


SolidPower

ULTRA HIGH ENERGY, SAFE & LOW-COST SOLID-STATE BATTERIES

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Solid Power History and Opportunity

- Initial research on ultra high energy, safe and low cost all solid-state batteries performed at CU-Boulder under funding from DARPA
- Company established in 2012; company operations initiated in 2013; worldwide exclusive license & company facility established in early 2014
- Solid Power is a long-term play to displace Li-ion:

"Solid-State Batteries Will Offer the Highest Technical Value for Consumer Electronics Within 15 Years"*

*Source: Lux Research, "Beyond Li-Ion: A Roadmap for Next-Generation Batteries," 2013

WHY SOLID-STATE?

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Conventional Li-ion can be safe, but safety is expensive

- Non-flammable
- 5V+ stable voltage window
- High temperature stability
- Long calendar life
- Could enable Li metal anode
  - High specific capacity and discharge rate capability
  - Could eliminate the need for copper current collector
- Could enable new cathode materials or enhance conventional materials
- Allows for more packaging options (bipolar designs, unpackaged cells, etc.)

AJ Gill/YouTube

Solid-State Battery Types

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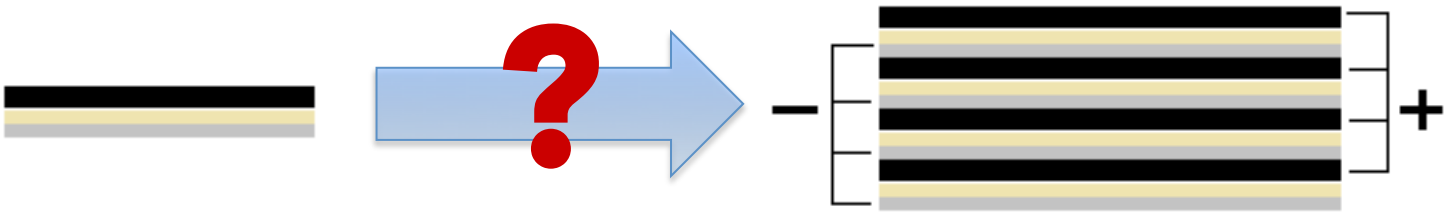
Thin Film Batteries

- Several mAh or less
- Typically based on lithium phosphorus oxynitride (LiPON)
- Processing methods include magnetron sputtering, chemical vapor deposition (CVD), pulsed laser deposition (PLD), thermal evaporation, and various printing methods
- Ideal for microbatteries: sensors, smart cards, embedded electronics, medical devices, and RFID applications



High stack-level energy

But how do you scale?

