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Changing the economics of energy storage

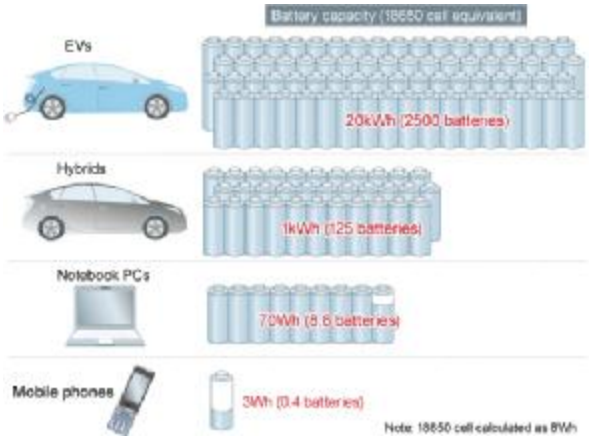
Opportunities & Challenges – Energy Storage

February 2011

The National Academies Workshop
Phoenix, AZ

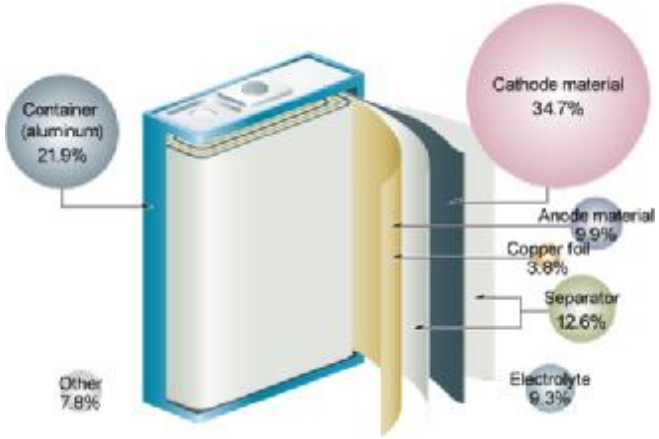
Battery Industry is Stuck

Volumes are Substantial



8300 cell phone batteries

Nano-Materials Costs Are Substantial



68% cell is engineered materials

- NiMH, Pb, Li ion are mature
- Industry Requires dramatic
  1. Materials leverage
  2. Cost reductions
  3. Energy densities
  4. Lifetime & Safety
  5. Form Factor Flexibility
  6. Environmental Friendliness

•Scaling “is” the challenge

http://www.altenergystocks.com/archives/2010/01/storm_warnings_for_lithiumion_batteries_and_electric_vehicles.html
http://www.altenergystocks.com/archives/2009/06/understanding_the_development_path_for_liion_battery_technologies_1.html

