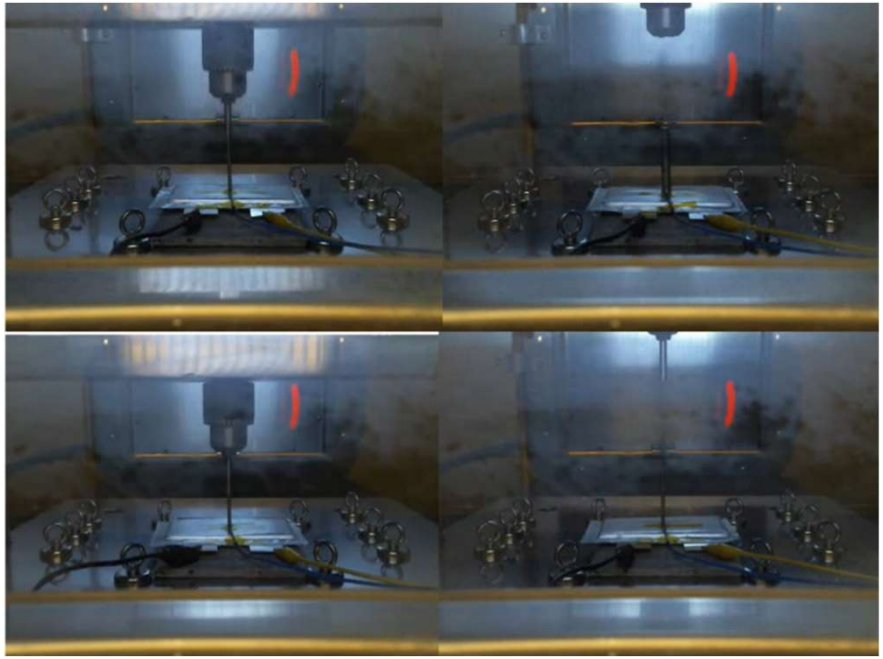
Soteria Vision

Inherently safe cells everywhere.

Soteria cells do not Ignite

Standard Cells

Soteria Cells



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

Soteria technology applies to all cell types

Standard Cells

Soteria Cells

Watch Video:
https://youtu.be/nya_PaVL70I

Soteria cells continue to function at >85% capacity

Soteria™

Soteria cells continue to function after damage

Watch Video:
https://youtu.be/R0-Ec-GLSPY

Soteria delivers a complete revolutionary safety solution

REVOLUTIONARY SAFETY

Eliminate root cause of cell ignition

Cells keep working after damage

FULL COMPATIBILITY

20-30% weight reduction

Drop-in to manufacturing

Lower material costs

Electrical performance

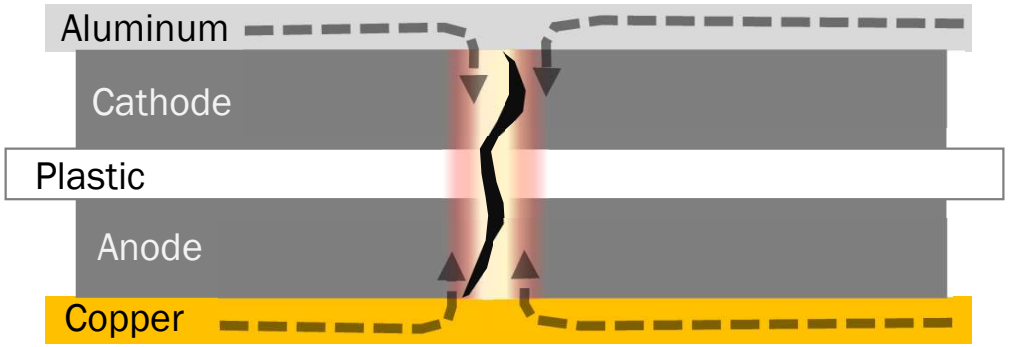
INDUSTRY SUPPORT

Open innovation consortium

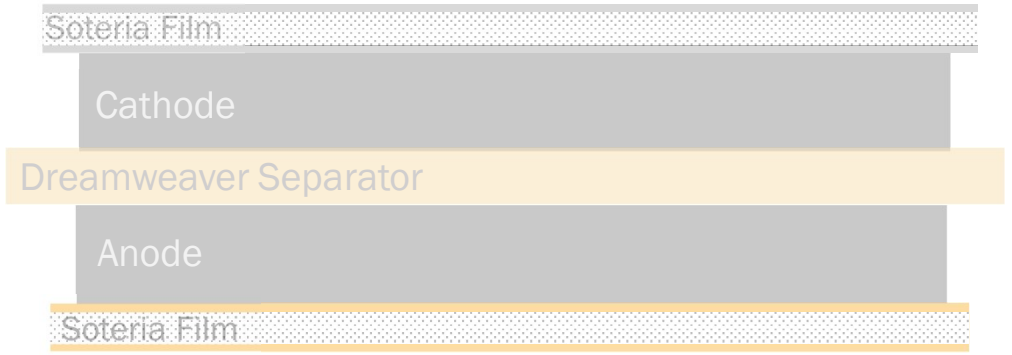
Broad and robust supply chain

Soteria eliminates root cause of cell ignition

Existing Technology



Soteria™ Technology

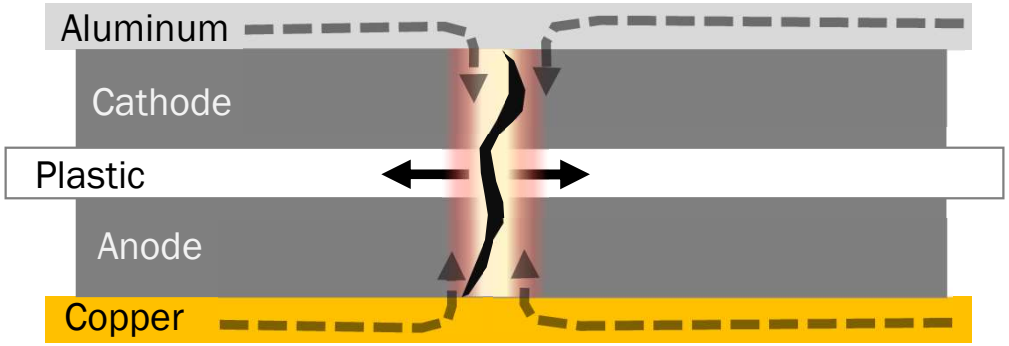


1. Internal short forms
2. High current generates heat

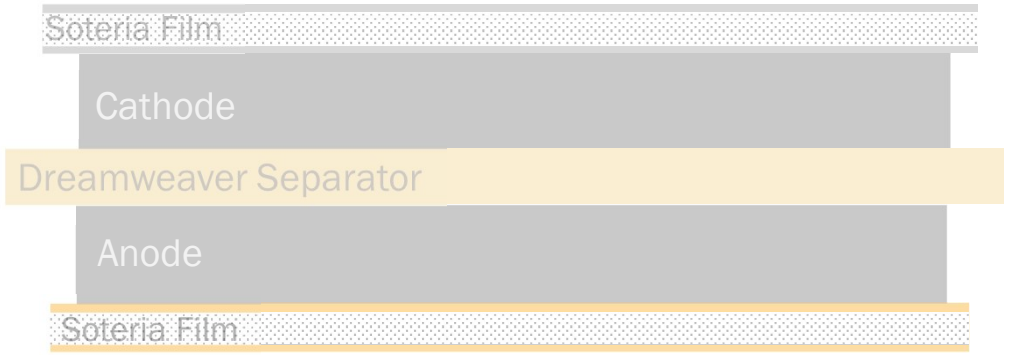
Watch Video:
https://youtu.be/II4a1An9zag

Soteria eliminates root cause of cell ignition

Existing Technology



Soteria™ Technology



1. Internal short forms
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3. Plastic membrane retreats
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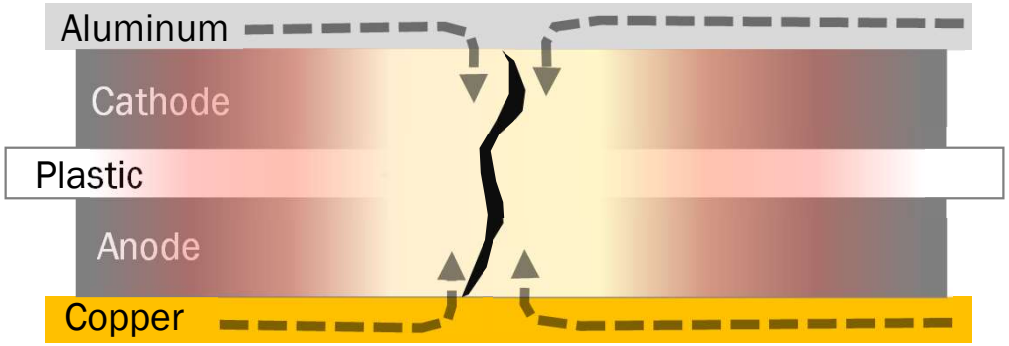
Existing Technology