Solid-State Battery Types

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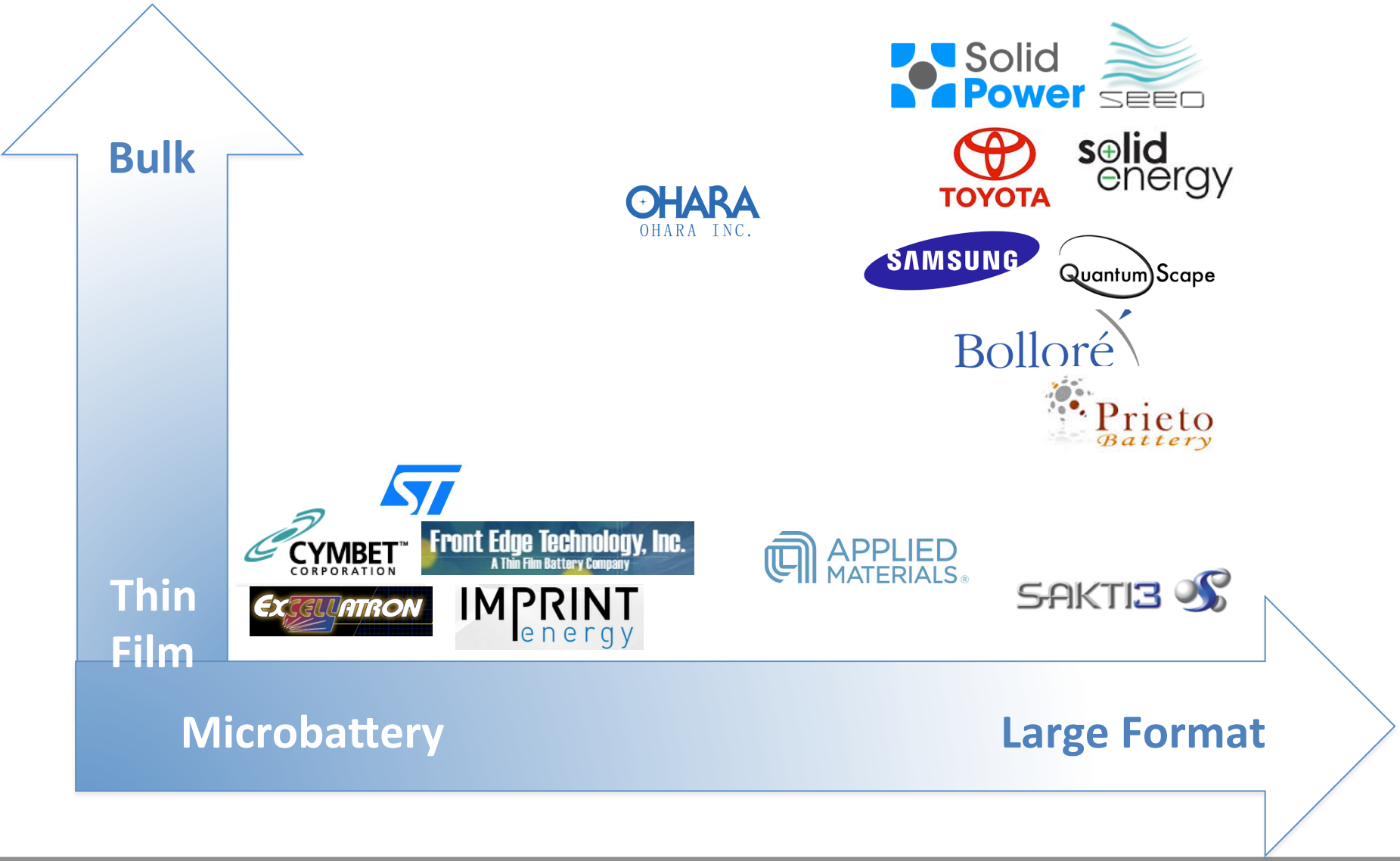
Bulk Solid-State Batteries

- Higher areal cathode capacity loadings (mAh/cm^2) and current densities (mA/cm^2)
- Electrolyte/separator materials include poly(ethylene oxide) (PEO), glassy or ceramic Li-P-S, oxides and phosphates with garnet, perovskite, or NaSICON structures
- Materials produced as powders or melts and processed using extrusion, compaction or tape casting combined with sintering, or various coating techniques

More scalable, but high current densities and non-ideal material layers pose issues