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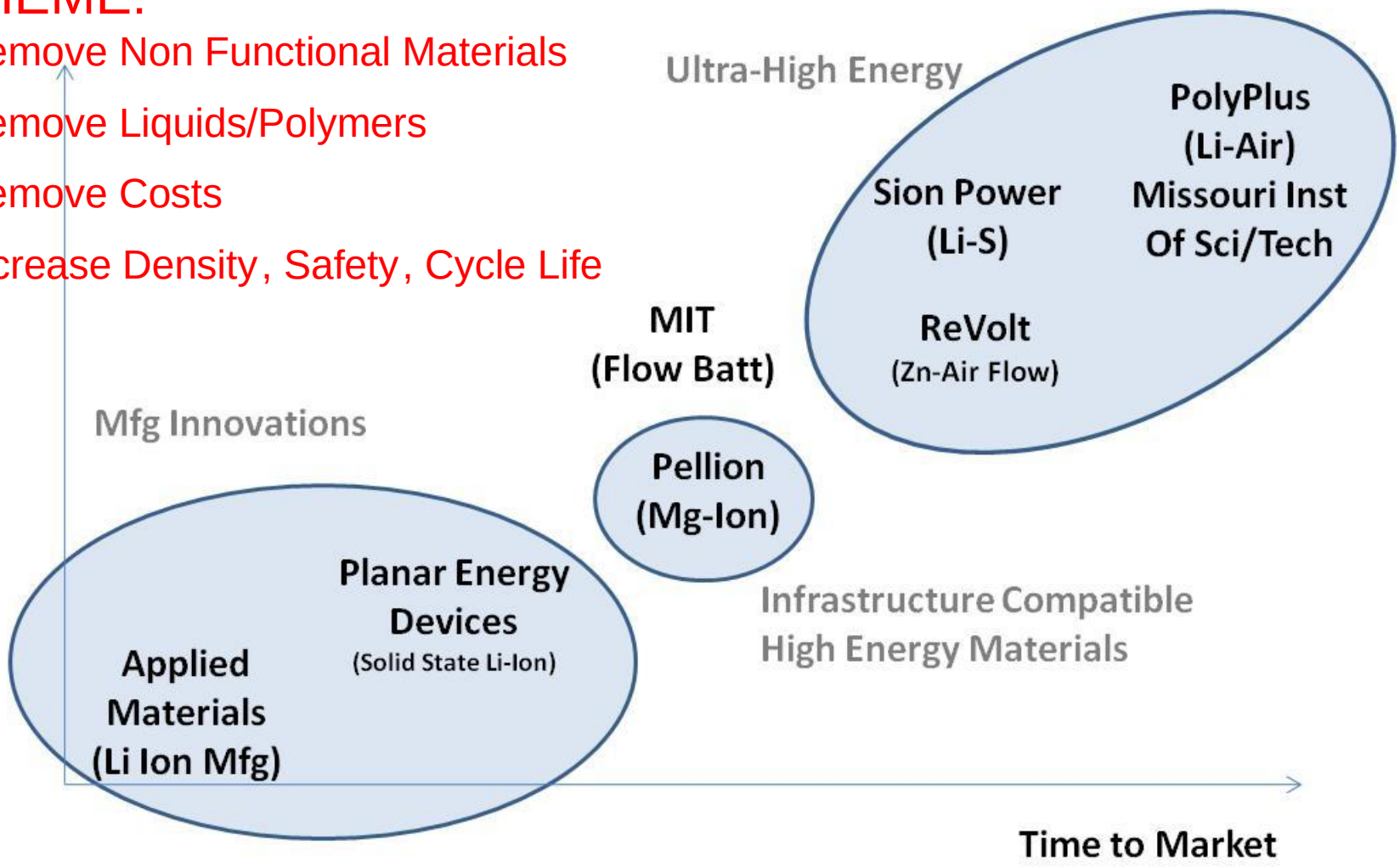
ARPA-e Portfolio of Fixes

THEME:

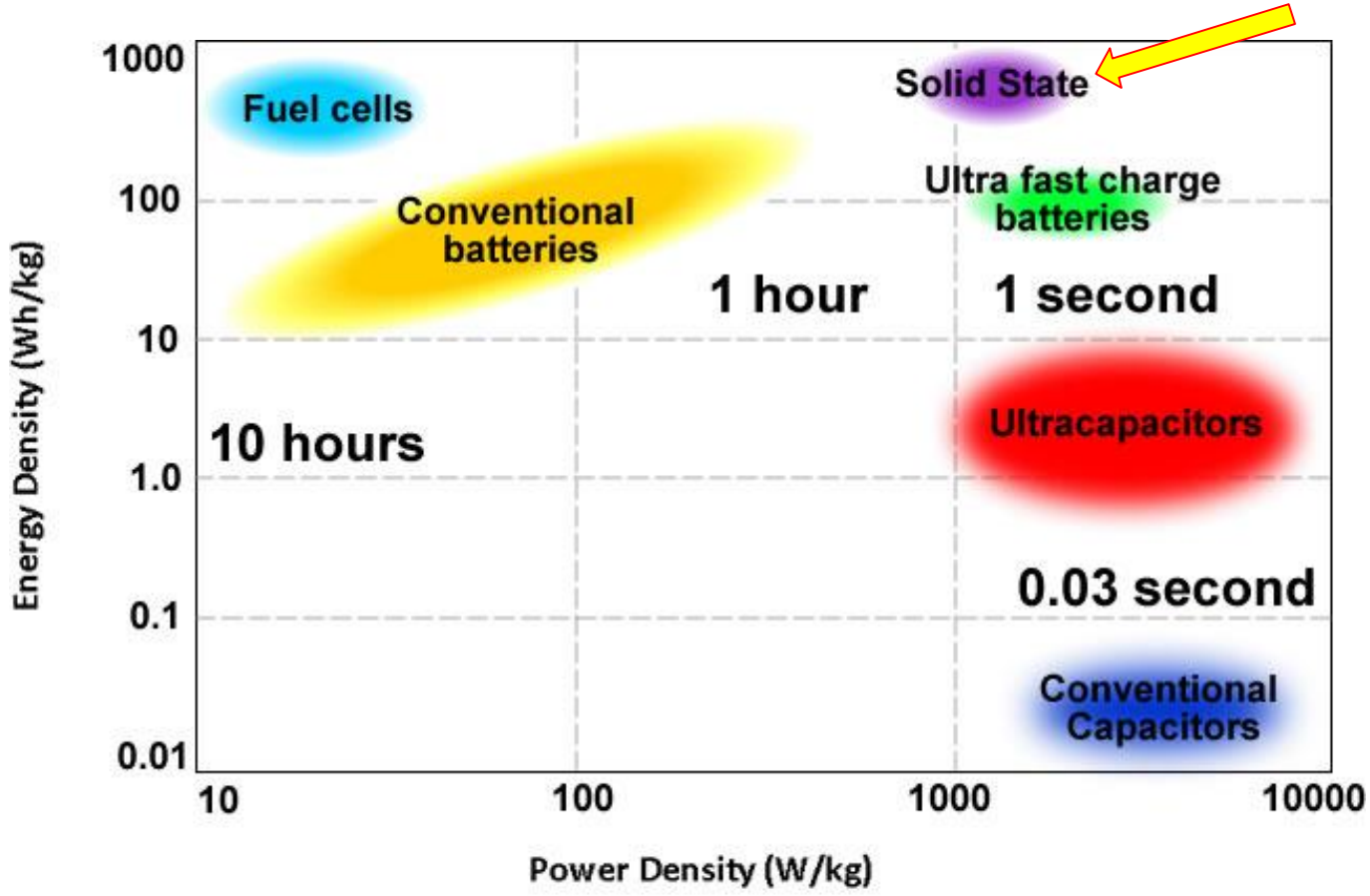
- Remove Non Functional Materials
- Remove Liquids/Polymers
- Remove Costs
- Increase Density, Safety, Cycle Life






