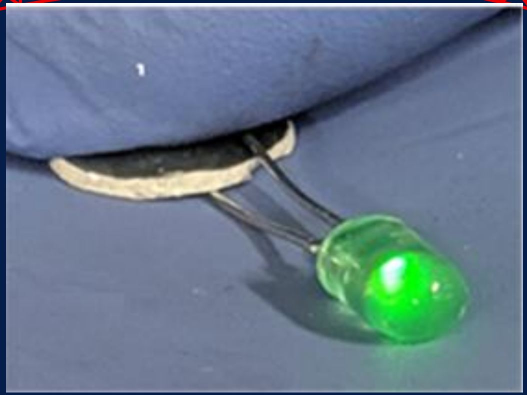

Solid-State Li-ion Battery for High-Safety and Longevity

Dr. Jitendra Kumar,

Team Leader & Dist. Battery Scientist, UDRI

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University of Dayton Research Institute

Ninth Triennial Conference / FAA Fire Safety (10/30/2019)

What we need from battery?

More energy?
More Power?
More cycle-life?
More safety?
Faster charge?
Lower Cost?

Outline

- Introduction: UDRI, Battery R&D, battery team
- Li-ion: Liquid vs solid electrolytes
- Advantages of solid electrolyte over liq. electrolyte
- UDRI’s solution to improve safety of commercial LIB
- UDRI’s R&D: primary, secondary all solid state battery
- Summary
- Acknowledgement

UDRI Overview

- Established in 1956
- Perform basic & applied research, and provide engineering services
- Fully supported by external customers and research sponsors
- Integral part of the University; reinforces UD's mission

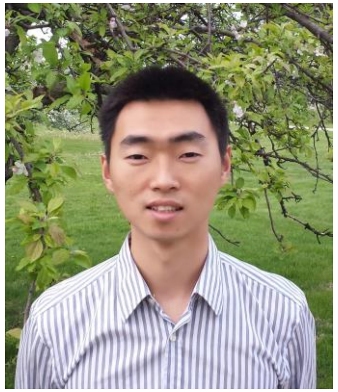
University of Dayton Research Institute (UDRI)

- 60+ years of specialization in research, development, application and transition of technology
- Largest university materials engineering research effort in the US
- Second largest engineering research program in Ohio
- Focus areas
  - Materials
  - Energy
  - Intelligence
  - Propulsion
  - Sustainment
  - Structures
  - Sensors
  - Systems Engineering
  - Manufacturing

Solid state battery R&D at UDRI

- Synthesis / Solid State Electrolytes
- Interface study
- Cell fabrication & tests (electrochemical & safety)
- Chemistries: Li-ion, Li batteries
- Applications: electronics, oil & gas exploration, defense, aero space and space exploration.

UDRI Energy Storage Research Team



Yuxing Wang, Ph.D.
Research Scientist

- Solid-State Electrolyte synthesis
- Structure-property relation: experimental, computer simulation
- Solid-State Batteries
- Implantable MicroBatteries

Badri Shyam, Ph.D.
Research Scientist

- Thin-film fabrication
- X-ray and morphological characterizations
- Battery fabrication/testing
- Fuel cell characterizations

Luis Estevez, Ph.D.
Research Scientist

- Specialty carbon
- Si-C anode
- Capacitors
- High-temperature batteries

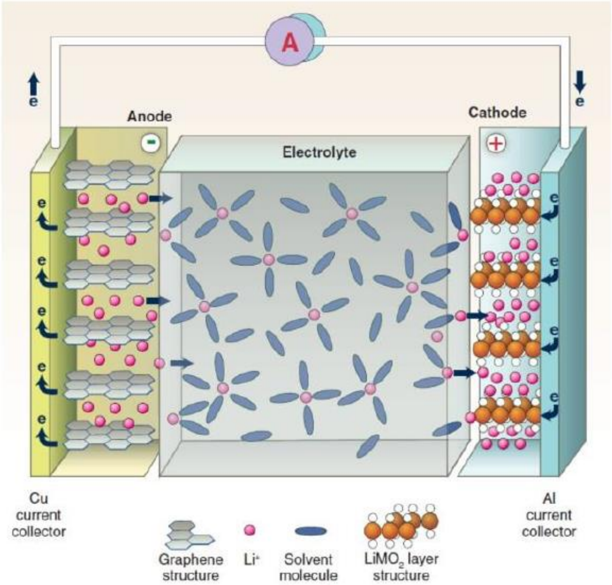
Mr. Nick Vallo (Ph.D. Student)
Dendrite sensing, Wireless BMS; LIBs safety