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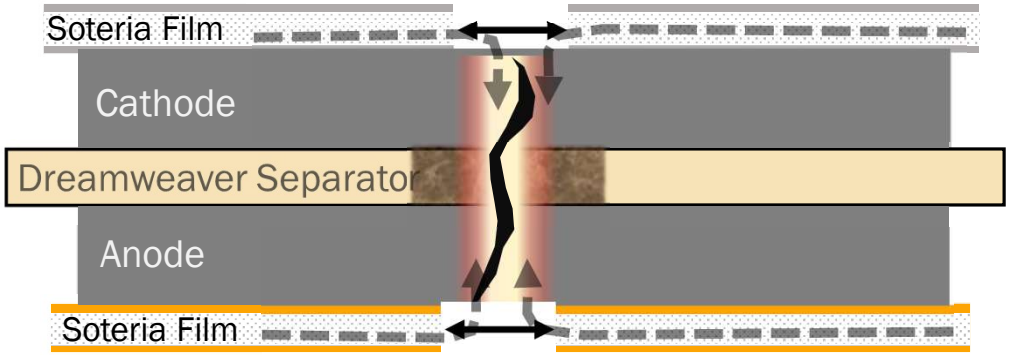
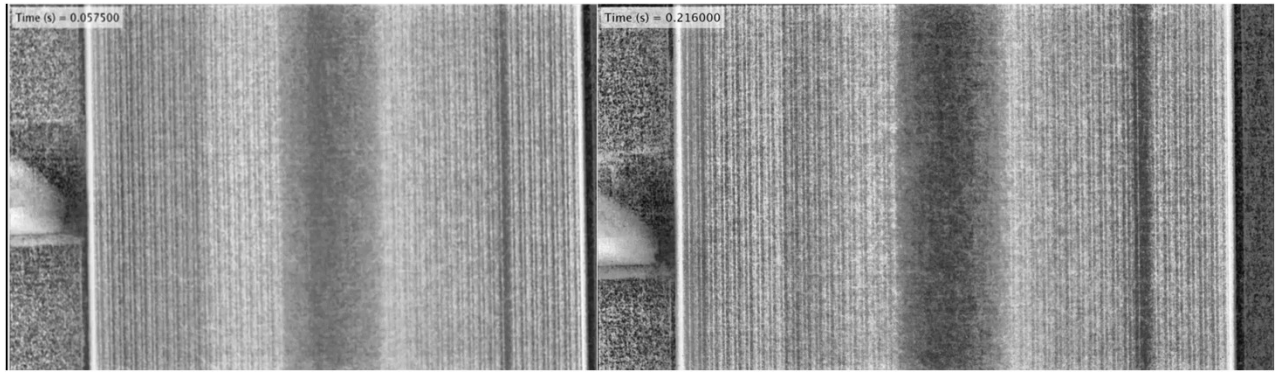
Soteria™ Technology



1. Dreamweaver separator maintains shape
2. Soteria films oxidize, act as internal fuse
3. Energy flow stops
4. Rest of cell continues to function

Watch Video:
https://youtu.be/II4a1An9zag

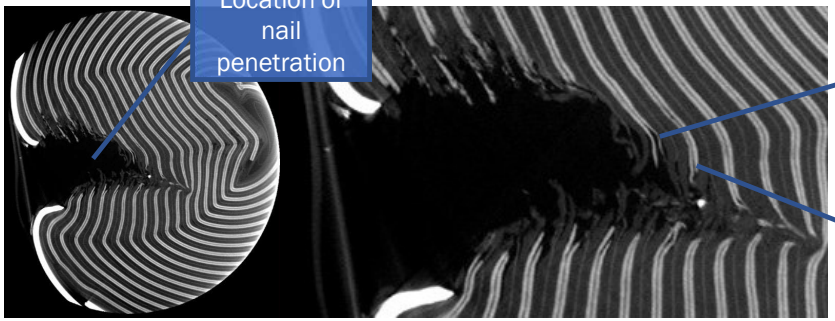
NASA Demonstrates Internal Fuse Effect



Standard materials

Soteria aluminum current collector

Watch Video:
https://youtu.be/Z8s3jNAZLYU

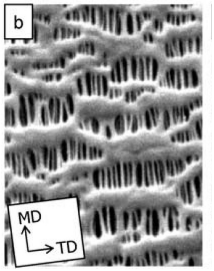


Open “alligator jaws” show residual electrode after collector retreated.

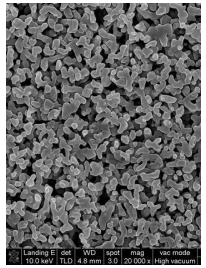
Light cathode layers have retreated below grey anode, preventing short through nail.

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

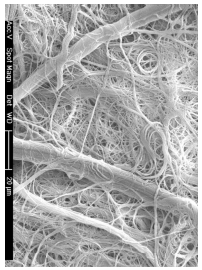
Dreamweaver Separators Inherently Stable