Why Solid State for Batteries?

Paradigm Changer



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Why Solid State Batteries ?

Comparison of Battery Performances

Battery Type	Weight Specific Energy (Wh/kg)	Volume Energy Density (Wh/1)	Speed Specific Power (W/kg)	Cycle Life
Nickel Cadmium	40	100	400	400
Nickel Metal Hydride	90	245	180	600
Lithium ion (liquid electrolyte)	155	410	300	500
Lithium Polymer	180	380	360	500
Thin Film Li-ion	250	1,041	2,500	1,000
Solid State	300	959	6,000	40,000

Source: WinterGreen Research, Inc.

Ceramic Battery Difference:

Replace the plastics, binders, powders and liquids with durable, nanostructured films

Operating Benefits:

- Long operating lives at optimal performance
- Elimination of shorts and battery failures
- 50%+ reduction in cell weight & volume
- Fast recharge cycles
- Higher operating temperature ranges reduces thermal management challenges
- No liquids eliminates “thermal runaway”

Enabling new products & applications

- Battery/Capacitor hybrids

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A New Approach to Energy Storage

Game Changing Platform Technology

Solid State Energy/
Monolithic Ceramic Batteries

→ **Embedded Power Source**

Superior Economics

50% Reduction in Capex Per KwH
65% Reduction in Materials Cost

→ **Lower Cost Batteries**

Superior Performance

2-3 X Energy Density Increase
Long Life (5,000 cycles)
Fast Charge & Disharge (5C)