Mr. Ashish Gogia (Ph.D. Student)
Solid electrolyte development and Thin film Li-ion battery

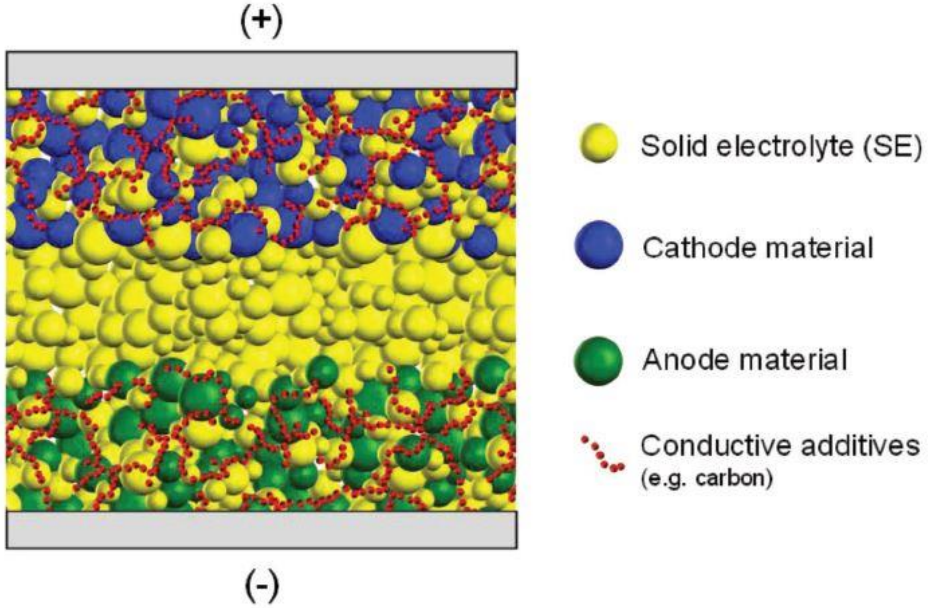
Mr. Liu Tongjie (M.S. Student)
Next generation battery: Solid state Li-S batteries

Mr. Kum Lenin Wung (Ph.D. Student)
Solid electrolyte coated electrodes (LIB)
Battery-renewable integration and performance evaluation