1st Generation:
Bare Film

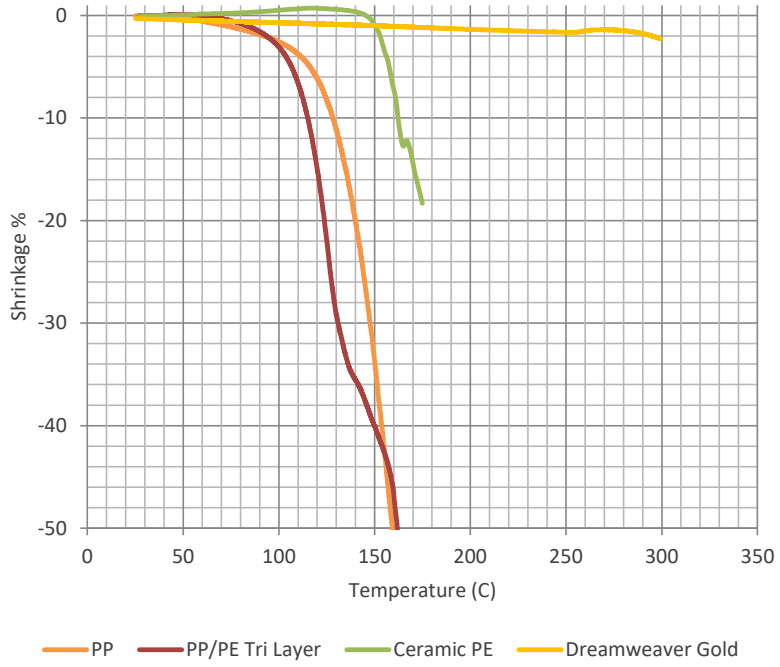


2nd Generation:
Ceramic Coated



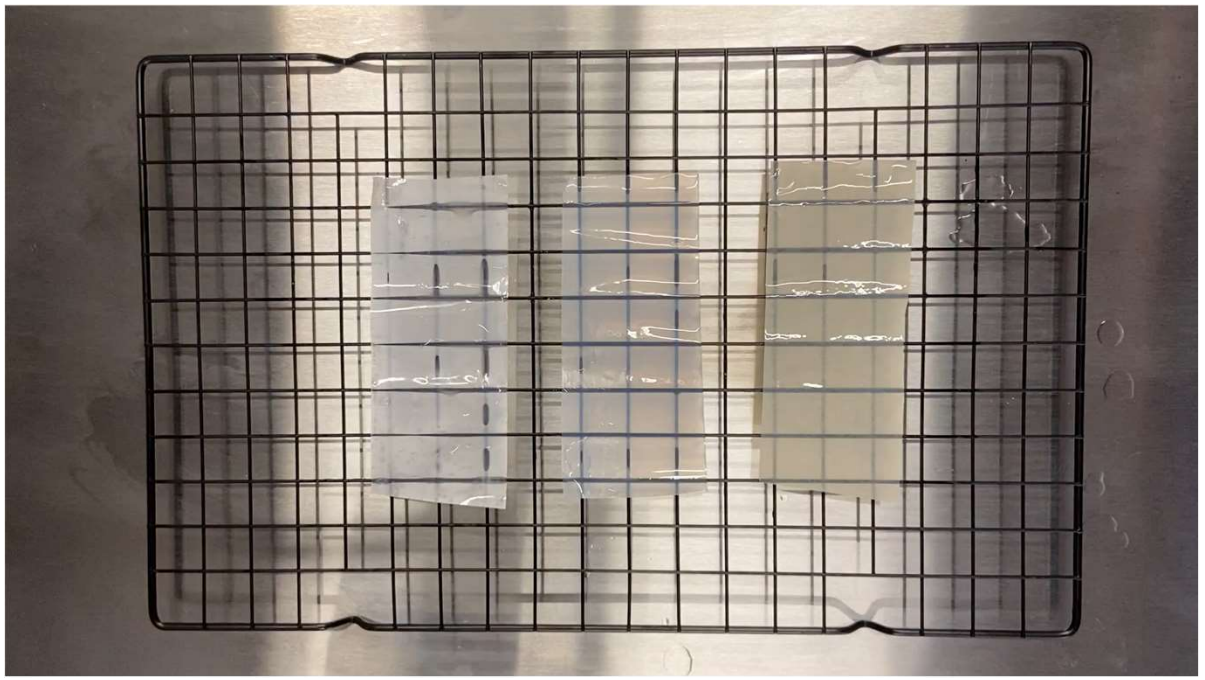
3rd Generation:
Dreamweaver

- Bare films shrink between 110—130°C.
- Heavy ceramic coatings improve only 30—40°C.
- Dreamweaver separators are stable to 300°C.
  - Reinforced with aramid fibers, stable to 550°C.



Dreamweaver Separators Inherently Stable

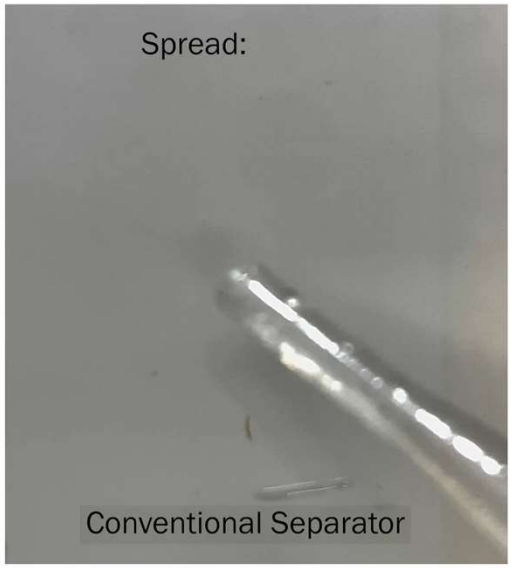
Plastic & ceramic coated separators immediately shrink

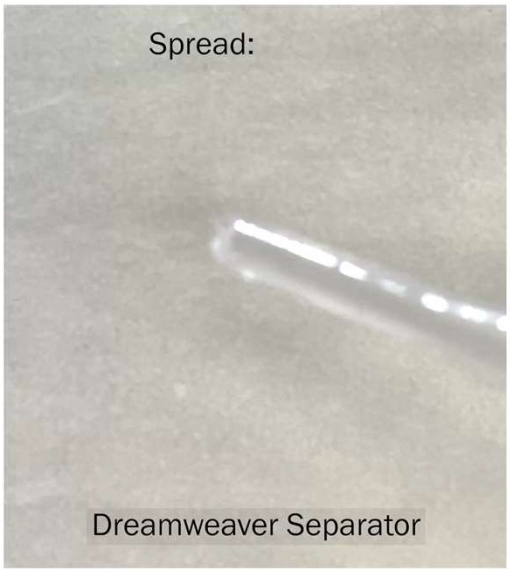


Dreamweaver separators char, but do not shrink or melt

Watch Video:
https://youtu.be/wDsX-h7YqFE

Faster Electrolyte Wetting





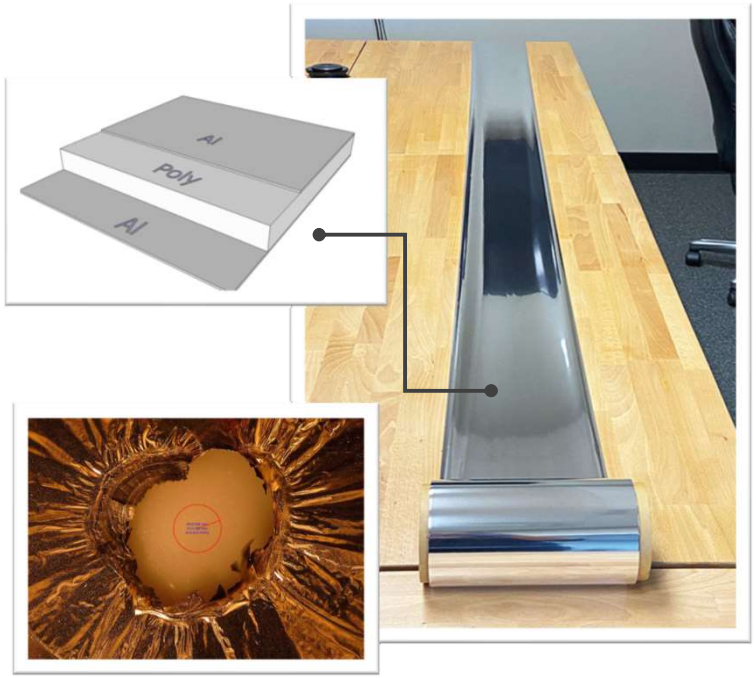
Watch the video:
https://youtu.be/rJx6MIaxxkM

The Dreamweaver separator wicks electrolyte up to 40x faster than conventional separators, promoting faster cell formation.

Lighter & Flexible Metallized Current Collector

	Traditional Aluminum Foil	Soteria Aluminum Film	Thin-film Aluminum Kapton®
Substrate	N/A	6um PET	4um Kapton®
Total Thickness	15um	8um	5um
Weight	43 g/m^2	12.9 g/m^2	9.8g/m^2
Tensile N/mm^2	150N/mm^2	120 N/mm^2	355N/mm^2*
Elongation	4%	39%	55%*

* Kapton® tensile and elongation numbers are for the bare film



Lighter & Flexible Metallized Current Collector

	Traditional Copper Foil	Soteria Copper Film	Thin-film Copper Kapton®
Substrate	N/A	9um PET	4um Kapton®
Total Thickness	10um	10um	5um
Weight	90 g/m^2	21.5 g/m^2	13.8g/m^2
Tensile N/mm^2	400 N/mm^2	120 N/mm^2	335 N/mm^2*
Elongation	4%	37%	55%*

* Kapton® tensile and elongation numbers are for the bare film

Third Party Cell Builds Validate Technology

Many cell builds have validated the Soteria and Dreamweaver technology. Soteria can share the results from:

10Ah, NMC523

Dreamweaver Separator

25Ah, NMC523

Dreamweaver Separator

2.1Ah, NMC523

Soteria Current Collector

5Ah, NMC811

Soteria Current Collector

10Ah, NMC811

Soteria Current Collector

2.1Ah, NMC523

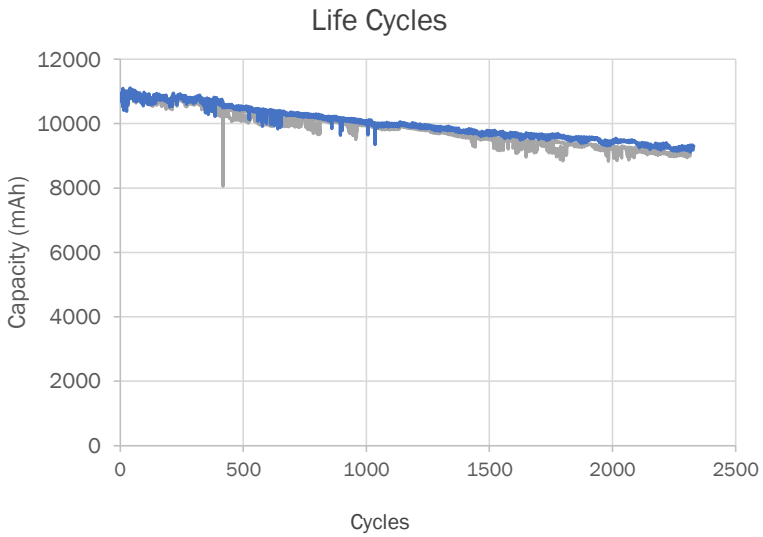
Soteria Current Collector

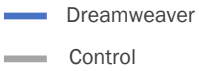
1Ah, LCO

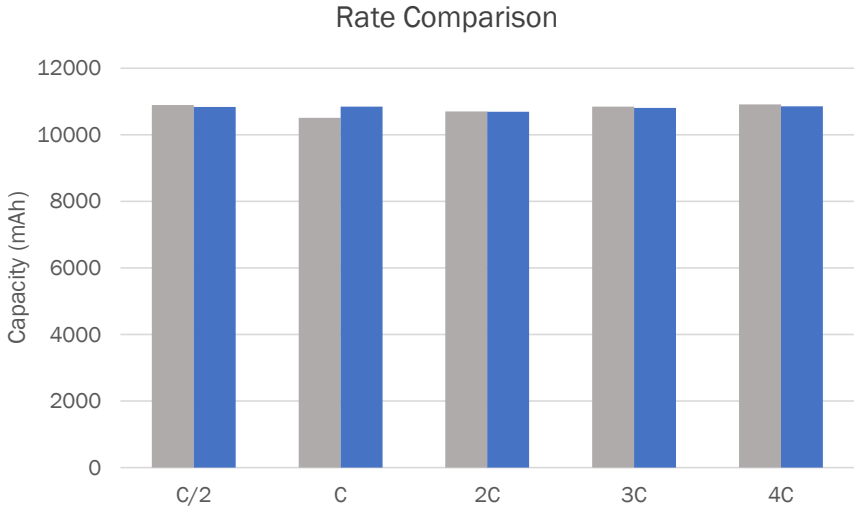
Soteria Current Collector

Excellent Performance of Dreamweaver Separator

The Dreamweaver gold separator exhibits high rate and life cycle performance, as exhibited in these 10Ah pouch cells.

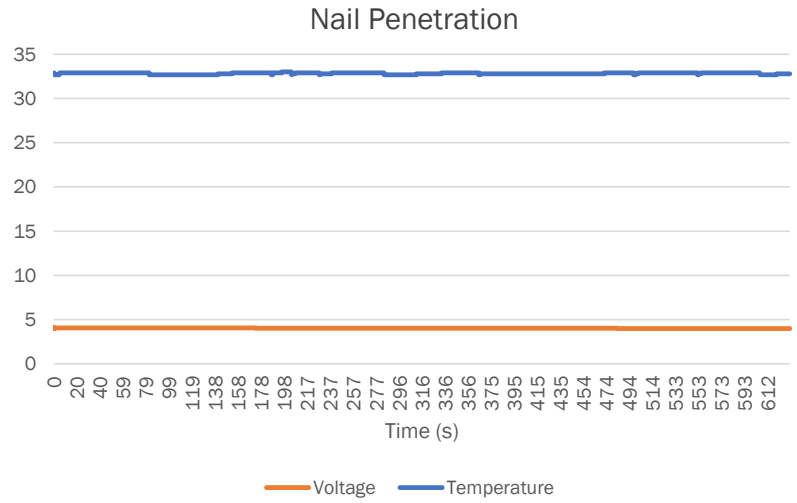


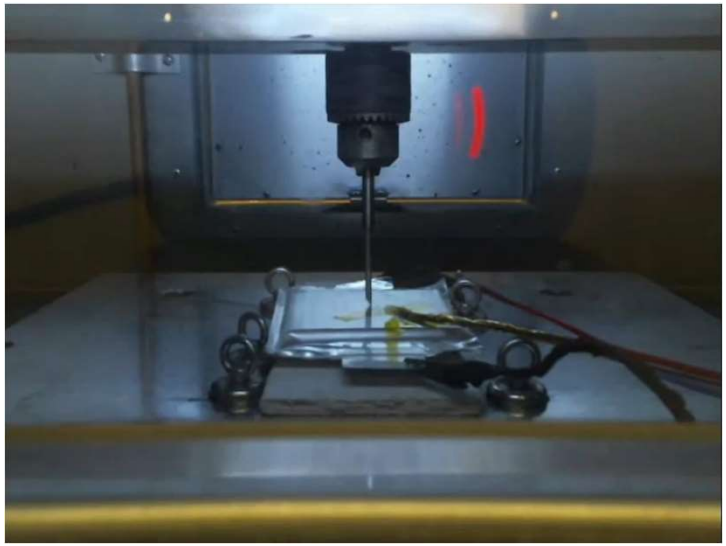




Excellent Performance of Dreamweaver Separator

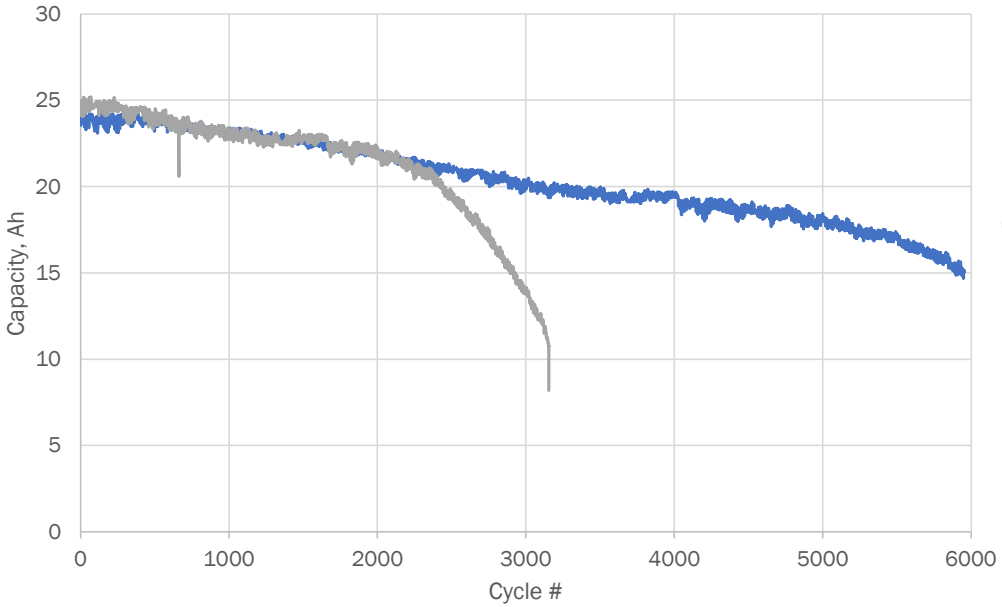
The separator's thermal stability shows improved abuse tolerance, passing nail penetration in 10Ah pouch cells with no temperature rise or drop in voltage.

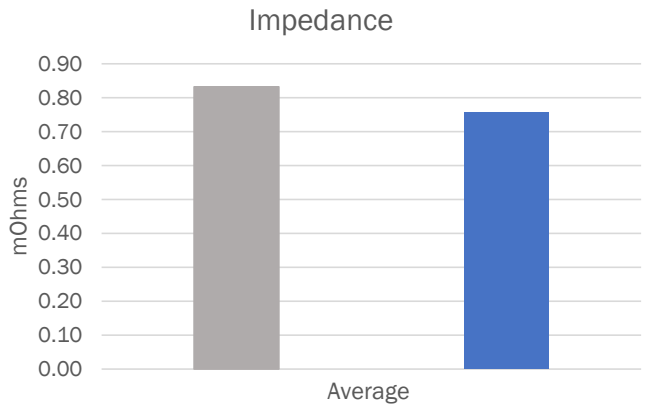




Watch Video:
https://youtu.be/dfA0LCkfWHo

Excellent Performance of Dreamweaver Separator





25Ah pouch cells with Dreamweaver Gold separator from licensee Delfort demonstrate **lower internal resistance** and exceptional life cycle, retaining 80% capacity at nearly 6,000 cycles.