→ **Longer "Lifecycle" Runtime**
New Feature Sets

Absolute Safety

Nothing flammable
High Temperature Range

→ **Consumer Proof**

Scalable Manufacturing Approach

Roll to Roll Manufacturing
Eliminate "Formation" of Cells
No Vacuum

→ **New Levels of Integration**

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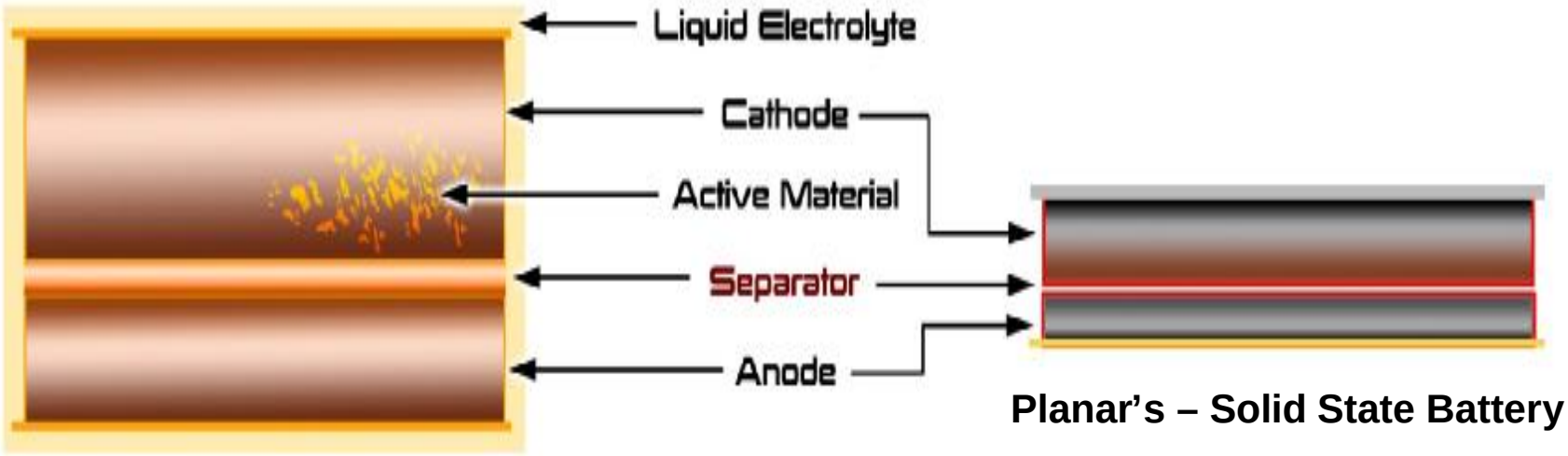
Solid State Architecture



Planar's – Solid State Battery

Traditional Li-ion Battery

- Dramatic Reductions in Materials (50%)
- Higher Performance Materials (1000X)
- No Liquids (No Fires)
- Monolithic Cell Architecture (R2R Mfg.)

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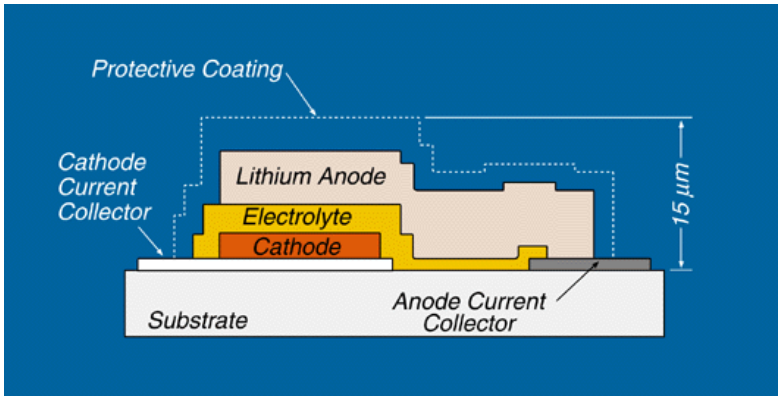
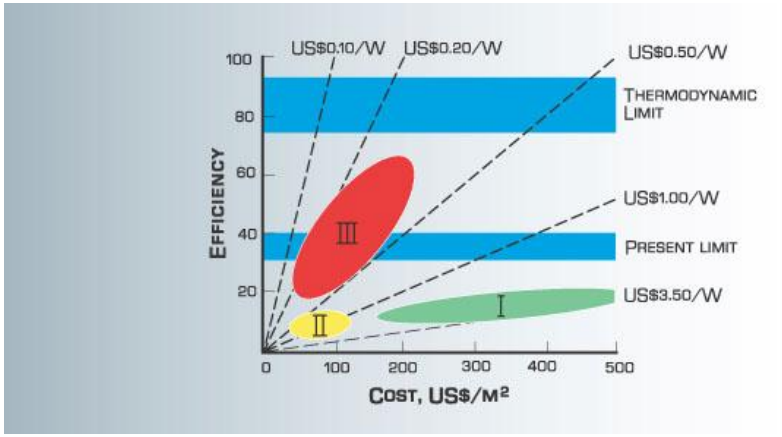
Solid State Micro-Batteries Don't Scale



Thin Films Have Limited Storage Capacity & Rates



Traditional Deposition Approaches are Expensive

- .5mAh/cm vs 20mAh/cm
- Lipon is poor conductor
  - 1-2 Orders of Magnitude Too Low
- Limited Cathode opportunities
- $100's+ Sq M for Thin Film
  - Needs to be $1's
- Slow Deposition Rates
  - Thin Film tough, Thick Film non-starter
- Complex Mfg. Processes & Device Designs/Packaging

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Practical Challenge of Solid State Batteries

13mm x 13mm
4 micron film

?