Li ion batteries: Liquid vs. solid state batteries



Liquid electrolyte: $LiPF_6$ in organic carbonate electrolyte

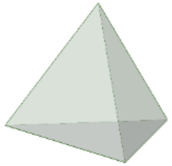


Solid electrolyte: sulfides or oxides or phosphates

Advantage of solid state batteries

Power/Energy density

Safety



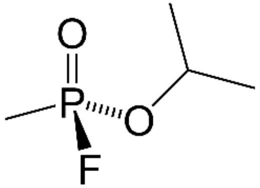
Cost

Cycle life

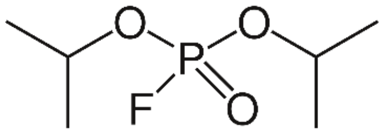
Better thermal stability

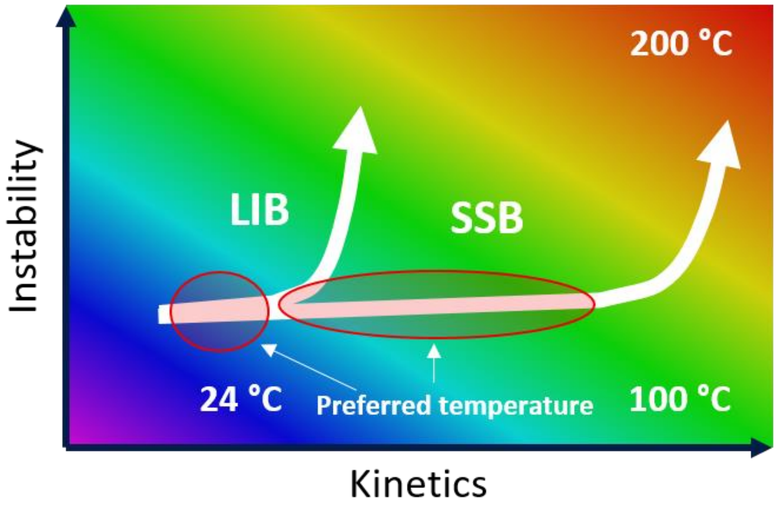
Bad things happen to LIBs at > 60 °C

Sarin gas

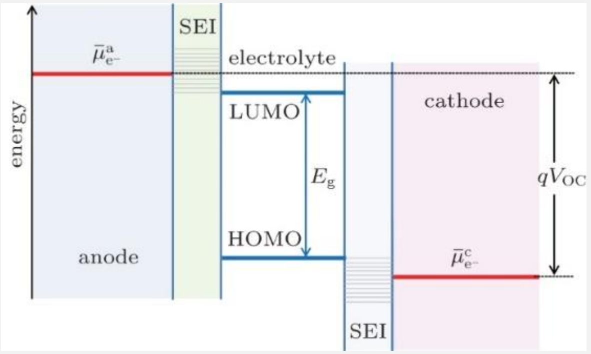


Decomposition product of liquid electrolyte



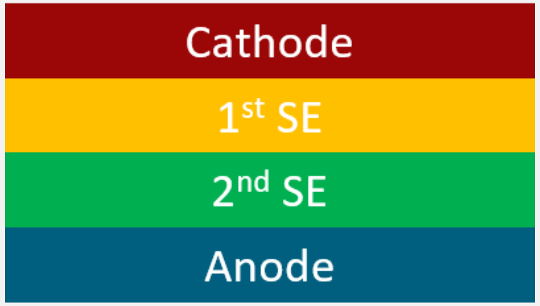


Dimensional stability



Liquid electrolyte: one material

Solid electrolyte: two materials



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Polymer separator vs ceramic coated separator

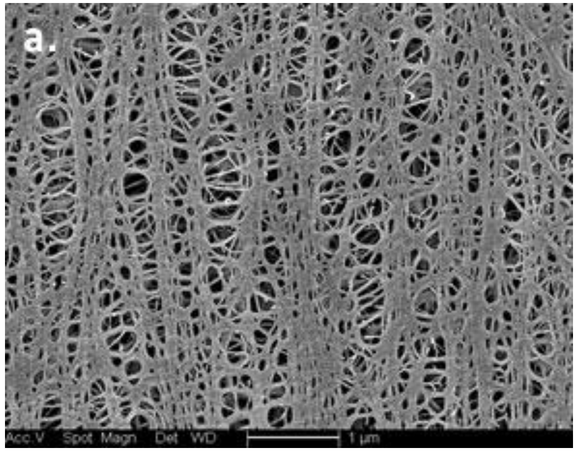
Current bottleneck:

- Polymer separators: low thermal stability, susceptible to dendrite
- Ceramic electrolytes (LiSICON/Garnet): Low mechanical strength /brittle

UDRI's approach:

- Blend property of polymer separator with ceramic electrolyte
- Funded by FAA

Thin-film ceramic (20-500 nm) on SOA separator and morphology change



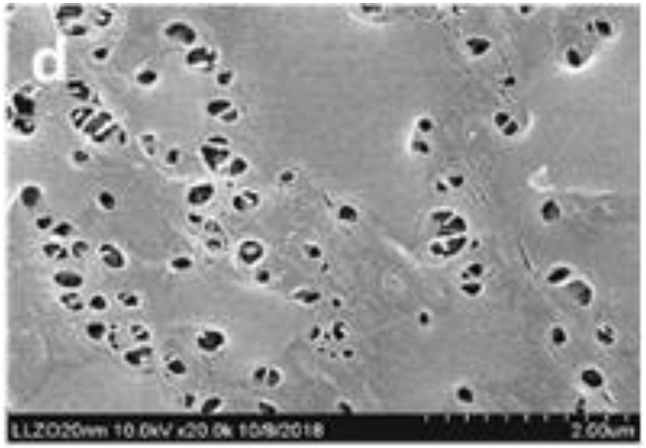
Entek pristine

Garnet / LAGP

EB-PVD

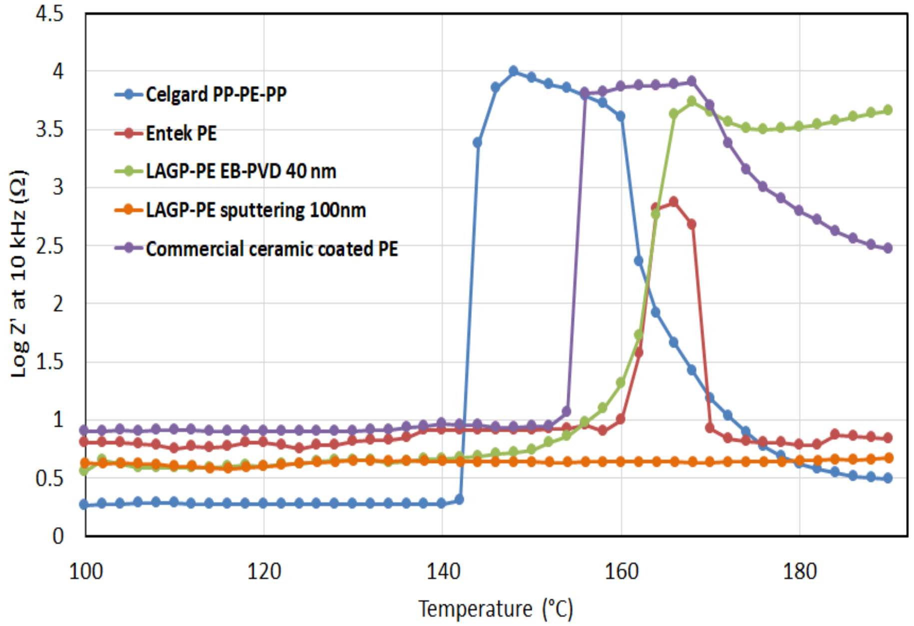
Sputtering

