

10.16.2017

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LITHIUM ION BATTERY CELL R2R MANUFACTURING

AIMCAL R2R Technical Conference USA 2017



Lithium Ion Battery Cell R2R Manufacturing

David A. Telep

AIMCAL R2R Conference USA 2017

Naples, FL

October 16, 2017

R2R Contributions to Li+ Cell Manufacturing

- Familiarize you with the R2R processes associated with Li+ cell manufacturing
- Provide relevance to AIMCAL members:
 - Equipment and material vendors
 - Consultants
 - Cell manufacturers and toll manufacturers
 - Cell and battery customers
- Indicate where process improvements can and are being made
- Highlight what goes (and shouldn't go) into producing a cell
- Persuade our members interested in the cell manufacturing process that AIMCAL is the right place to learn and network

R2R Contributions to Li+ Cell Manufacturing

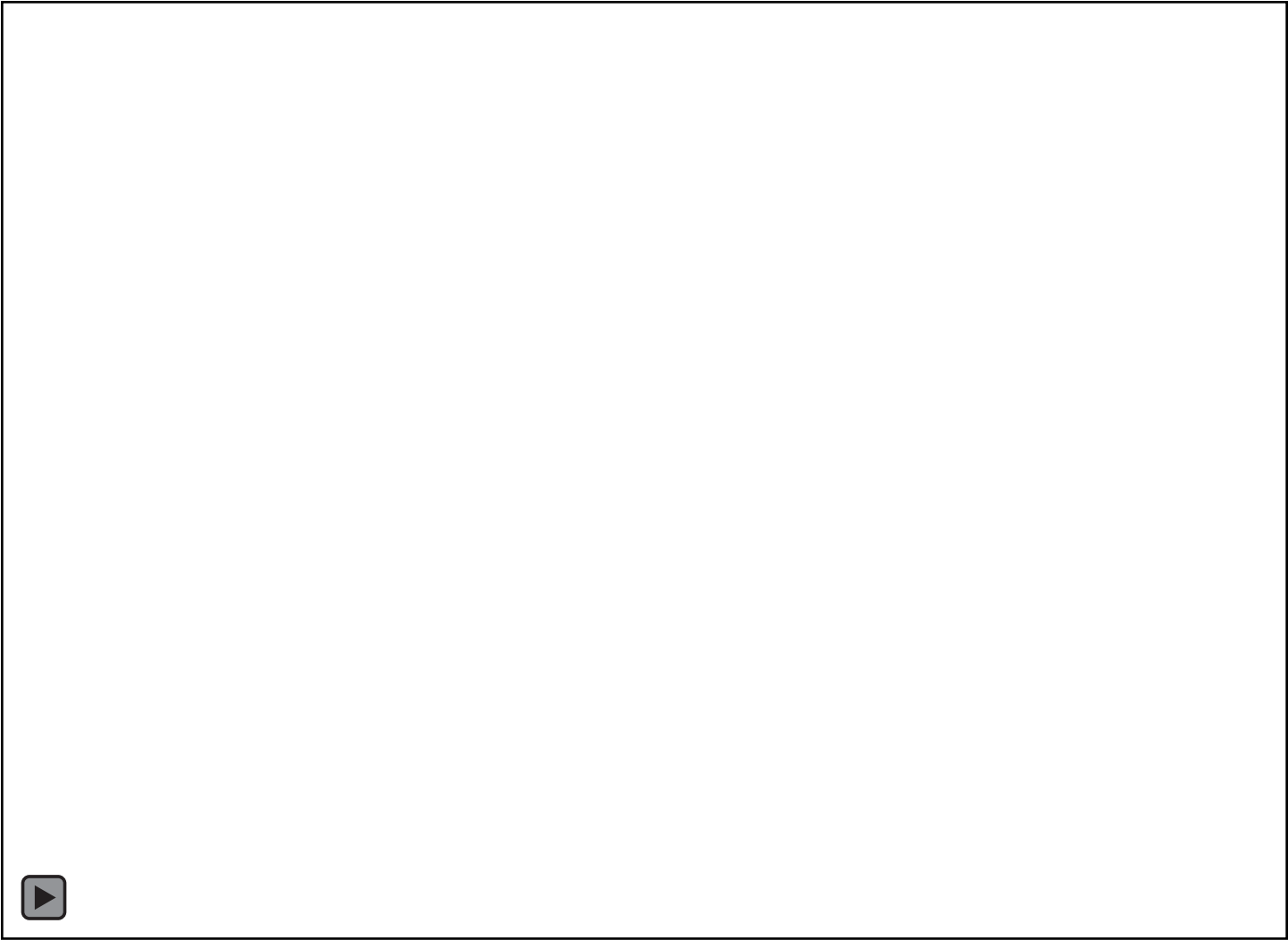
- Types of lithium ion cells
- R2R Components of a pouch cell
- Cell function
- Cost
- R2R cell production steps
 - Each major R2R Process
 - Current practices
 - Highlight areas ripe for improvement
- Cost Reduction Opportunities in R2R Electrode manufacturing

Li+ Battery Applications

Lithium ion Battery Applications



**Most people hear about
lithium ion batteries via
the national news.....**



Video courtesy of University
of Michigan, Ann Arbor

Samsung Galaxy Note 7 Recall

United States
CONSUMER PRODUCT SAFETY COMMISSION

Search CPSC

Menu


Home » Recalls » Samsung Recalls Galaxy Note7 Smartphones »

Samsung Recalls Galaxy Note7 Smartphones Due to Serious Fire and Burn Hazards

En Español

f t e p + 25

Report an Unsafe Product



Name of product:
Galaxy Note7 smartphones

Hazard:
The lithium-ion battery in the Galaxy Note7 smartphones can overheat and catch fire, posing a serious burn hazard to consumers.

Remedy:
Refund
Replace

Recall date:
September 15, 2016

16-266

Recalled Samsung Galaxy Note7 Smartphones

Hazard:
The lithium-ion battery in the Galaxy Note7 smartphones can overheat and catch fire, posing a serious burn hazard to consumers.

<https://www.cpsc.gov/Recalls/2016/Samsung-Recalls-Galaxy-Note7-Smartphones/>

Hoverboard Recall

United States
CONSUMER PRODUCT SAFETY COMMISSION

Search CPSC

Menu

Home » Recalls » Self-Balancing Scooters Hoverboards Recalled By 10 Firms »

Self-Balancing Scooters/Hoverboards Recalled by 10 Firms Due to Fire Hazard

En Español

f t e p + 278

Name of product:
Self-Balancing Scooters/Hoverboards

Hazard:
The lithium-ion battery packs in the self-balancing scooters/hoverboards can overheat, posing a risk of the products smoking, catching fire and/or exploding.

Remedy:
Refund
Replace
Repair

Recall date:
July 6, 2016

Recall number:

Report an Unsafe Product

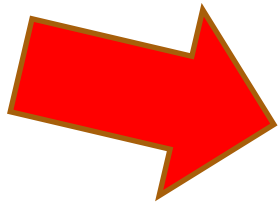



<https://www.cpsc.gov/Recalls/2016/Self-Balancing-Scooters-Hoverboards-Recalled-by-10-Firms/>

Hazard:

The lithium-ion battery packs in the self-balancing scooters/hoverboards can overheat, posing a risk of the products smoking, catching fire and/or exploding.