300mm x 100mm
75 micron Active Film

Current solid state battery fabrication methods do not scale to large format batteries because of:

Vacuum Deposition Cost of Thick, Large Area Films

$25,000 Sq. M
Vs
$1's Sq. M

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Planar Breakthrough: High Performance Printed Electronic Films & Devices

Streaming Process for Electroless Electrochemical Deposition "SPEED"

- **Solution Based Process Enabling Roll to Roll**
- **Cap Ex: 10% Cost of Vacuum - 1000x Faster than Vacuum**
- **Materials: $1's/kilo vs. $100's/Kilo**
- **Unlimited Materials Sets**

Cost of Printed Electronics with Performance of Vacuum Deposited Films

Enables new, flexible manufacturing model for large area Semiconductor devices.

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Nanomaterial Growth Innovation

Other Methods

Primary chemicals

↓

Nano-particles formation

↓

Slurry or ink formulation

↓

Web coating or ink printing of nano-particle film

SPEED

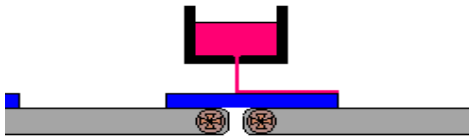
Primary chemicals

↓

Water based solution formulation

↓

Direct nano-particle film deposition



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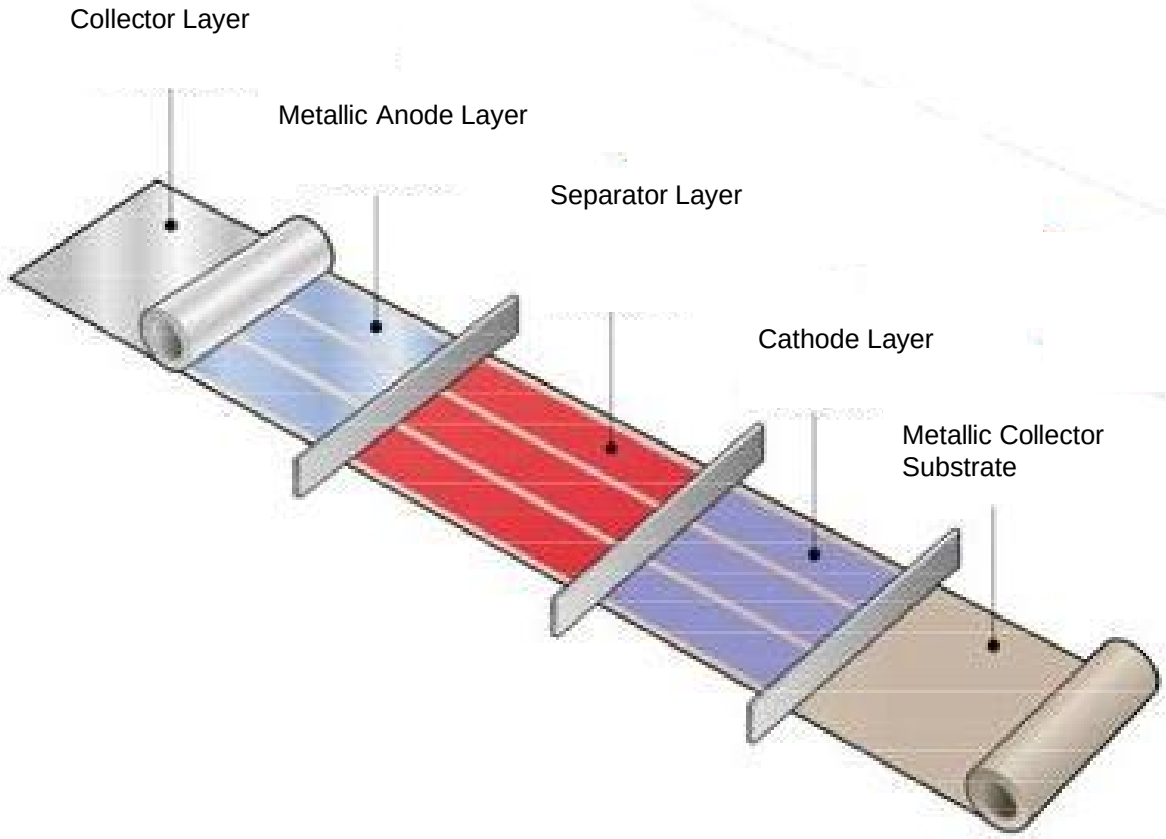
New Approach to Battery Manufacturing



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SPEED R2R Battery Manufacturing