Soteria™

High-Energy Pouch Cell Abuse Testing

(5Ah NMC811-Graphite Pre-production Cells)

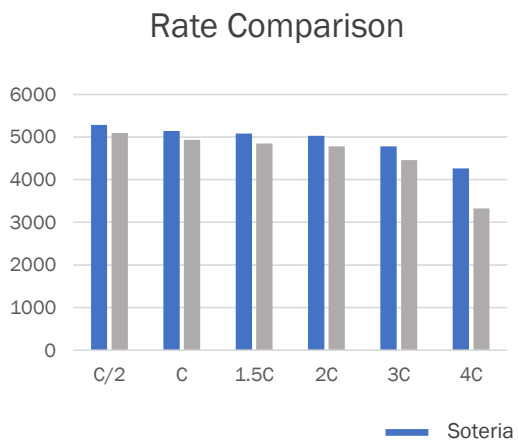
Watch Video:
https://youtu.be/Yt5Q_F8QDW4

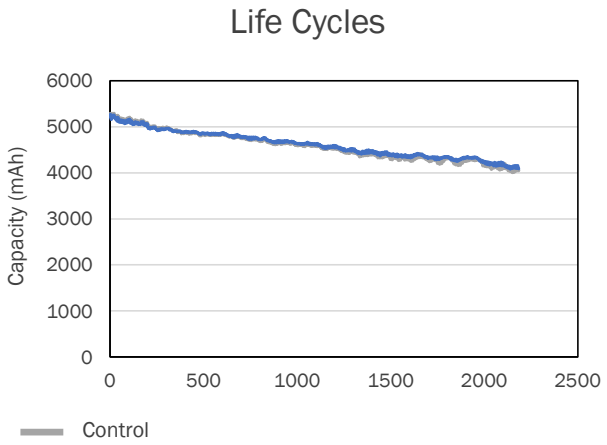
Improved Safety with Equivalent Performance

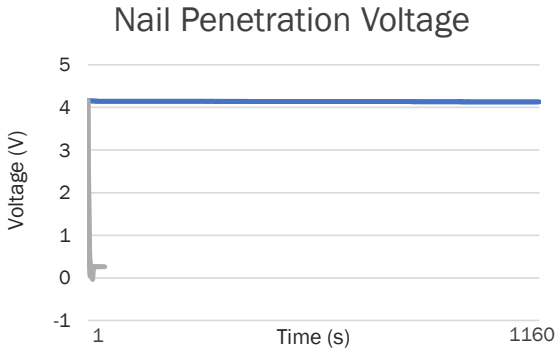
5Ah pouch cells with Soteria film match rate and cycle performance of control cells.

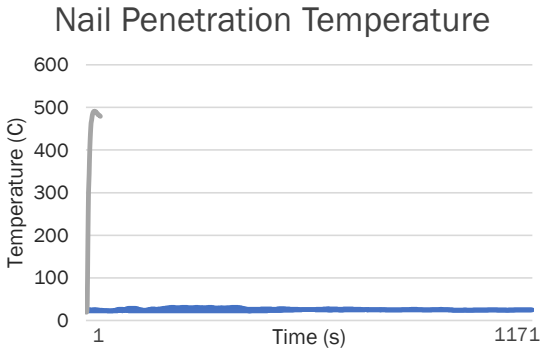
Control cells exhibited typical thermal runaway behavior.

Soteria aluminum current collector cells maintained voltage, minimal temperature rise.



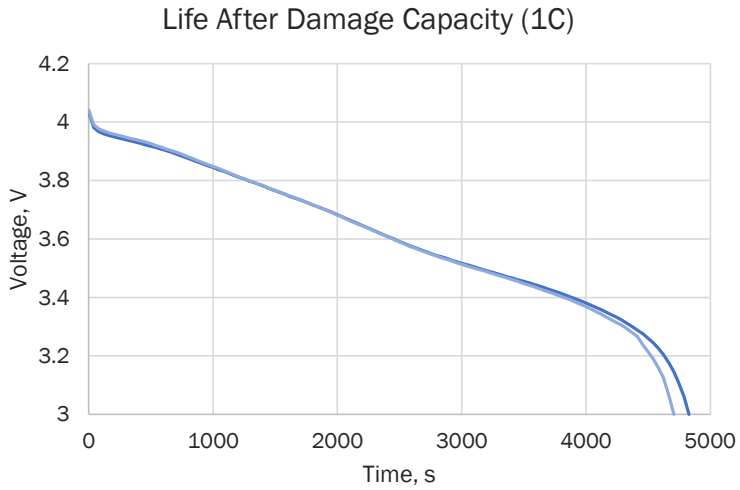






Soteria Technology Enables Function After Damage

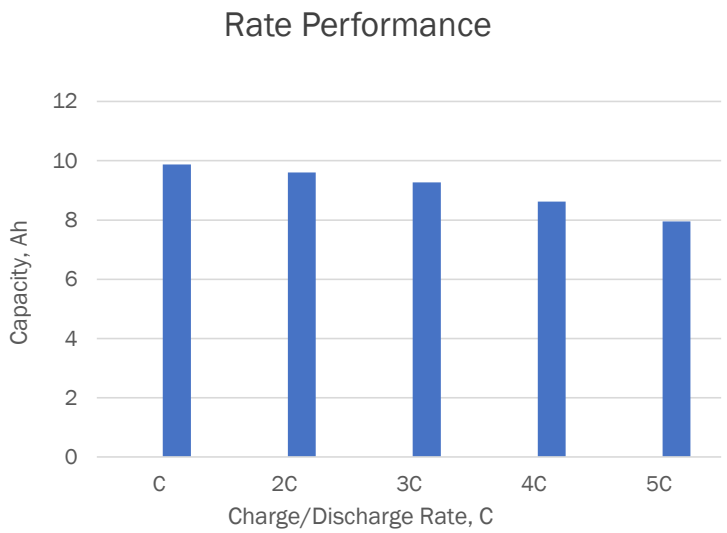
Various abuse tests of 5Ah (NMC811) cells show novel life after damage performance

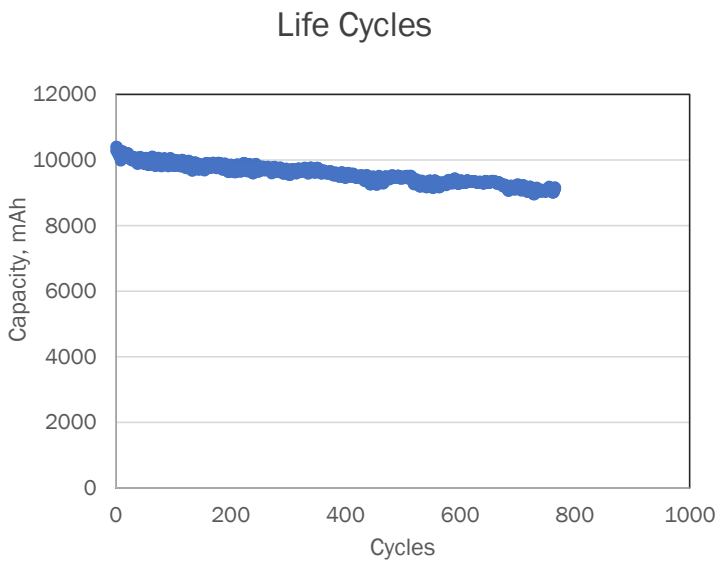


These cells all continue to function at >85% capacity.

Advanced Performance at Higher Capacity

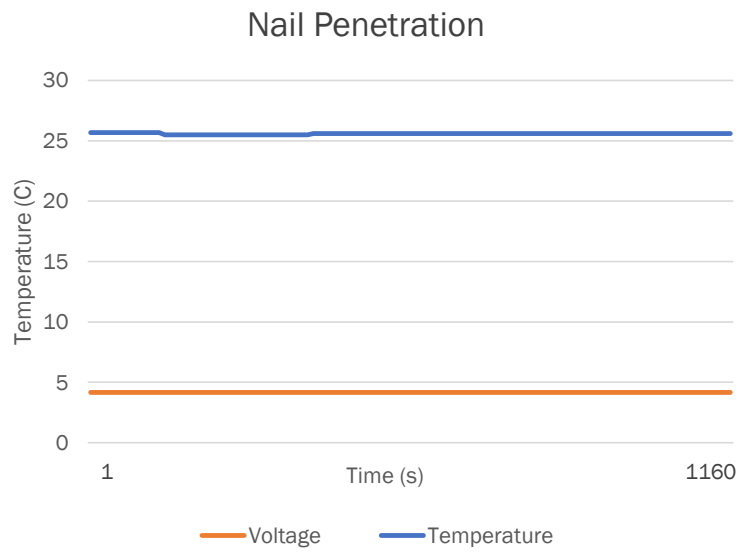
Scaling to high-energy 10Ah pouch cells demonstrated excellent rate capabilities, dropping less than 20% capacity at 5C.

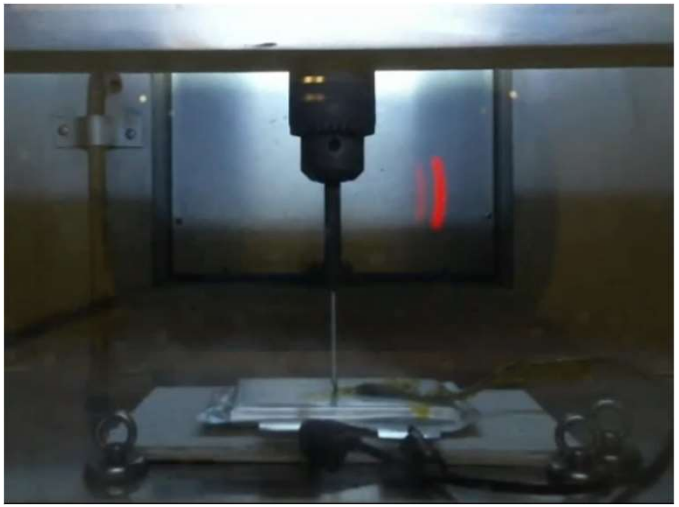




Consistent Safety Performance

Nail penetration results showed consistent abuse tolerance, even when scaled to 10Ah NMC811.