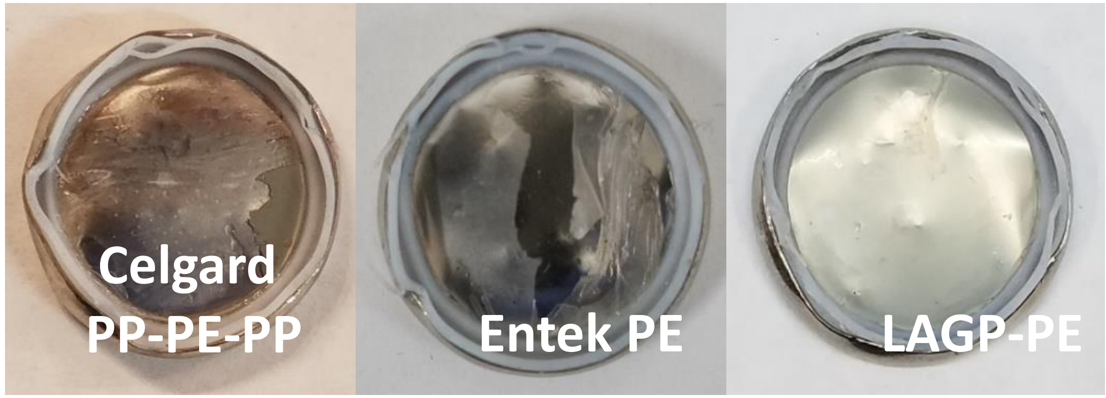
PLD



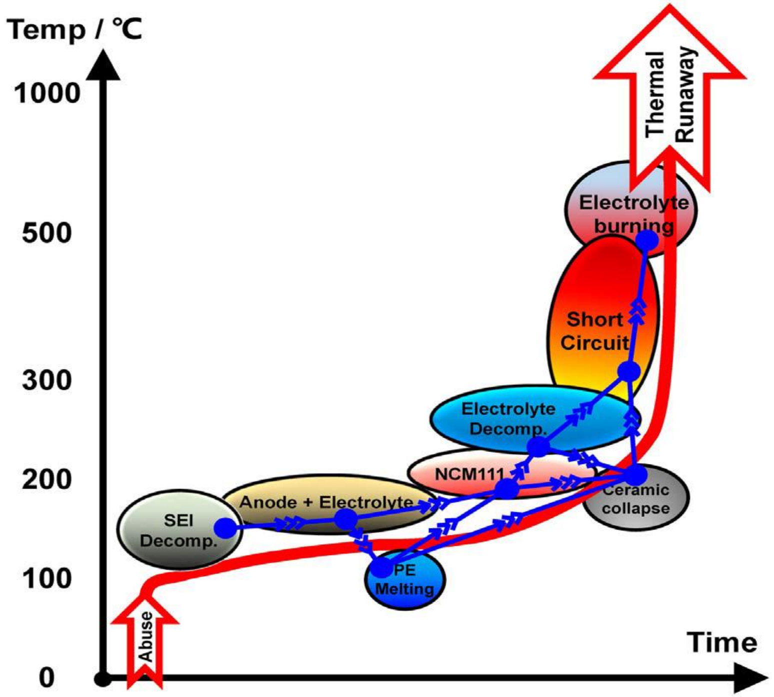
Garnet (100 nm) / Entek

Ceramic coating and thermal stability/battery safety





- Shutdown: increase resistance and cease battery operation
- Breakdown: allow electrical shorting and eventual thermal runaway