Grounding of 787 Dreamliners



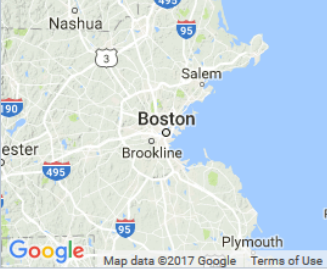
 NATIONAL TRANSPORTATION SAFETY BOARD

HOME NEWS & EVENTS SAFETY ADVOCACY **INVESTIGATIONS** DISASTER ASSISTANCE LEGAL ABOUT

Home > INVESTIGATIONS > Accident Investigations

Boeing 787 Battery Fire

https://www.nts.gov/investigations/pages/boeing_787.aspx

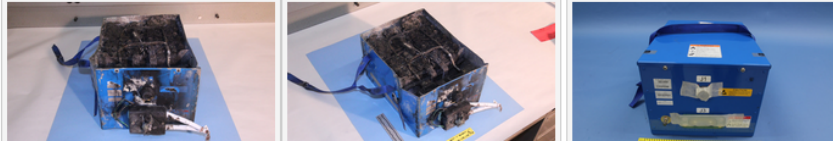


Accident No: DCA13IA037
Accident Type: Office of Aviation Safety
Location: Boston, MA
Date: 1/7/2013

WASHINGTON - Investigators with the National Transportation Safety Board are investigating a battery fire aboard a Boeing 787 at Boston's Logan Airport. The Japan Airlines 787 was on the ground and empty of passengers at the time of the incident. Comments or offers of assistance related to this investigation may be submitted by email: B787investigation@ntsb.gov

Follow us on twitter (@ntsb) for announcements related to the investigation.

