Safe, High-Energy-Density, Solid-State Li-Batteries

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Overcoming the performance limitations to enable a new generation of safe, high-energy-density, solid-state Li-batteries
Surface modification overcame interfacial impedance.

Novel 3D architecture supports thin, dense central separator layer with low ASR that blocks Li dendrites.

Porous outer layers infiltrated with electrodes provide large electrolyte/electrode interfacial area, and pore filling mechanism removes external cell dimensional changes upon cycling.
Team

Eric D. Wachsman, Director, Maryland Energy Innovation Institute
President-Elect, The Electrochemical Society
Founder & Executive Chair, Ion Storage Systems
30 yrs experience solid ion conducting materials, electrochemistry, and ceramics

Liangbing Hu, Director, Center for Materials Innovation
Advanced materials processing, R&D 100 Award

Ricky Hanna, CEO, former Executive Director Battery Operations, Apple

Greg Hitz, Founder & CTO Solid-state battery pioneer

Charles Lewinsohn, VP Ceramic Technology
20 yrs industrial ceramic manufacturing experience

Liz Santori, Director Cell Development Battery R&D in industry and federal labs

Venkataraman Thangadurai, Professor Chemistry
Founder & Science Advisor, Ion Storage Systems
25 yrs experience solid ion conducting ceramics - inventor of garnet electrolytes
Project Objectives

Advancing technology to pouch and prismatic cells
Developing repeatable processes and QC procedures
Scaling manufacturing for initial deliveries in Q1 2021 and beyond…

Optimizing cell microstructure and reducing cathode/garnet impedance to further increase cell energy & power density

Advancing garnet chemistry and interface stability

Currently advancing pouch cell fabrication and performance toward delivery of 3 Wh Conformable Wearable Battery (CWB) prototypes to Army Automotive and consumer electronic prototypes to follow…
Results - High Rate Li-Metal Cycling

Adapted from:

Status and challenges in enabling the lithium metal electrode for high-energy and low-cost rechargeable batteries

Achieved IONICS and DOE VTO Fast-Charge goals for current density

Achieved area specific resistance far below conventional batteries
High Voltage Spinel Cathode

~99% Coulombic efficiency and no capacity fade for 480 cycles

Li-metal/garnet structure provides transformative battery solution for wide range of cathode chemistries with high efficiency & stable cycle life

Li-NMC Battery

~300 Wh/kg and ~99% Coulombic efficiency with no capacity fade for 30 cycles

Li-S Battery

~300 Wh/kg and ~99% Coulombic efficiency with no capacity fade for 300 cycles
Results - High Temperature Capability and Safety

Wide operating temperature range with low activation energy
- Energy Density based on Total Cell Mass
- Significant increase in energy density with increasing temperature
- 280Wh/kg-total cell achieved at 25°C
- 350Wh/kg-total cell achieved at 90°C
- Dramatically reduces cost, complexity, mass & volume requirements of current battery technology

Even higher temperature capability demonstrated with certain cathode chemistries

Safe operation even after cutting open and exposing to air
Challenges, Risks and Potential Partnerships

Tape casting is a highly scaleable, low-cost, conventional ceramic fabrication technique without dry room.

Challenge is scaling from coin cells to reproducible, flat, full format garnets with desired microstructure, QC, and yield.

This microstructure is a platform to reduce the risk of solid-state Li-metal batteries. We welcome the opportunity to partner with companies that have advanced cathode and Li metal deposition solutions, as well as pack/system and end user partnerships.
Moving from university incubator to 20,000 ft\(^2\) facility this month enabling 10 MWh/yr production

Initial prototypes available Q1 2021 for customer/partner evaluation

First product in defense market (CWB) due to lower volume and higher margin

Moving to higher volume markets as we scale production volume
Summary

Developed unique 3D architecture and surface modification to enable high-rate (10 mA/cm$^2$) Li-metal cycling at RT with non-flammable solid-electrolyte

Demonstrated high energy density (~300 Wh/kg) cells with multiple cathode chemistries

Wide operating temperature range reduces/removes need for thermal controls

Scaled size from coin to pouch cells
Scaling manufacturing to 10 MWh/yr production
Prototype cells available Q1 2021