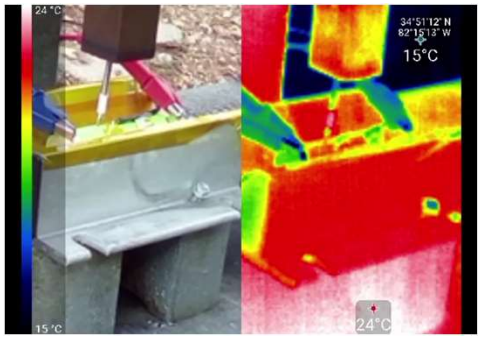




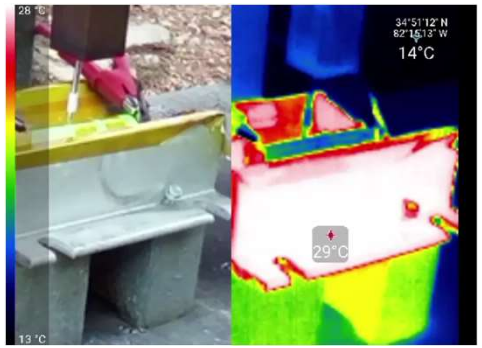
Watch Video:
https://youtu.be/JOQ6FP8G0fI

Improved Abuse Performance of Cylindricals

Standard materials



Soteria aluminum current collector



BAK 深圳市比克动力电池有限公司 SHENZHEN BAK POWER BATTERY CO.,LTD

Control cells quickly exhibited thermal runaway.

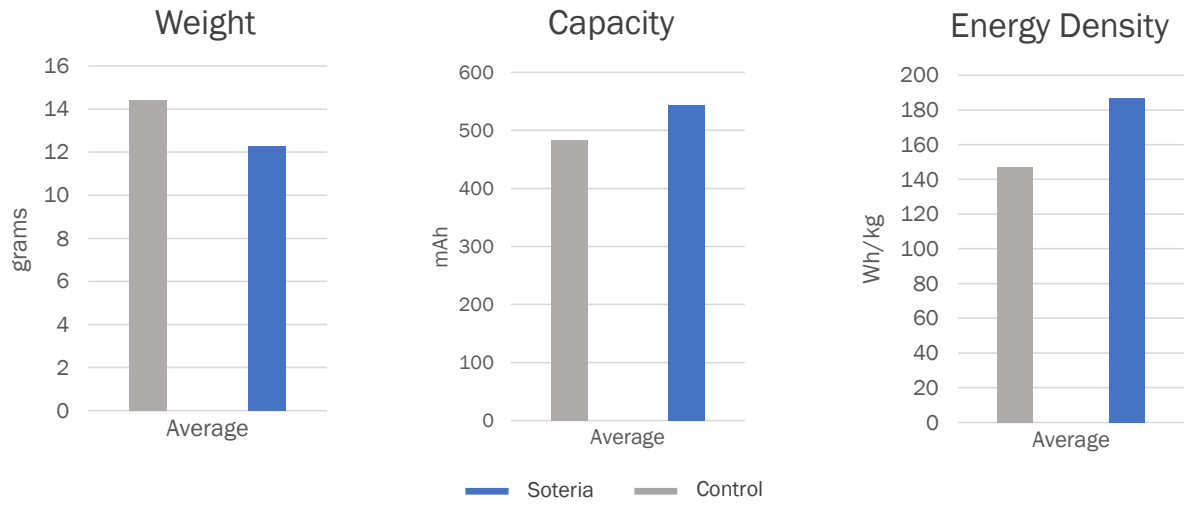
Soteria cells continued to function, retaining 90% of initial capacity.

Cell	1000Hz Impedance (mohm)	Initial Capacity (mAh)	SOC (%)
ST4-34	45.12	2380	100
Life After Damage (LAD)	46.03	2144.4	90.1008403

Thinnest Films Dramatically Reduce Cell Weight

Incorporating metallized Kapton® reduces cell weight by 14%, improving energy density by 26%. Capacity and run time also increased.

	Control	Soteria
Impedance (mOhm)	42.8	60.0
Capacity (mAh)	483.2	543.5
Weight (g)	14.4	12.3
Energy Density (Wh/kg)	147.0	186.7



Soteria™

Power of Working with Full Supply Chain

Separator Members

Equipment/Raw Materials

DuPont, Voith, Lenzing, Teijin, Hallimand, Sonoco

Paper Manufacturers

Glatfelter, Ahlstrom Munksjö, delfort, mativ

Current Collector Members

Equipment/Raw Materials

DuPont, Applied Materials, Hermann Ultrasonics, Celanese, Steinerfilm, AMCO Polymers, Sabic

Metallizers

CY

Cell & Pack Level Members

Saft, Inventus Power, one, ABF American Battery Factory, Cuberg, amte power, Gotion, Customcells, Navitas Systems, XALT Energy, American Battery Solutions, Forge Nano, amprius, Britishvolt, KULR, InoBat, Bren-Tronics, Inc., Coreshell, Nanotech Energy, Teledyne Technologies, Anthro Energy, Altris, CHAM 创明电池, Haylon Technologies, 3DBattery, Fullriver, Nanoramic Laboratories, zenlabs, Stryten Energy, 海立电子, Sepion Technologies, sionic energy, LeydenJar, Li Metal, MP, Conamix, Sion Power, Dynami, Galvion, Safire, GDI, Battery Streak, 天弋能源, Vervecap, JENAX, Qingtao Development, ATEX

End User Members

NASA, Zebra, Motorola Solutions, Mercedes-Benz Research & Development North America, Inc., Daimler Truck, Bosch, Eviation, Lenovo, ElectricFish, Rimac Automobili, BYE Aerospace, ecom, Aurora Flight Sciences, A Boeing Company, Hilti, Williams Advanced Engineering, Valqari, 3ME Technology, AgEagle, Lift, Aurora Aerial, Market, brilliantly, Green Cube Aero

Collaborator & Other Members

Oak Ridge National Laboratory, Energy Assurance, Civata global, OPEI Powering good., 云蜗科技 Cloudtech Technology, SpectraPower, Solvionic, astrolabe, ICL, Photon Automation, Inc., Shmuel De-Leon Energy Ltd, The Ohio State University College of Engineering, OBIC, Advano, Li-Cycle, Anton Paar, Valgotech, P3, Machinery Analytics, Duesenfeld, Polaris Battery Labs, iontra, The University of Michigan

Open-innovation approach delivers market breadth

Open-innovation platform technology

Result is a >10:1 multiple of Soteria R&D $$.

License technology using FRAND terms

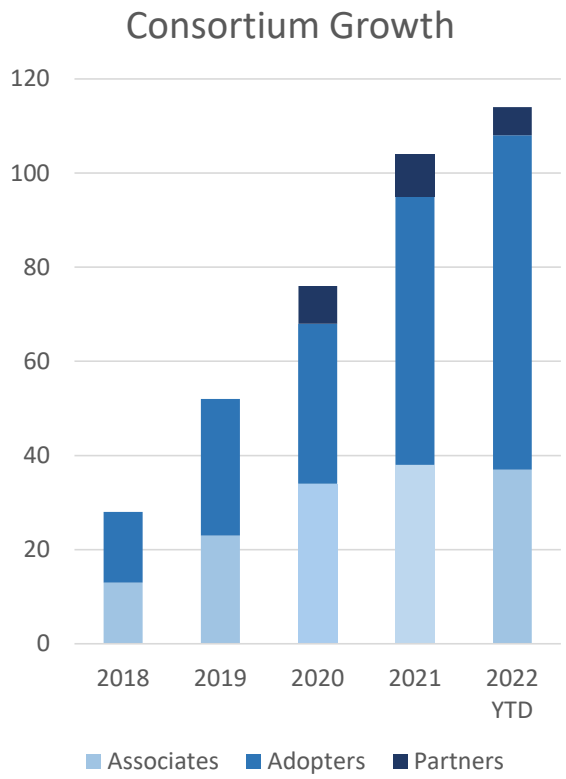
Everybody has access to battery safety.