Solid-State Battery Companies

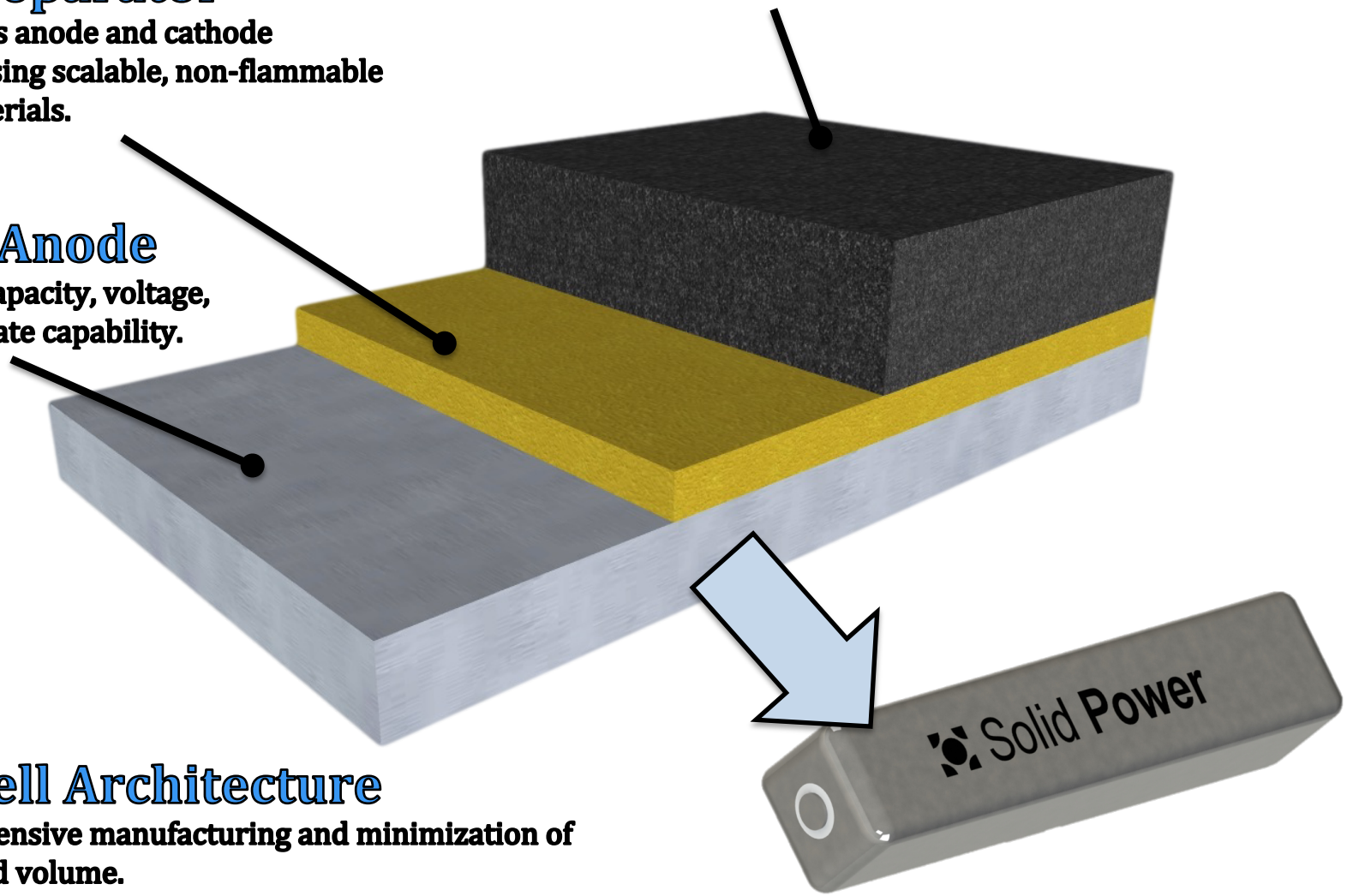


Solid Power Technology

High Capacity Cathode
Delivers up to 700 mAh/g with low impedance and long cycle life.

Robust Separator
Thin layer offers anode and cathode compatibility using scalable, non-flammable electrolyte materials.

Li Metal Anode
Provides high capacity, voltage, and discharge rate capability.



Simple Cell Architecture
Allows for inexpensive manufacturing and minimization of passive mass and volume.

Cell-Level Performance Projections

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Parameter	SOTA Li-Ion	Solid Power
Energy (Wh/kg)	150-260 → 2-3X Improvement →	**400-500**
Energy (Wh/L)	400-600 → 1-1.5X Improvement →	**500-800**
Power (W/kg)	100-2000	>300 (temp. dependent)
Cycles	>500	>500
Safety	Acceptable w/ Features	**Excellent**
Shelf Life	2-8 years	**10+ years**
Temp. Operation	-20-60°C	0-150°C