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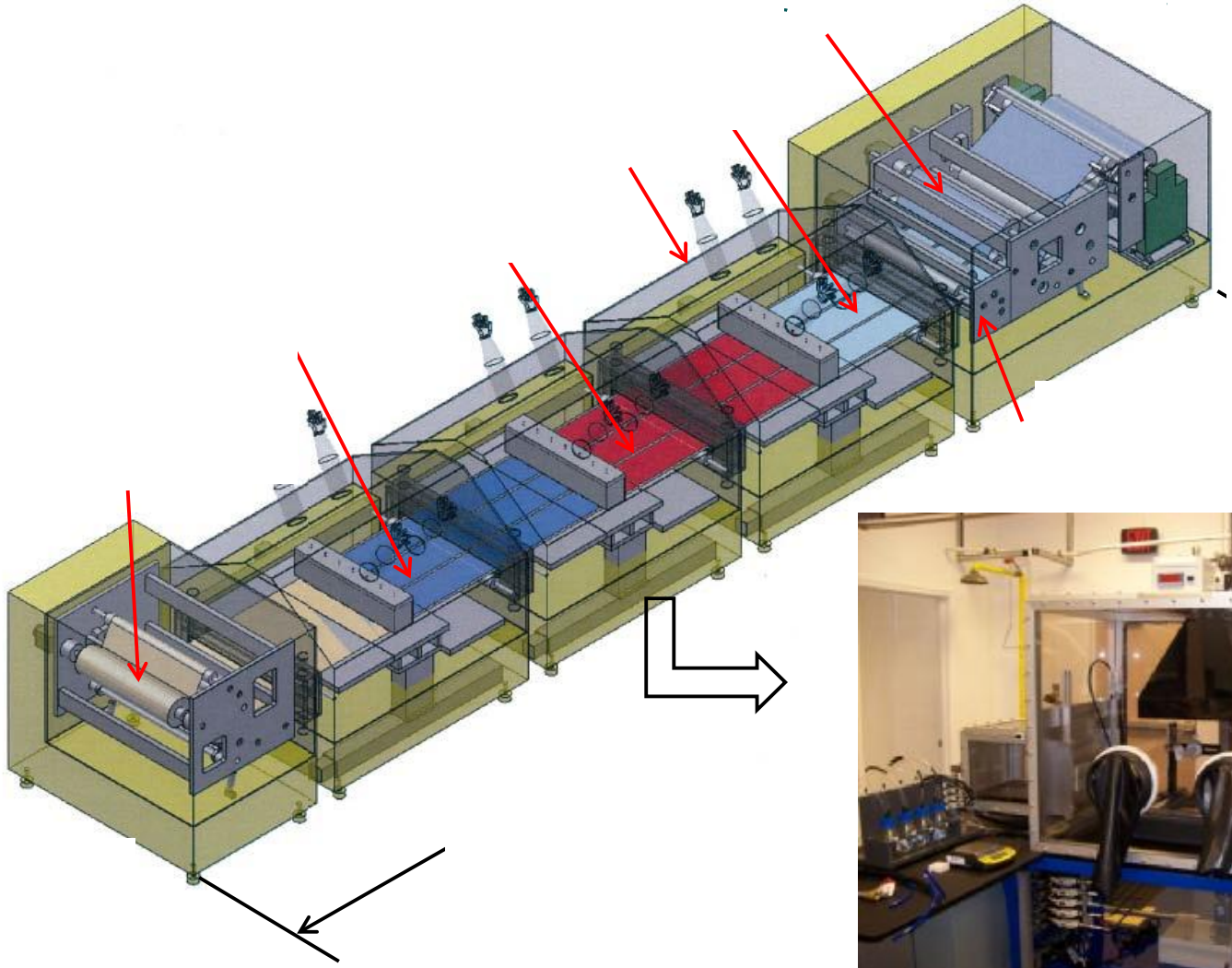
Real Hardware Demonstrated