Related Media



<https://www.nts.gov/investigations/AccidentReports/Pages/AIR1401.aspx>

Common Li+ Cell Types



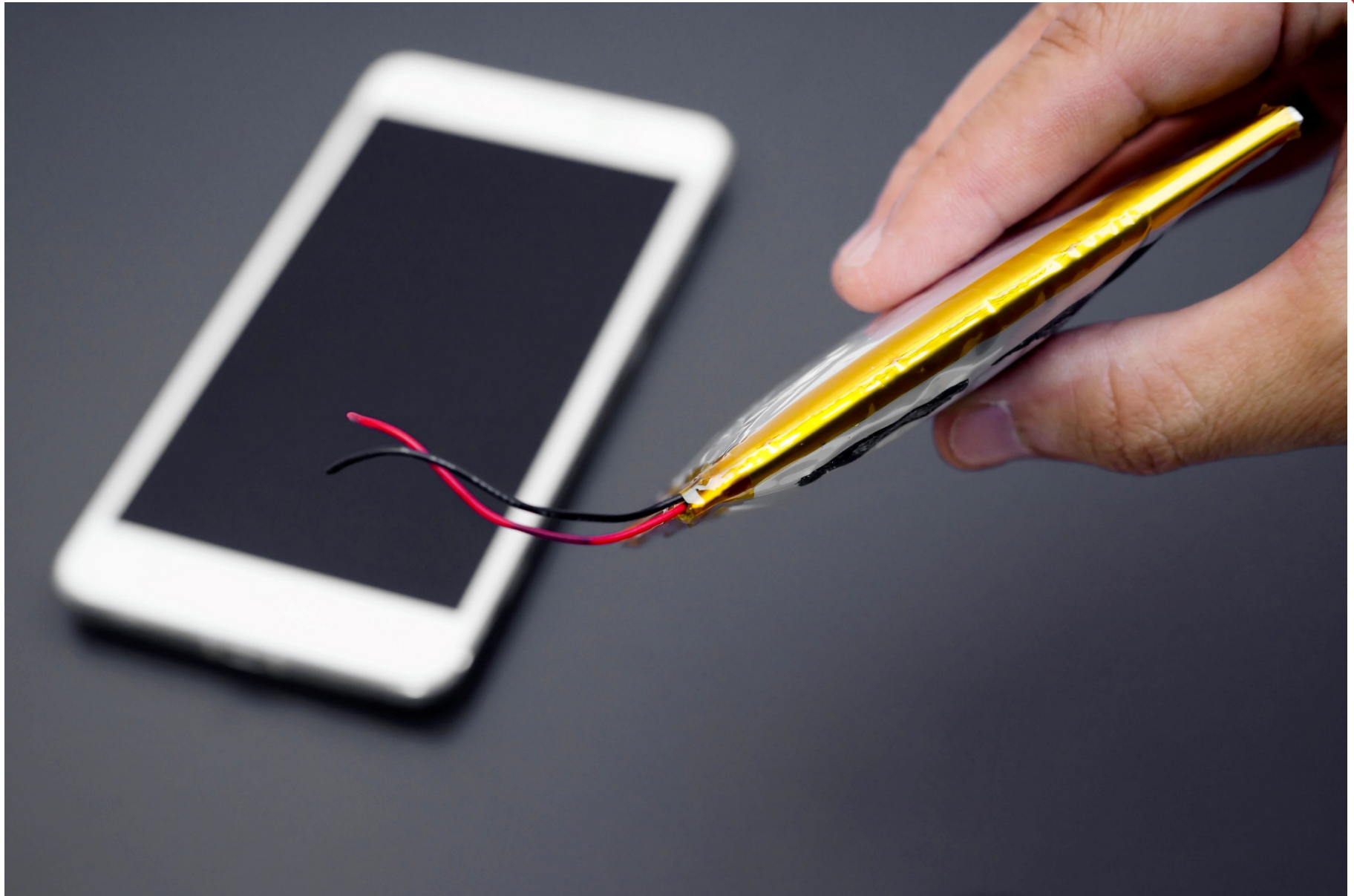
pouch



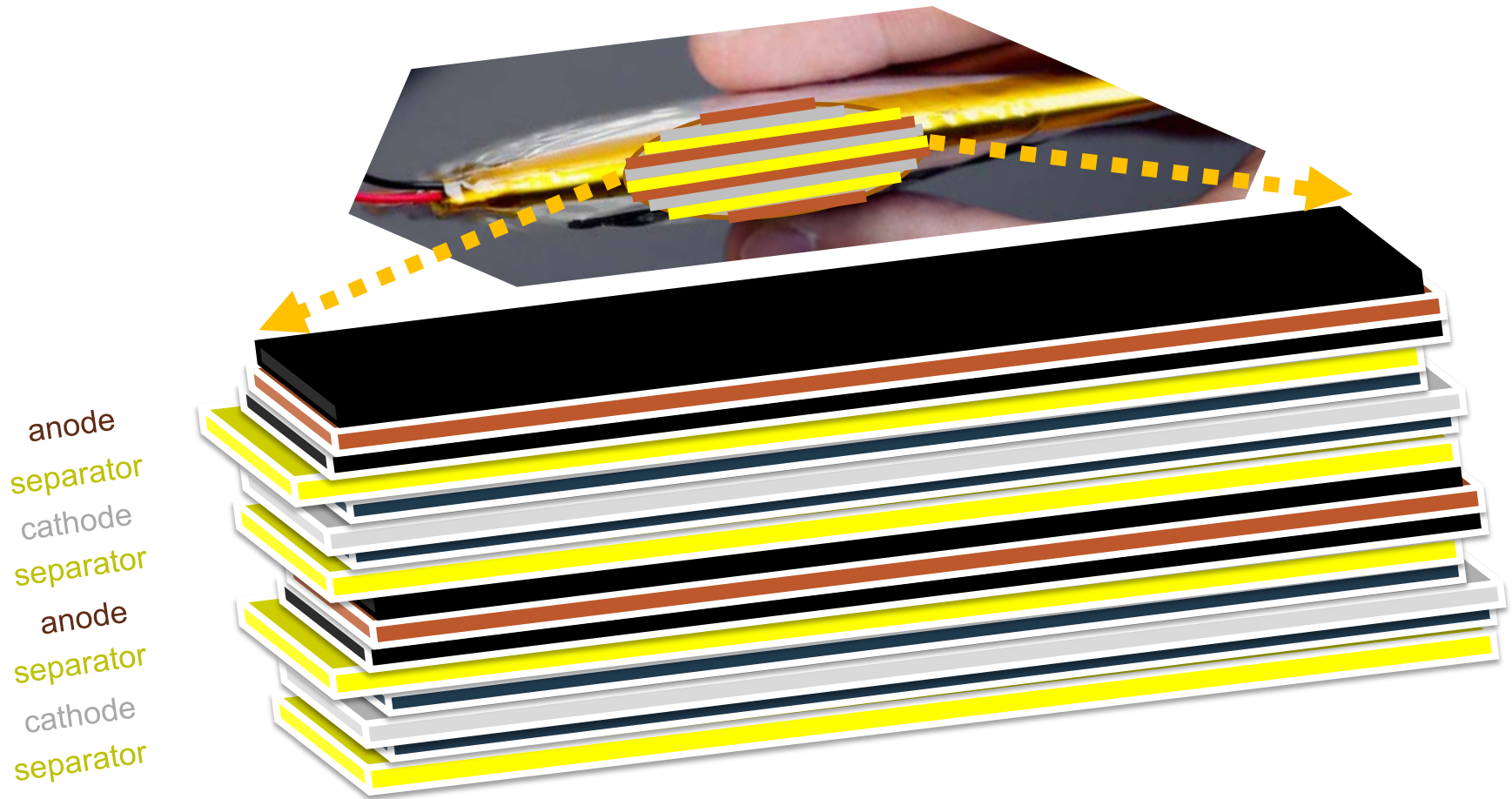
cylindrical



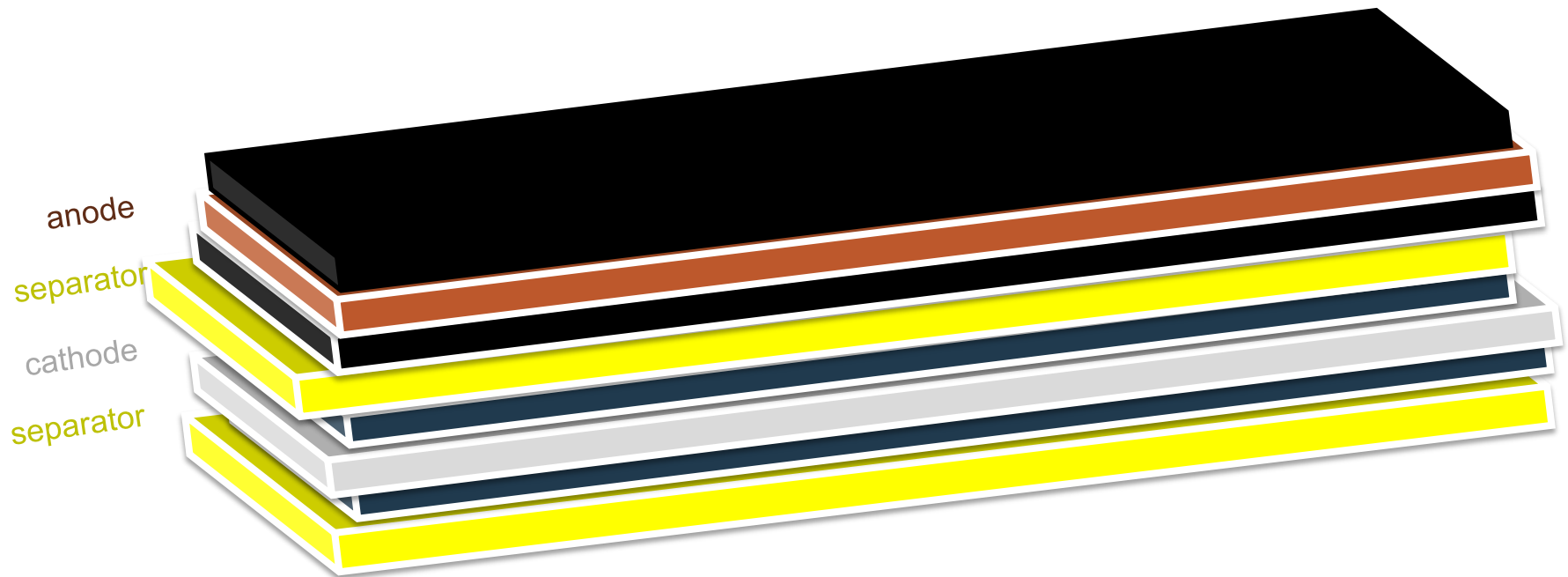
button



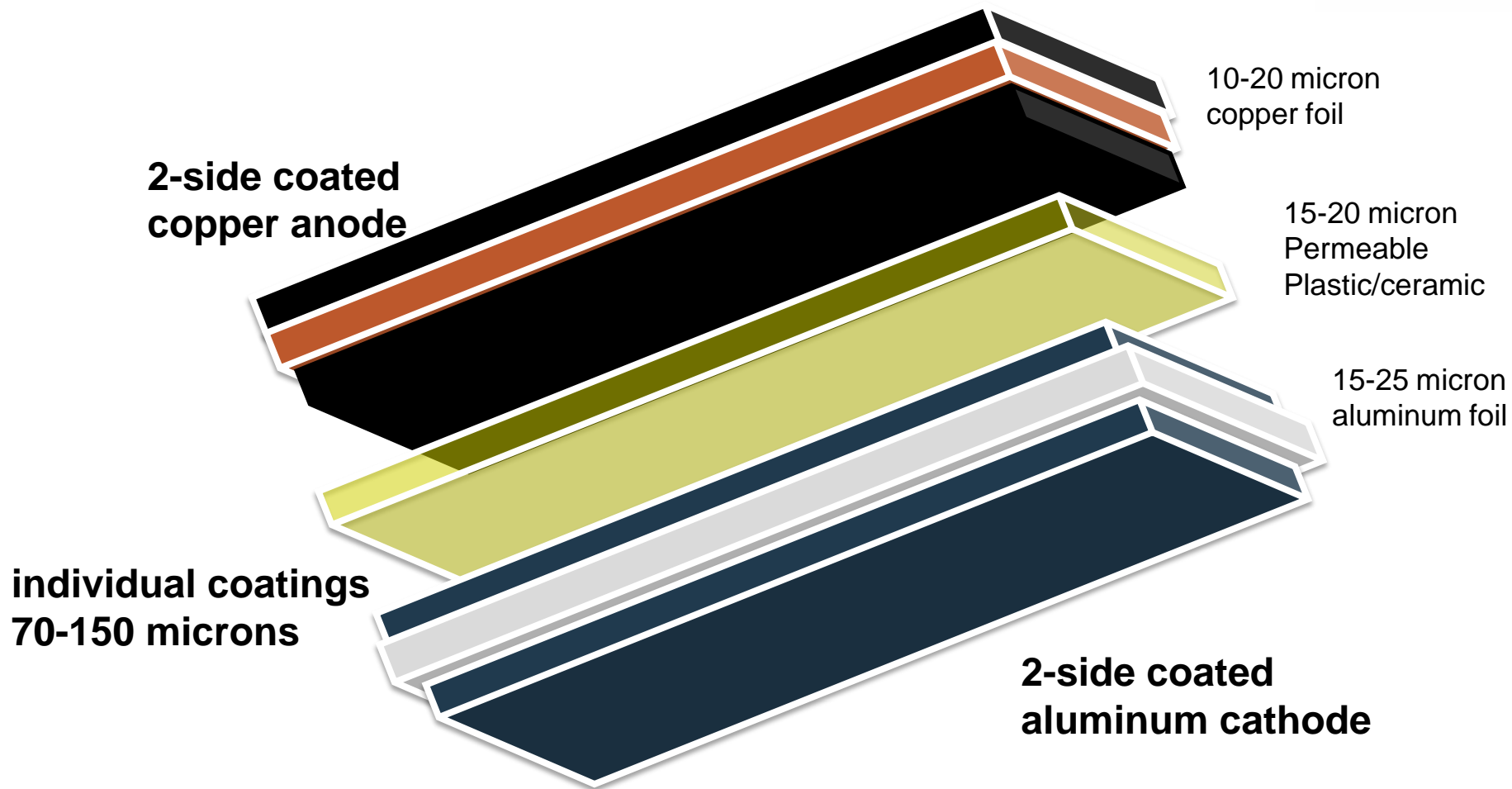
Pouch Cell Electrode Stacking



Pouch Cell Stacking: Unit