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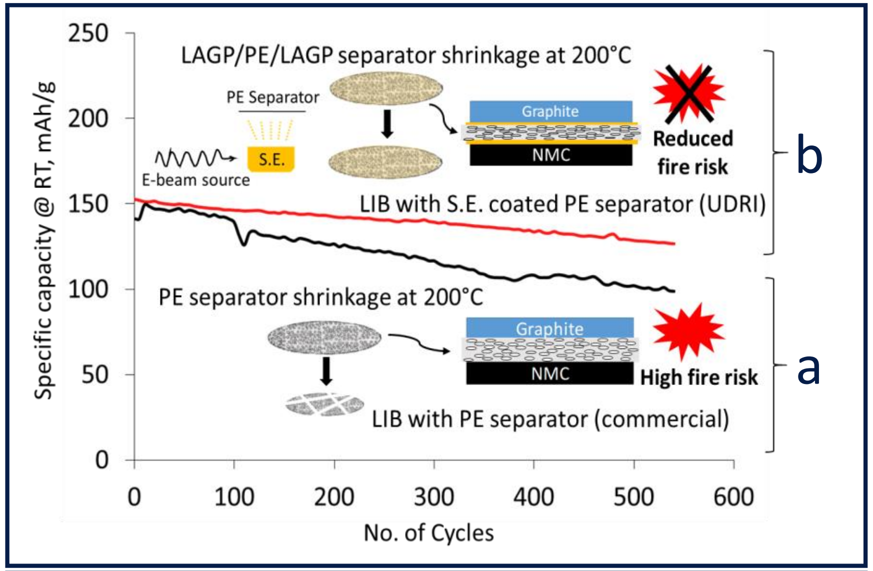
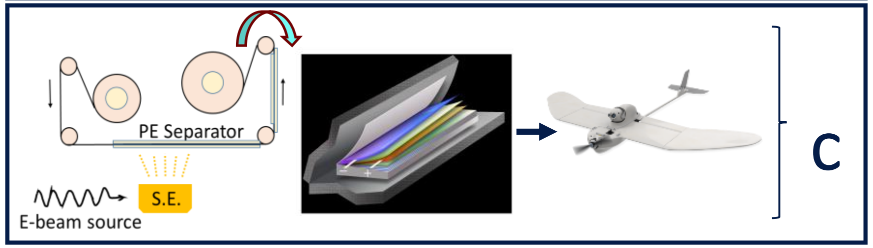
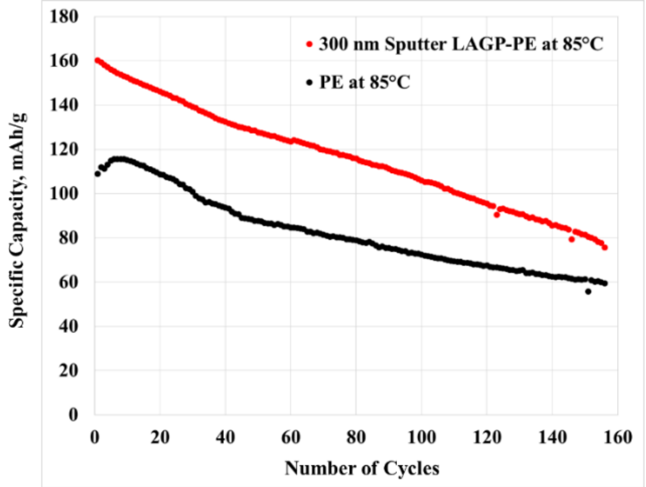
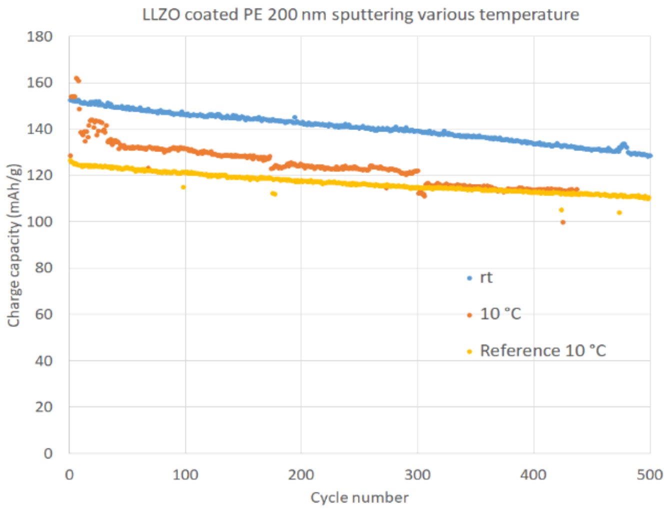
Ceramic coating and electrochemical performances