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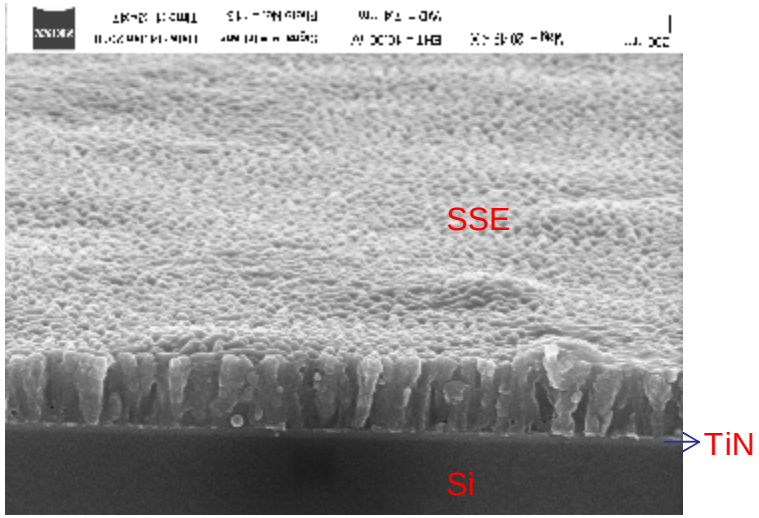
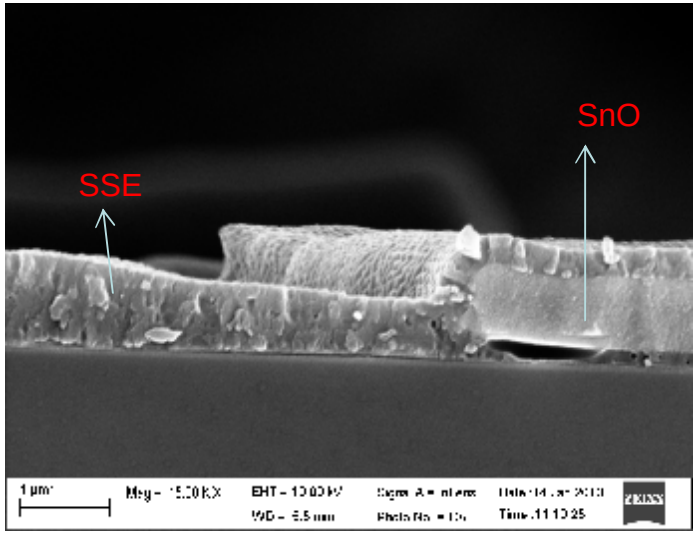
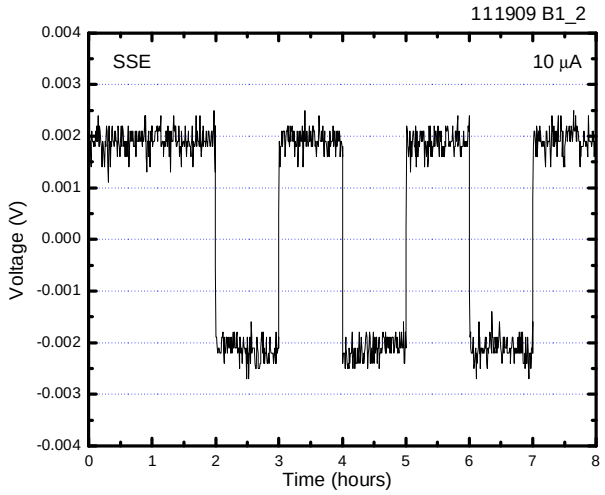
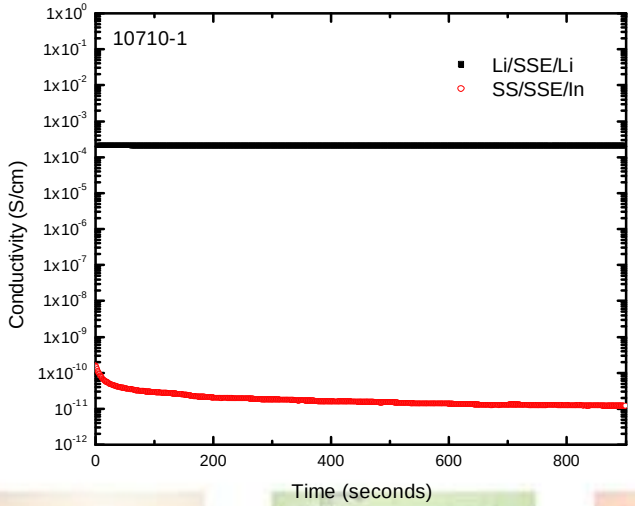
Real Materials: Solid State Electrolyte ThioLisicon