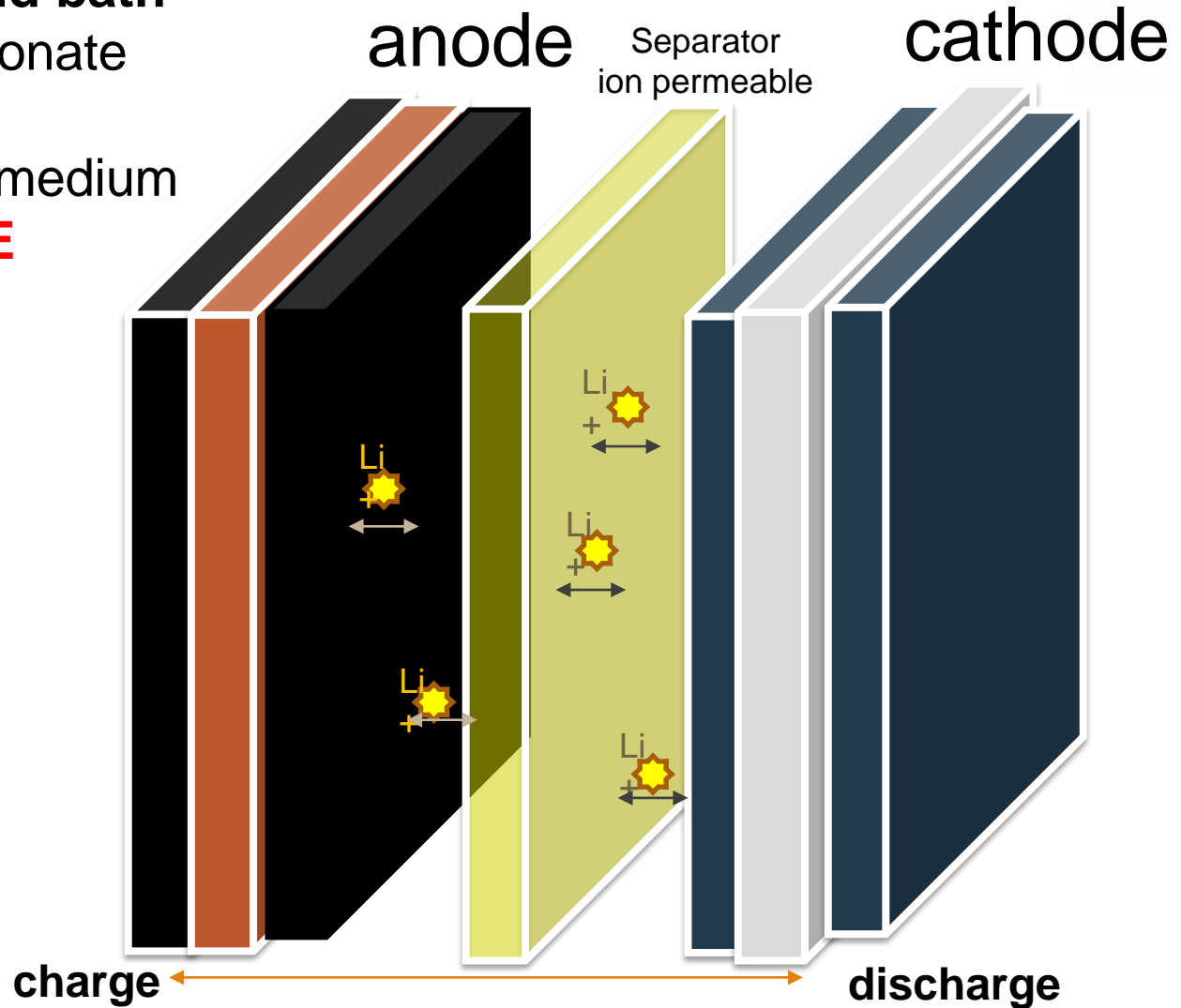


Individual Electrodes



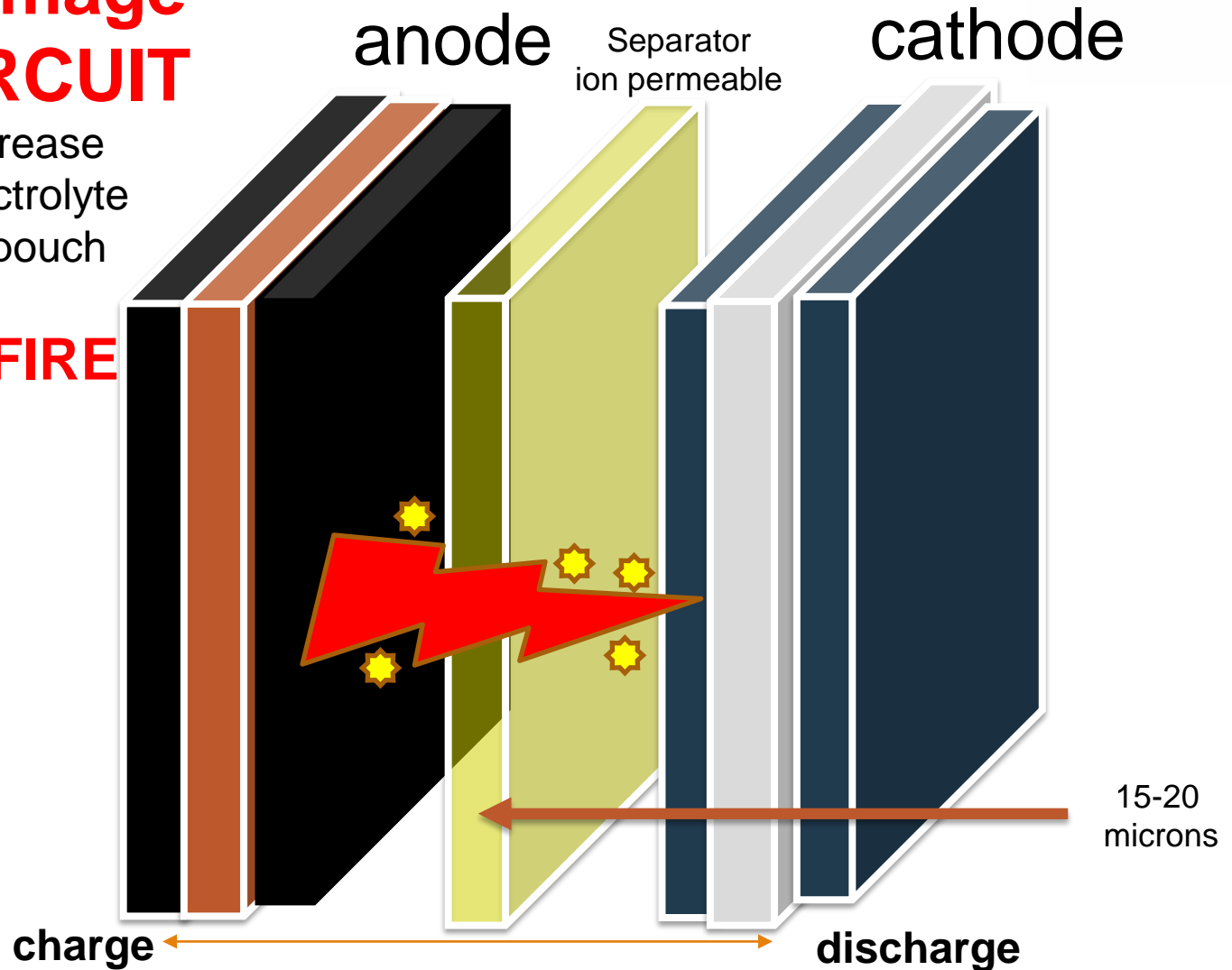
- **Electrolyte liquid bath**

- Organic Carbonate
- e- insulator
- Li⁺ transport medium
- **FLAMMABLE**



Internal Damage SHORT CIRCUIT

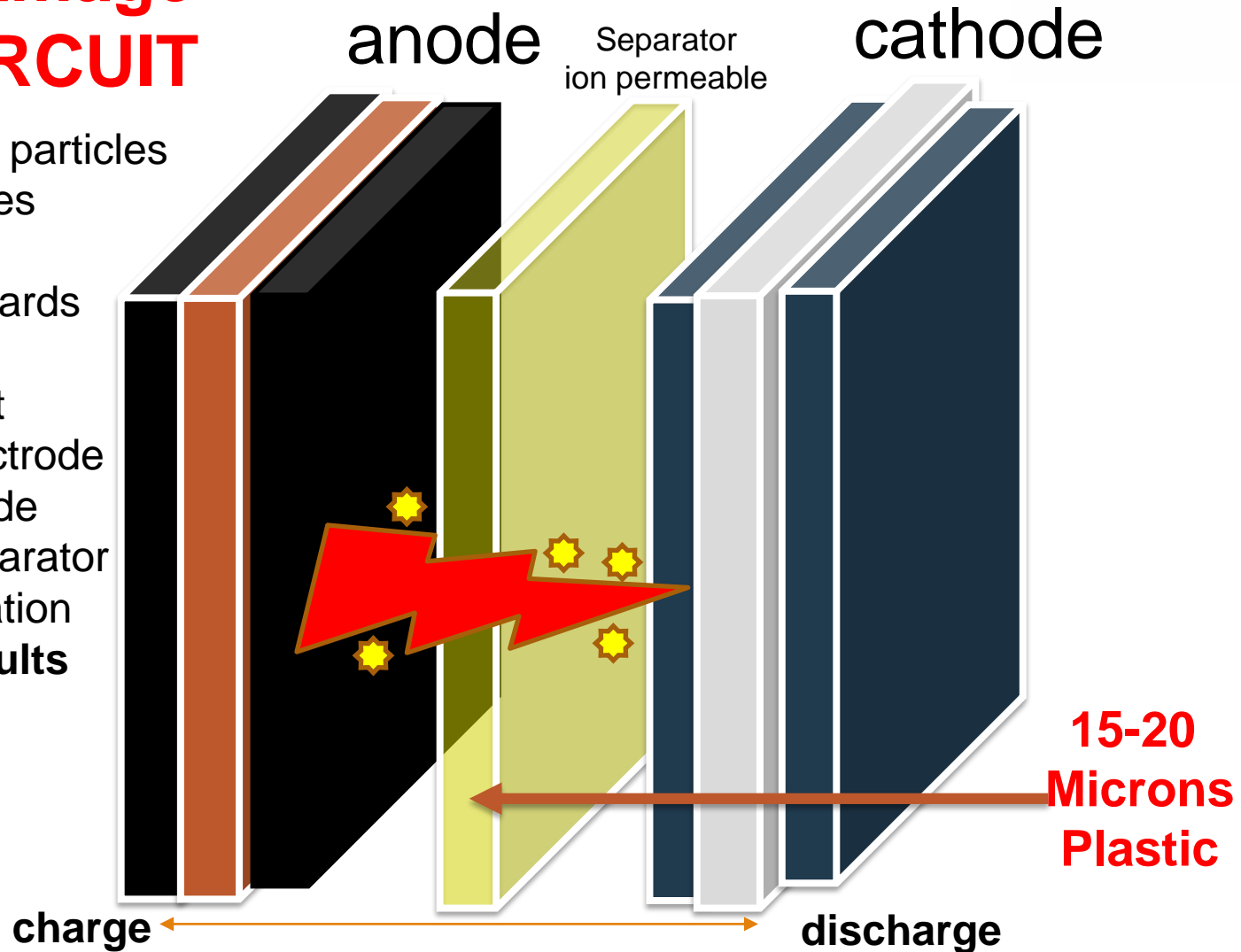
- **Dramatic** temp increase
- Vaporization of electrolyte
- Bulging/rupture of pouch