VALUE FOR MILITARY POWER

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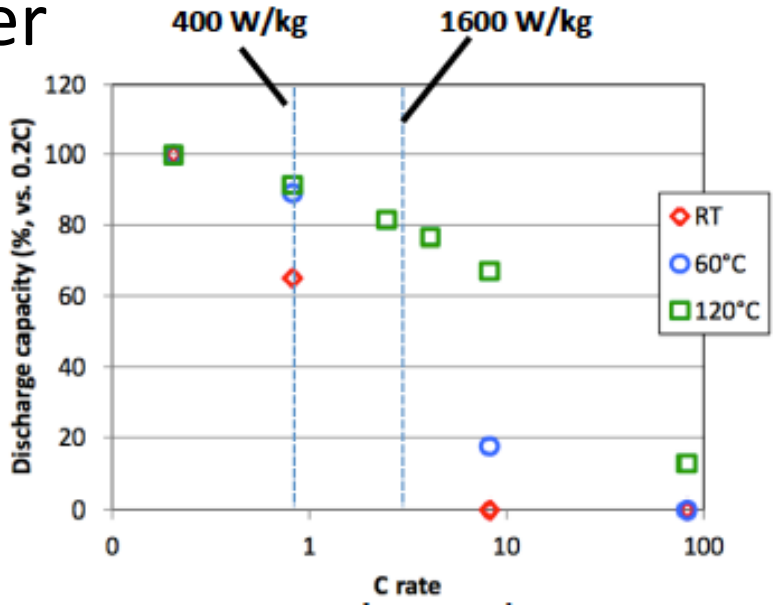
Unmatched combination of specific energy, cycle life, power and safety

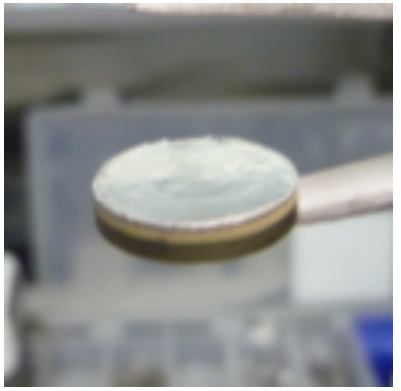
- Near-term cell-level specific energy >300 Wh/kg with mid-term potential >500 Wh/kg
- High rate capability for a high energy battery
- >90% capacity retention after 500 cylces
- Excellent safety features:
  - No volatile electrolyte
  - Stable at high temps
  - Oxygen-less system



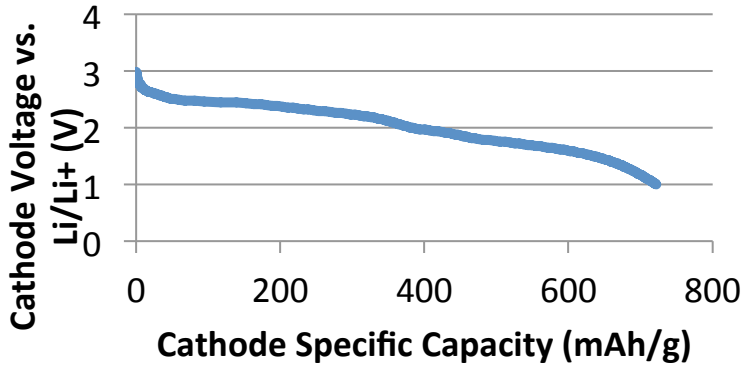
Early Lab-Scale Cell Demonstrations

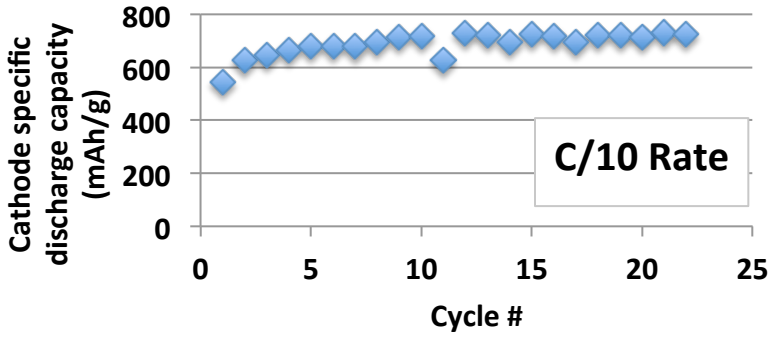
- Early cell-level demonstrations performed using small, thick single stack pellets
- Excellent material-level performance but in an impractical configuration