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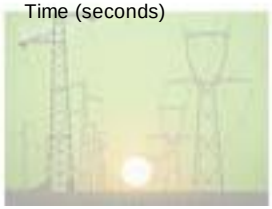
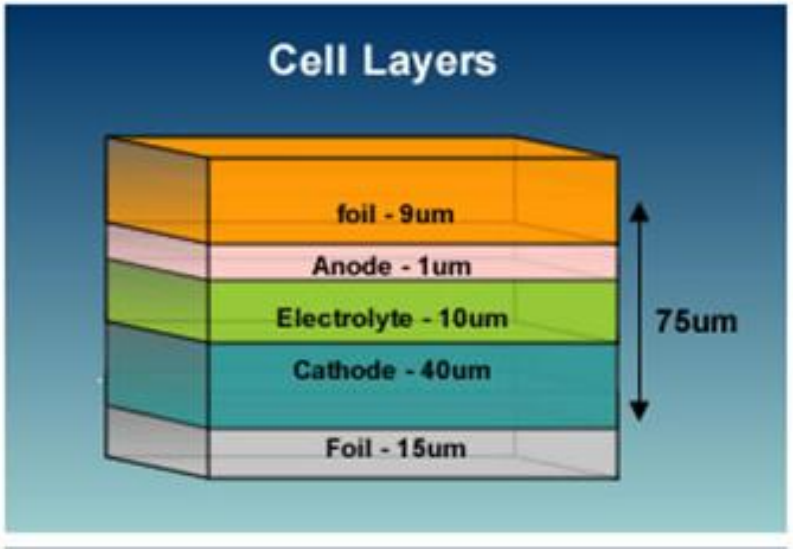


Real Ceramic Batteries Demonstrated



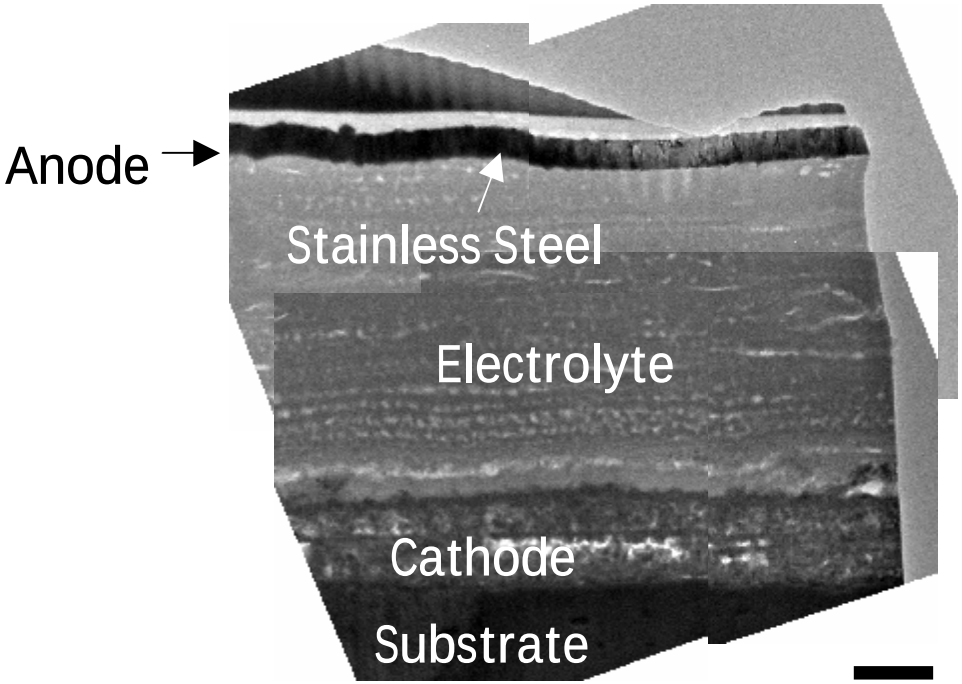


Fig 1 – Cell “Core” Design

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“Macro” Opportunities & Challenges

Long Development Cycles
- Materials Science
- Device Acceptance
- Market Acceptance

Complex Development Cycles
- Process
- Materials
- Device

Fragmented Innovation Network
- Pieces of puzzle spread far and wide
- Need to Agglomerate Technology

Cap Ex Intense Business Models
- Proof vs. Scale

Effective Strategic Partnerships
- University vs. Company
- Small vs. Big Company

FINDING VALUE ADD CAPITAL
- Research $’s
- Early stage vs. growth $’s

Fragmented Industry Structure
- Lack of Roadmaps
  - Process, Materials, Apps
- Global Playing Field
- Open Innovation vs. Proprietary IP

National Security Ethics
- Domestic vs. Foreign Partnerships

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“Execution” Opportunities & Challenges

New Hardware Development

- Complex Materials thru Complex Machines
  vs.
  Complex Materials thru Simple Chemistry & Simple Machines

Mfg. Metrology Challenges

- New Materials require new types of measurements
- R2R requires speed & precision from tools that are precise and slow

Materials Integration Challenges

- Modeling Tools & Expertise

Human Capital

- Electrochemists
- Manufacturing
- Immigration Constraints

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Thank You

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