- Spark source.....
- **EXPLOSION/FIRE**



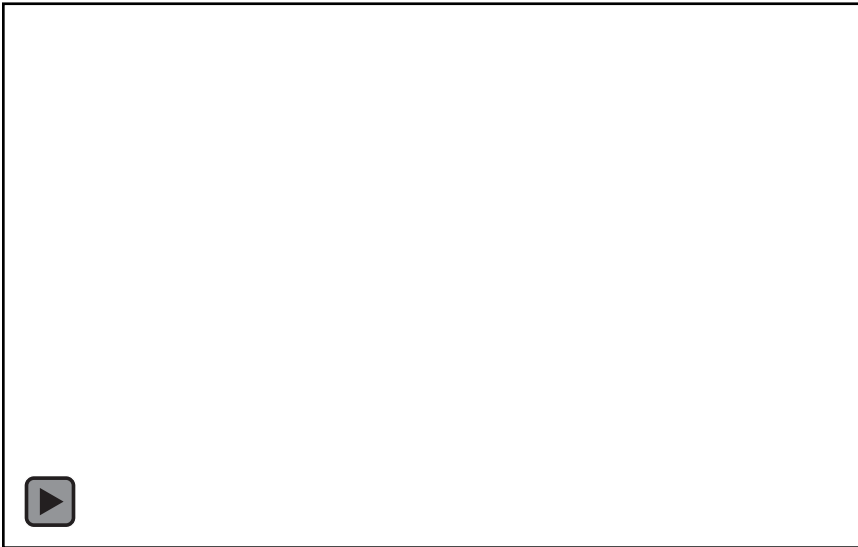
Internal Damage

SHORT CIRCUIT

- Coating-imbedded particles
- Ambient air particles
- Flaking coating
- Metal substrate shards
- Coating defects
- Edge/edge contact
 - Misaligned electrode
 - Mis-cut electrode
 - Misaligned separator
 - Pouch deformation
- **Manufacturing faults**