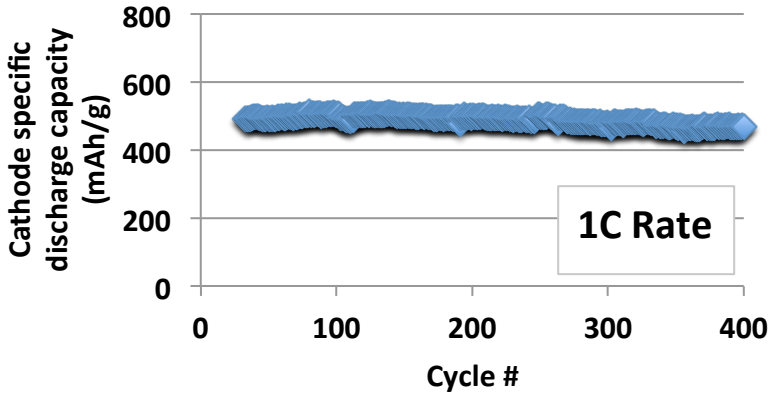
Early "Pelletized" Cell



- *Single-stack 1.27 cm diameter cell, InLi anode*
- *Capacities based on <u>total cathode mass</u>*
- *Tested at 60°C*







Recent Developments: Cell Processing

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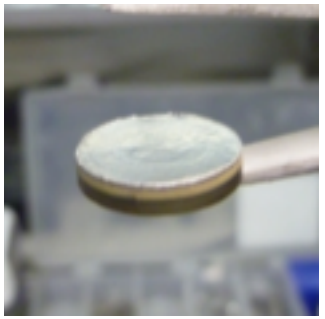
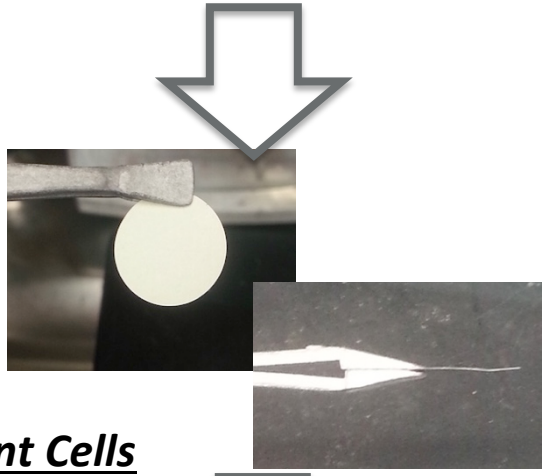
- Cathode and separator materials optimized for processing ease, mechanical robustness, and high conductivity
- Process allows for tunablity of material properties while maintaining scalability
- Enables truly high energy, "bulk" solid-state cells