Set uncompromising safety standards

Soteria cells do what we say they will do.

Soteria mark communicates safety

Consumer demand for safety will drive adoption.



Strategy	Examples	Weaknesses
Protection uses external means to protect the cell from the environment	Titanium plates on Tesla Model S, boxes around batteries, cooling systems	External to the cell and cannot shield against internal defects. The protection strategy will not prevent all damage to the cell.
Mitigation protects the external environment from the cell, if the cell goes into TR	Boxes built around batteries, thermally insulating materials, phase change materials	Only protects the environment (people) from a certain level of TR. Industry regulations exist that employ this strategy, but the defined limits may not approximate real-world situations.
Detection uses equipment or electronics to detect TR early, and takes measures to make it less likely to occur	Thermal sensors, gas sensors, voltage and current sensors	May not detect all events, and subsequent mitigation measures may not be enough to stop thermal runaway or could be applied too late.
Reduction involves replacing internal parts of the battery with materials that are not flammable, have reduced flammability, or are difficult to ignite	Ionic liquid electrolytes, solid electrolytes, graphite anode instead of lithium metal, lithium iron phosphate cathode instead of lithium cobalt oxide	The higher the energy density, the higher the density of reactive materials. They cannot be eliminated. Stated another way—eliminating reactive materials also eliminates the ability to store energy. And reactive materials will react—that is, burn.
Perfection involves the improbable process of producing millions of cells that are perfect, without defect	Manufacturing process control, CT scans of completed batteries	While the measures to make battery manufacturing more perfect have been fantastic, the battery itself is complex, and the defect required so small, that true perfection cannot be achieved. This is proven out by the ever-increasing number of battery recalls.
Control the flow of energy inside the cell, and stopping it if it goes above certain limits	Shutdown separators and current collectors, thermally stable separators	Control may not stop the flow of energy in all circumstances, allowing TR to initiate.

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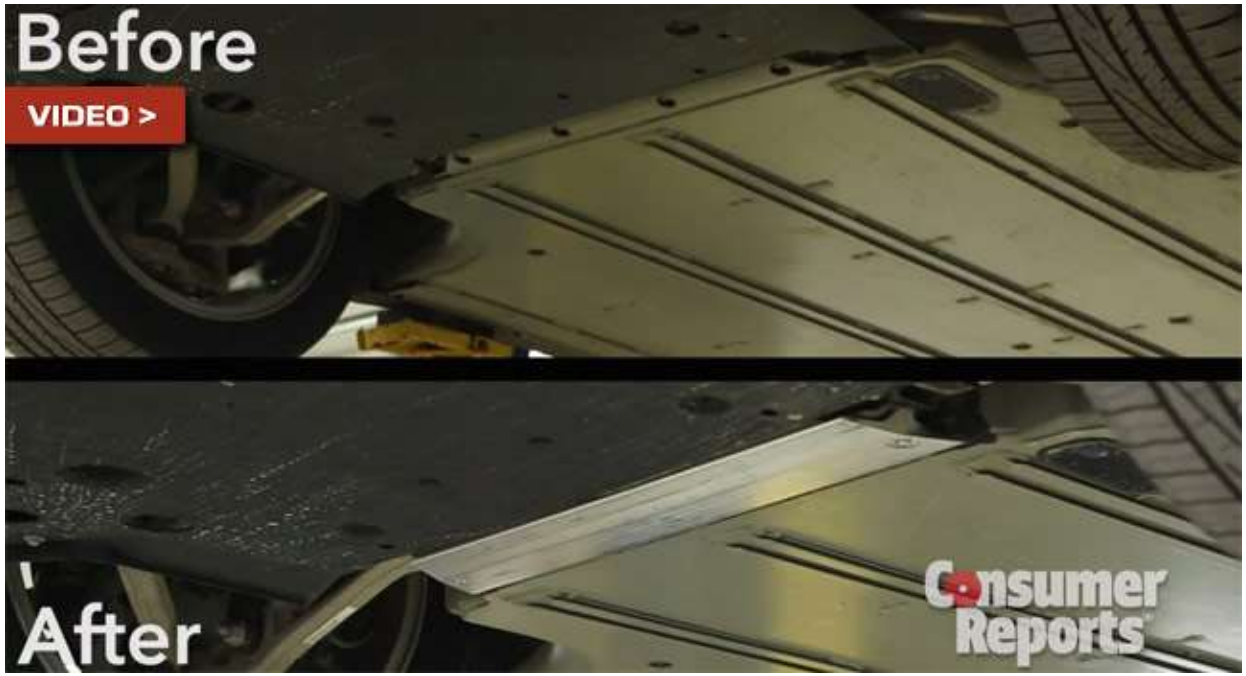

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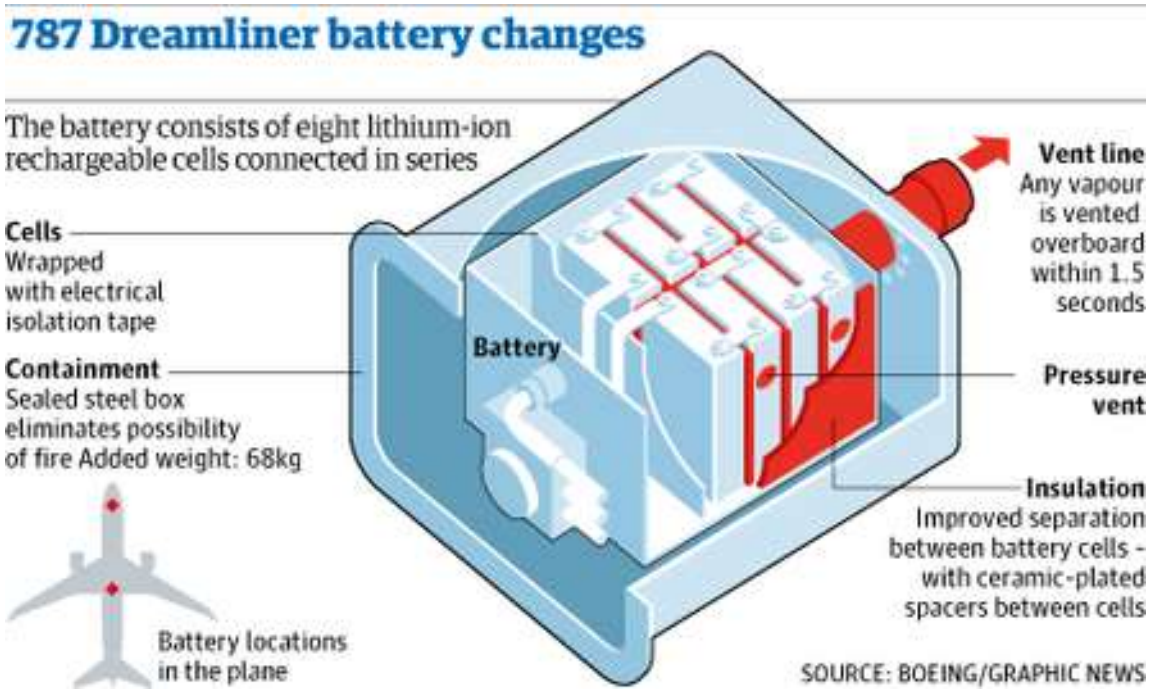

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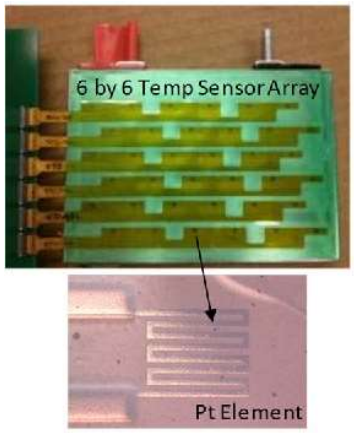