In-situ visualization of dendrite growth



Dendrite growth:

- Li metal “whisker” growth
- Consumes electrolyte
- Consumes lithium metal
- Can pierce plastic separator
- **Short-circuit potential !!**



Dendrites and Pits: Untangling the Complex Behavior of Lithium Metal Anodes through Operando Video Microscopy

[Kevin N. Wood](#)^{††}, [Eric Kazyak](#)[†], [Alexander F. Chadwick](#)^{‡§}, [Kuan-Hung Chen](#)[†], [Ji-Guang Zhang](#)^{‡||}, [Katsuyo Thornton](#)^{‡§}, and [Neil P. Dasgupta](#)^{††}

[†] Department of Mechanical Engineering, University of Michigan, Ann Arbor, Michigan 48109, United States

[‡] Joint Center for Energy Storage Research, University of Michigan, Ann Arbor, Michigan 48109, United States

[§] Department of Materials Science and Engineering, University of Michigan, Ann Arbor, Michigan 48109, United States

^{||} Energy and Environment Directorate, Pacific Northwest National Laboratory, Richland, Washington 99352, United State

Image and video courtesy of
University of Michigan, Ann Arbor
Dr. [Neil P. Dasgupta](#)

Samsung Galaxy Note 7 News Release

- “A short circuit within the battery may occur when there is damage to the separator that allows the positive and negative electrodes to meet within the jellyroll. Based on a detailed analysis of the affected batteries, both Battery A from the first recall and Battery B from the 2nd recall, we identified separate factors that originated in and were specific to the two different batteries.”

Main Causes of failures

- **Battery B:** High weld burrs on the positive electrode resulted in the penetration of the insulation tape and separator which then caused direct contact between the positive tab with the negative electrode.”
- **Battery A:** The negative electrode was deflected in the upper-right corner of the battery

<https://news.samsung.com/us/Galaxy-Note7-What-We-Discovered-infographic>

Dreamliner 787 Fires: NTSB Final Report

The NTSB identified the following safety issues as a result of this incident investigation:

- Cell internal short circuiting and the potential for thermal runaway of one or more battery cells, fire, explosion, and uncontrollable release of hazardous materials involving an APU battery cell as a result of thermal runaway of the other seven cells within the battery. This type of failure was not expected based on the testing and analysis of the main and APU battery that Boeing performed as part of the 787 certification process. This was the most severe condition possible for the final battery design certified for the main and APU battery design. Thermal runaway of the battery could occur as a result of the manufacturing processes. After the incident, the NTSB found that the cell manufacturing process. During the investigation, debris (FOD) generation during cell welding operations and a post assembly inspection process that could not reliably detect manufacturing defects, such as FOD and perturbations (wrinkles) in the cell windings, which could lead to internal short circuiting. In addition, the FAA's oversight of Boeing, Boeing's oversight of Thales, and Thales' oversight of GS Yuasa did not ensure that the cell manufacturing process was consistent with established industry practices.
- Cell internal short circuiting
- Cell manufacturing defects and oversight of cell manufacturing processes.

<https://www.nts.gov/investigations/AccidentReports/Pages/AIR1401.aspx>

Hoverboards tbd

Hoverboard, left charging overnight, cause of blaze that heavily damaged basement of Longmeadow home, investigators say

Updated on **Sep 14, 2017** at 01:25 PM EDT

https://articles.masslive.com/news/index.ssf/2017/09/hoverboard_left_charging_overn.amp

Jay Whitacre, a Professor of Materials Science & Engineering at Carnegie Mellon University, says that by nature, all lithium-ion batteries have a flammable electrolyte in them. And while most hoverboards are made safely, Whitacre points to two reasons for why this gadget in particular is having these kind of problems. **Their batteries are more powerful than those in a smartphone or laptop, and some of those are poor quality.**

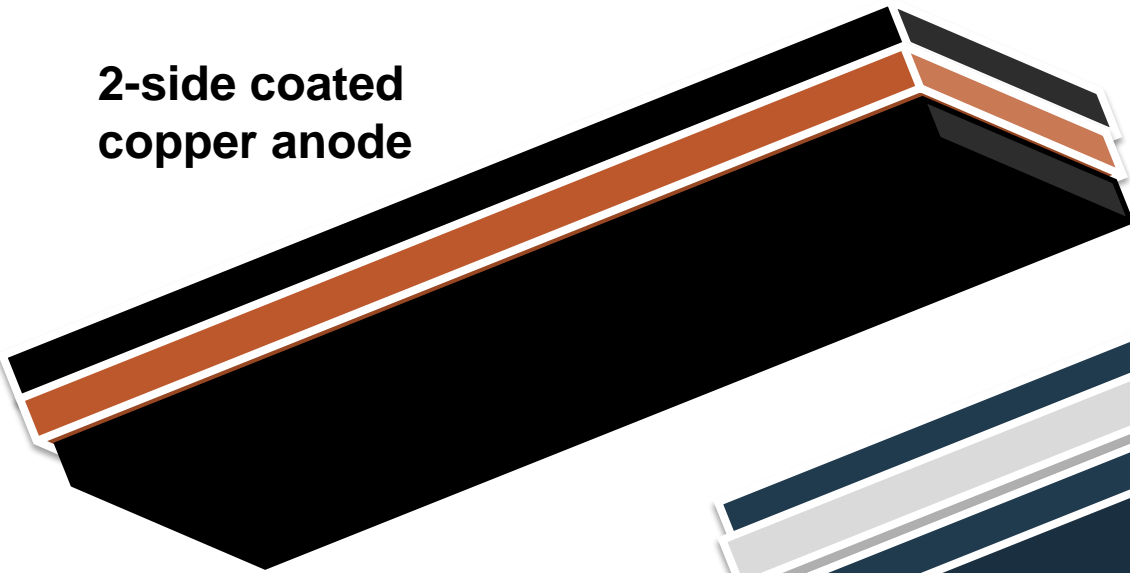
"I think a lot of them are using second-tier battery sources which are going to have probably a higher rate of defects," he says.