Legacy Cells Produced From "Pelletized" Layers

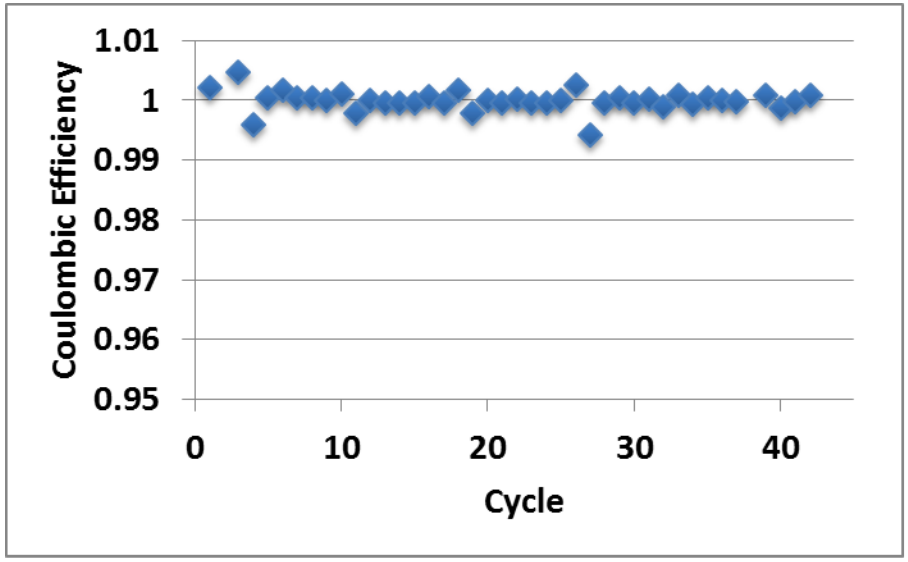


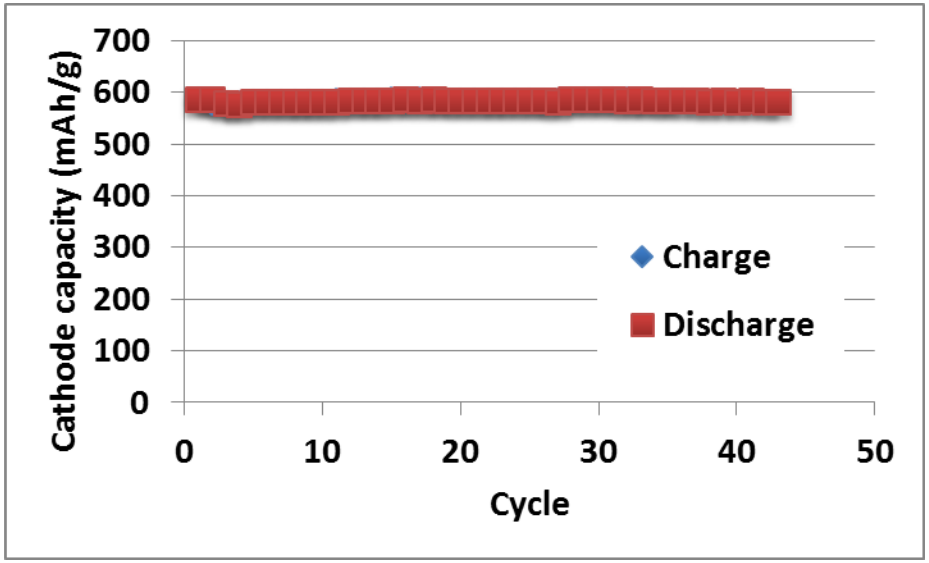


Recent Cells Produced from Thin, Coated Layers

Cycling with Li Metal Anode

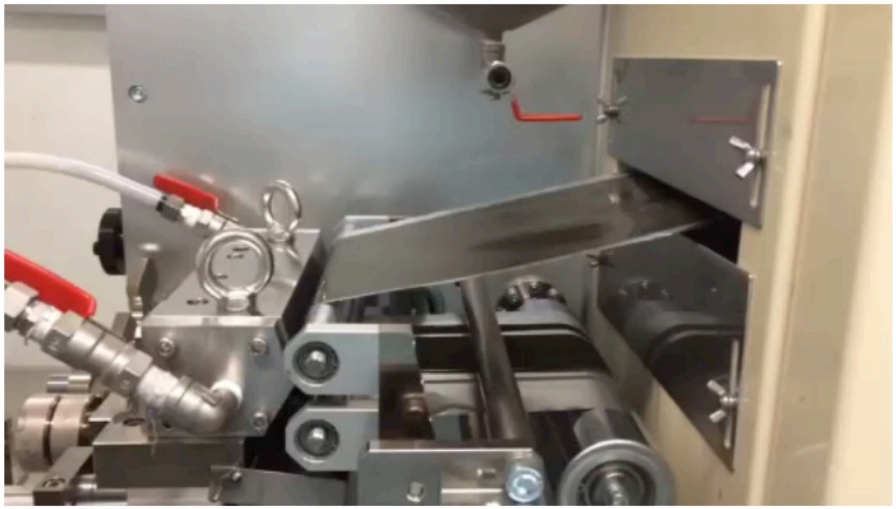
- Li metal anode, separator and cathode contain all scalable materials
- Tested at 60°C with C/10 rate; ~40 days of data collection
- Capacities based on total cathode layer mass
- ***High coulombic efficiency, stable capacity, and no resistance rise***