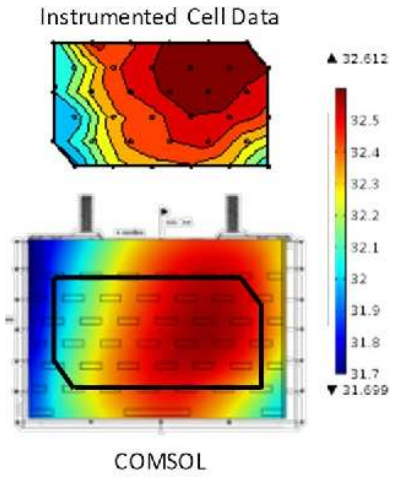

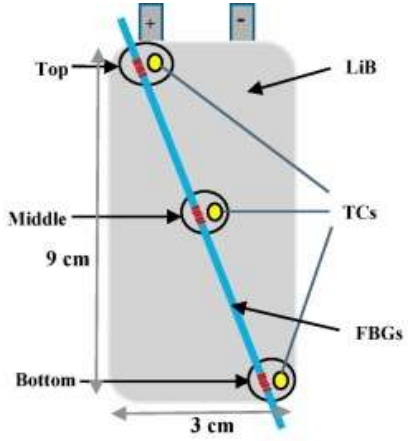

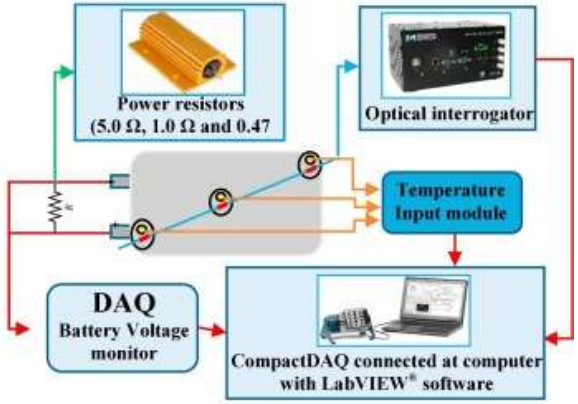

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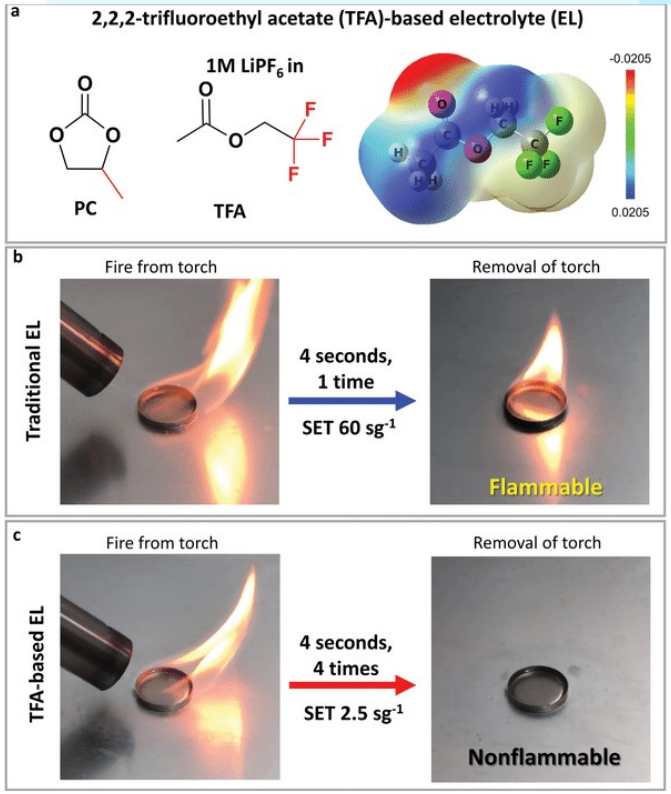

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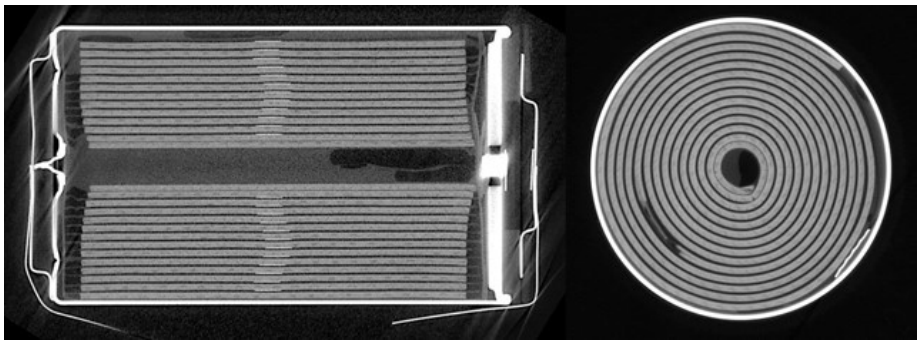

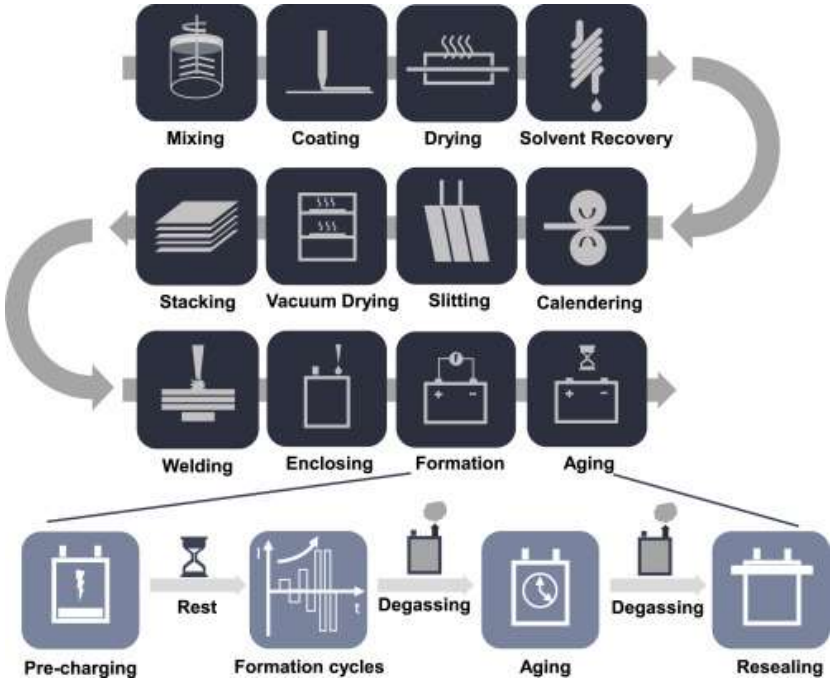

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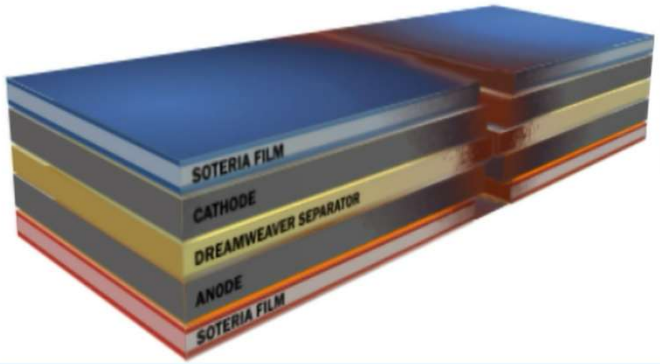


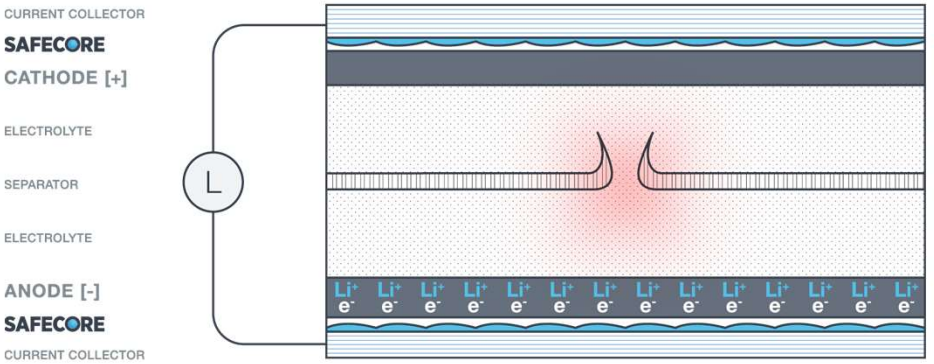
1 Replace plastic separators with a with a thermally

2 Replace solid aluminum and copper foils with thin metallized film current conductors

3 **The outcome is a safe cell that keeps working even after being damaged**

With an internal short now isolated, the rest of the cell continues to function. In short... No more FIRE or EXPLOSION!

replay animation



No single category is perfect

Develop best practices in each

- Peer review & publish
- Make technology broadly available

Analogous to crash protection today…

- Seat belts, shoulder harnesses, air bags, passenger airbags, crumple zones, anti-lock brakes, rear cameras, radar collision detection,

Soteria™

Save the date!

Soteria™

Inherently Safe Cells Everywhere

No compromises