All Tech Considered
National Public Radio
Weekend Edition Sunday
December 19, 2015

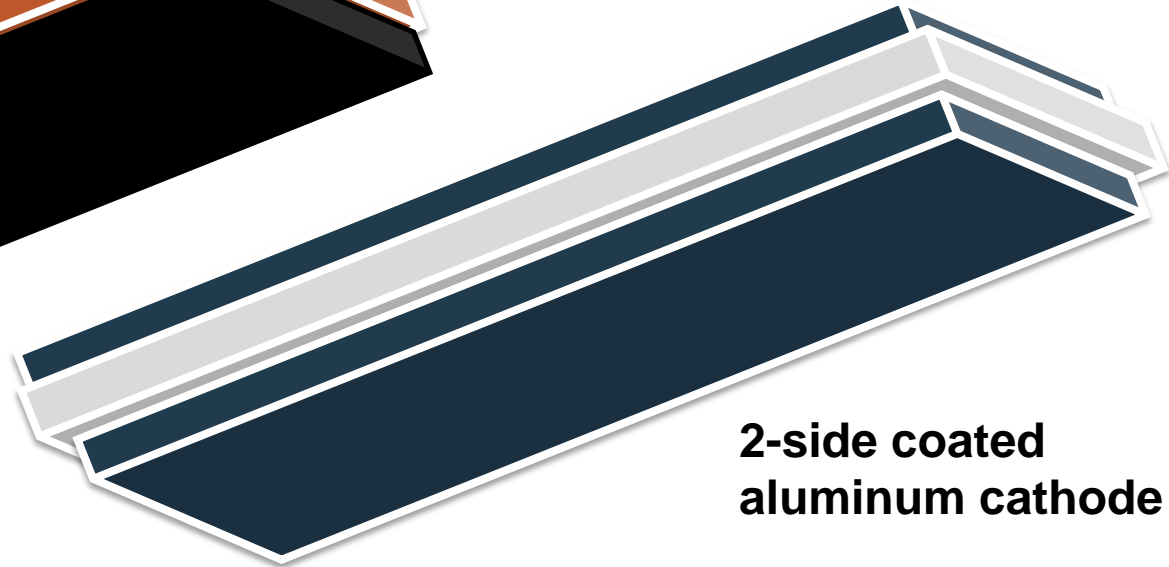
R2R Manufacturing

R2R Manufacturing Anode and Cathode Electrode

2-side coated
copper anode



2-side coated
aluminum cathode



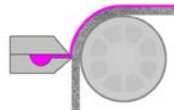
R2R Start



Raw Materials



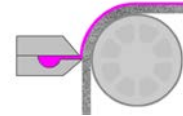
Slurry Mixing



Coating



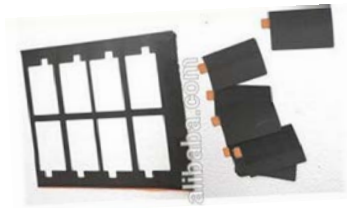
Drying



Coating



Drying



**Electrode
Punching**



Calendering

**To
Pouch
Building**

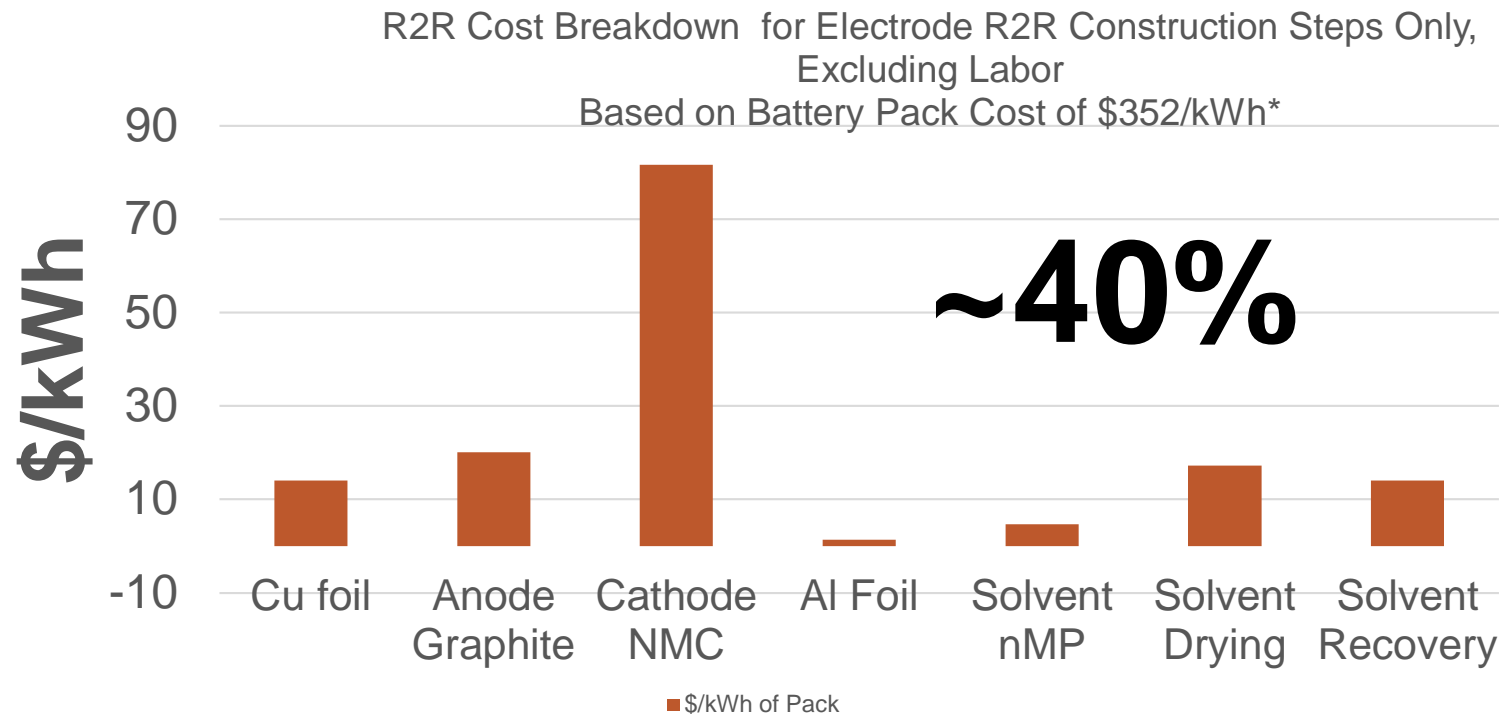
R2R Manufacturing Anode and Cathode Electrode



- Environment
 - Clean Room
 - Class 10000,
 - Class 1000
 - Dry room
 - < 10% RH
 - Expensive sq. footage

R2R Manufacturing Cost

Approximate R2R Electrode Processing Cost Contribution to a Battery Pack*



Journal of Power Sources, 275 (2015) 234-242
Prospects for reducing the processing
cost of lithium ion batteries
D. Wood, J. Li, C. Daniel

*Power Cells 52 Ah, 3.5 V

R2R Electrode Processing Cost Scrap Rate

- “inadequate flaw detection increases the average cost of LIBs to an unacceptable level because flawed electrode is unknowingly assembled into cells... State-of-the-art QC control may not be sufficient during electrode-manufacturing steps, and electrode scrap rates can be 10–20% during cell production”*

Materials Science and Technology Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37931-6083, USA
Energy and Transportation Science Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37931-6083, USA.
E-mail: mohanty@ornl.gov; wooddl@ornl.gov; Tel: +1 (865) 576 0813; +1 (865) 574-1157

* Anal. Methods, 2014, 6, 674.
Non-destructive evaluation of slot-die-coated lithium secondary battery electrodes by in-line laser caliper and IR thermography methods†
Debasish Mohanty, Jianlin Li, Rachael Born, L. Curt Maxey, Ralph B. Dinwiddie, Claus Daniel and David L. Wood, III

R2R Electrode Processing Cost

Poor Quality Testing Methodology

Off-Line Testing

- Viscosity
- Particle size analysis
- Coat weight
- Coating thickness
- Cross-web profile
- Coating Defects
- **Inefficient / costly**

Contributors to Cost

- Interrupts continuous process flow
- Increases waste
- Increases process time
- Introduces human error
- Substantial WIP at risk