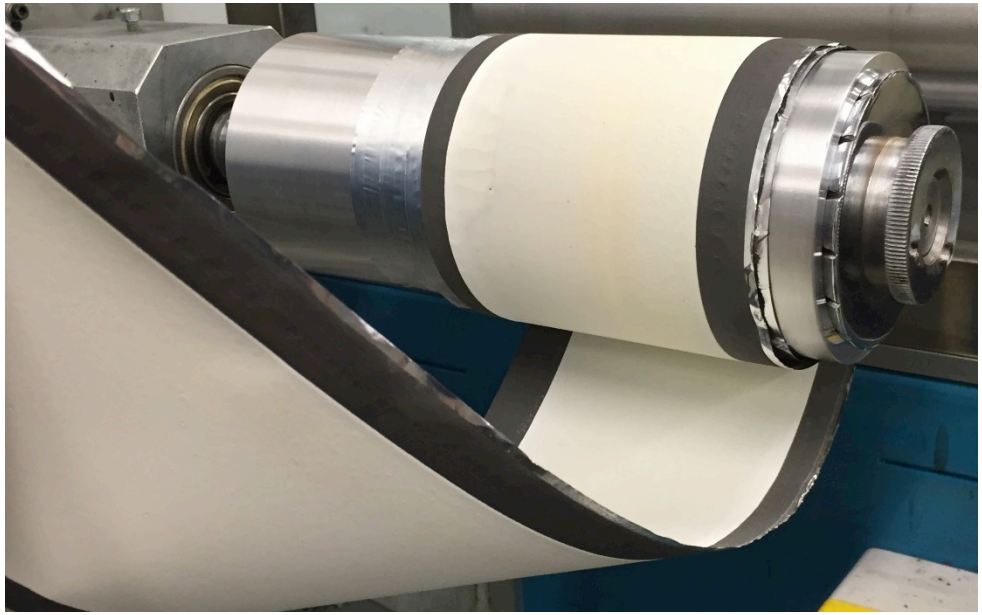




Cell Scale-Up

- Metal foil current collector coated on both both sides with cathode & separator
- High throughput roll-to-roll processes





Commercialization Strategy

1. Establish Solid Power as a U.S.-based supplier of high value energy storage systems for the military, aerospace and niche industrial markets
2. Engage the broader rechargeable battery market (high volume) via engaging strategic industry partners via licenses, joint ventures or partial acquisitions

Market Engagement

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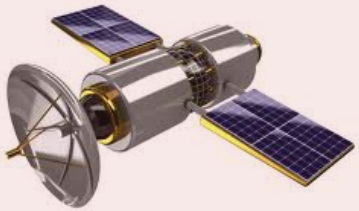

Strategic Partner


Technology & Product Development Timeline

Current Partners

- Research:
  - Technology development and qualification
  - IP portfolio expansion
- Product development:
  - Full-scale prototype devices for the military and aerospace markets
- Market Validation:
  - Formal Joint Development Agreements (JDA) with industry partners in oil & gas and aircraft markets
  - Numerous Material Transfer Agreements (MTA) w/ auto OEMs and suppliers for cell validation testing

KEY ONGOING INITIATIVES

- ARPA-E RANGE Program: ultra high energy rechargeable batteries for EV's
- U.S. Air Force: ICBM Liquid reserve battery replacements
- MDA: Thermal battery replacements
- U.S. Army: High energy batteries for smart munitions
- NASA: High energy, safe rechargeable batteries for manned spacecraft
- AFRL: Long-life rechargeable batteries for military spacecraft