R2R Electrode Processing Cost

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Promote on-line, real-time, non-contact quality testing

R2R Manufacturing

Raw Materials

R2R Start

Raw Materials

Slurry Mixing

Coating Drying Coating Drying

Calendering

Electrode Punching

To Pouch Building

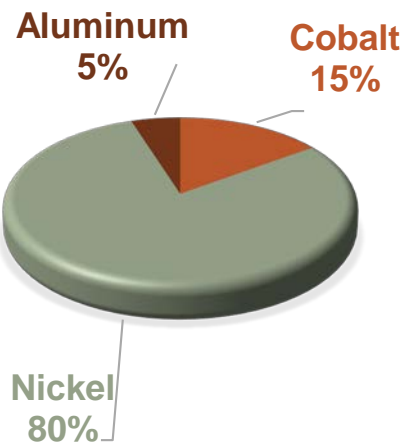
Typical Chemistry



- Anode – graphite
- Conductive agent – carbon black
- Binders
 - PVDF in solvent (nMP)
 - Water soluble (e.g. CMC, SBR)
- Others
- Cathode – Li oxide

Cathode Chemistries Vary

**TESLA
MODEL S**
NCA
LiNiCoAlO₂



**APPLE
IPHONE**
LCO
LiCoO₂

Cobalt
100%

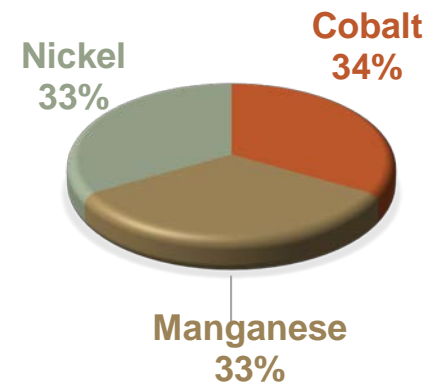


**NISSAN
LEAF**
LMO
LiMn₂O₂

Manganese
100%



**TESLA
POWERWALL**
NMC
LiNiMnCoO₂



Cathode Design Considerations

ENERGY DENSITY

VOLTAGE

SAFETY

COST

CYCLE LIFE

R2R Manufacturing Mixing

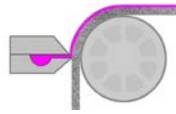
R2R Start



Raw Materials



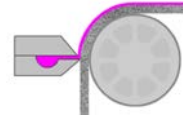
Slurry Mixing



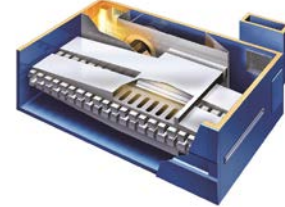
Coating



Drying

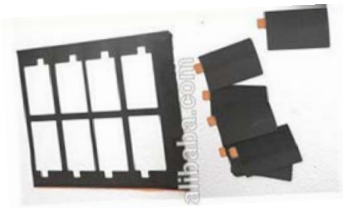


Coating



Drying

**To
Pouch
Building**



**Electrode
Punching**



Calendering

Typical Slurry Characteristics



Solvent
nMP
water

•Slurry

- 10-40K cps (@10/s)
- Very high P/B
- High % solids
- Well dispersed
- No agglomerates

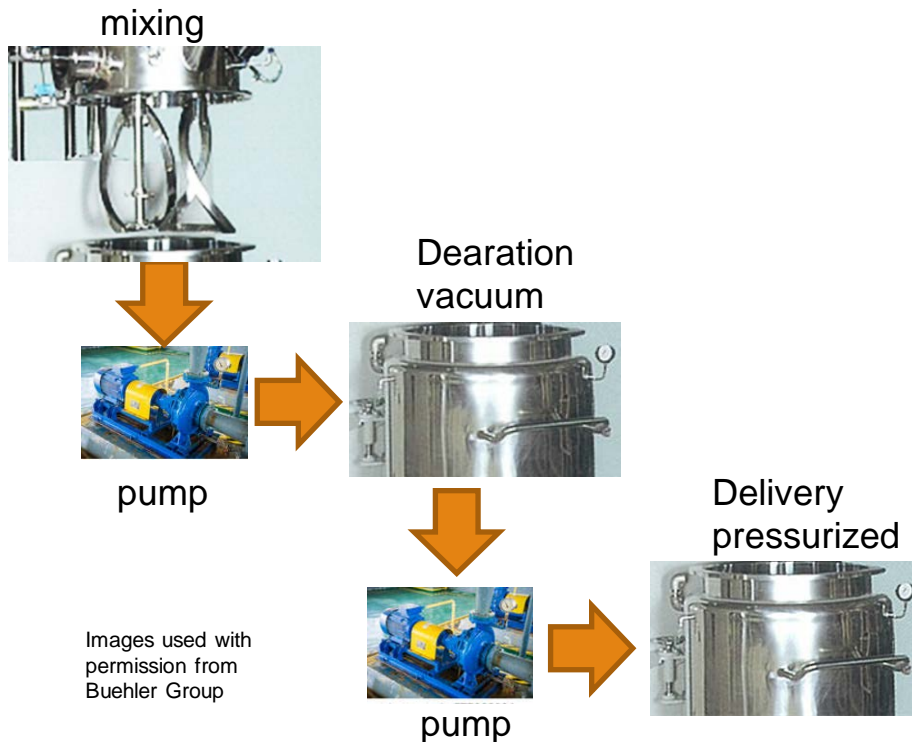
Cowles Blade Dispersing Technology



Image used with permission from Buehler Group

- Cowles blade dispersing
- Planetary blades bulk mixing
- Mixing 5-7 hours
- 3-Vessel configuration/pumps
 - Mixing
 - Deaeration
 - Delivery
- Significant material in process
- Mixing mechanism above tank
 - Contamination/cleaning issues

Cowles Blade Dispersing Technology



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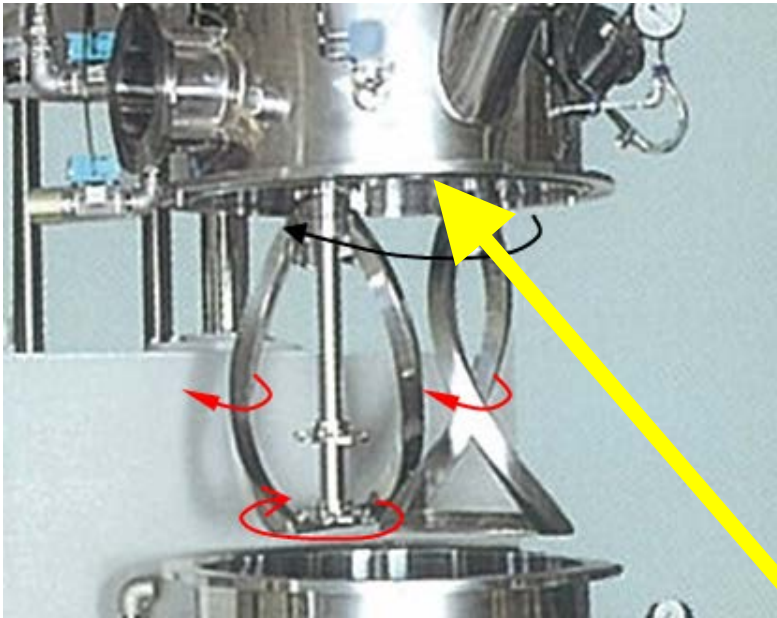


Image used with permission from Buehler Group

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