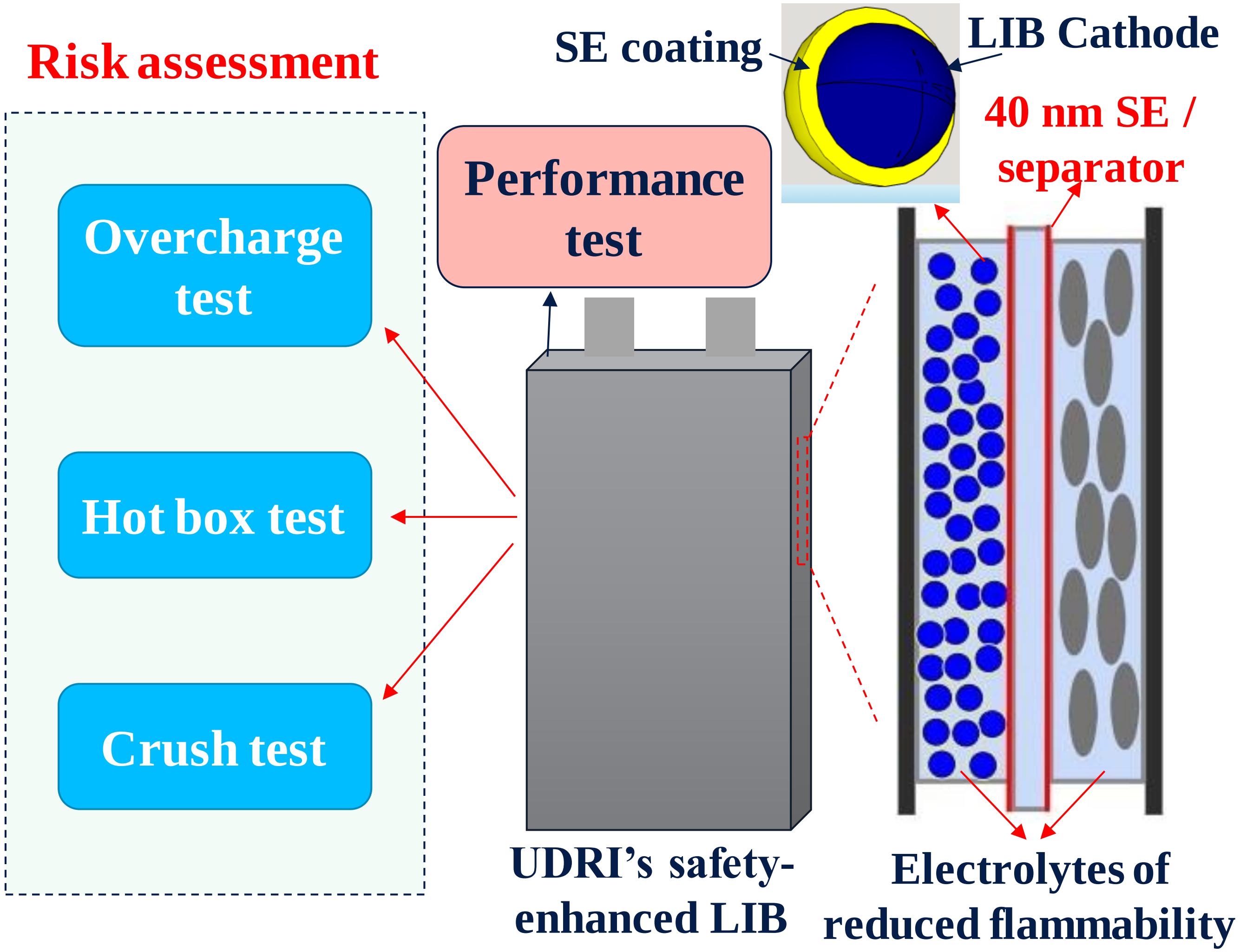




Need: customized electrolyte & electrodes too to achieve full potential of ceramic coated separator!!!

UDRI's proprietary.

UDRI’s overall effort to improve LIB (Liq. based) safety



UDRI’s proprietary.

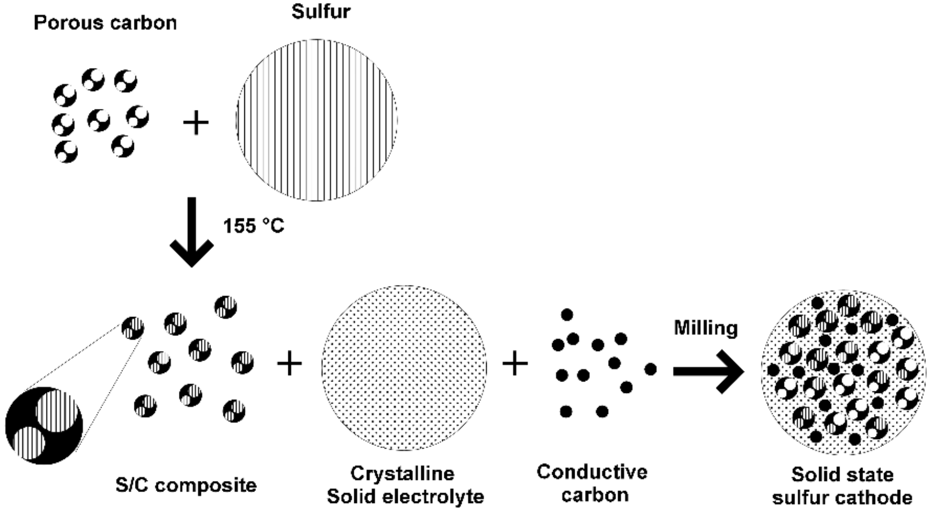
All-solid-state lithium sulfur primary battery (ASLSB)

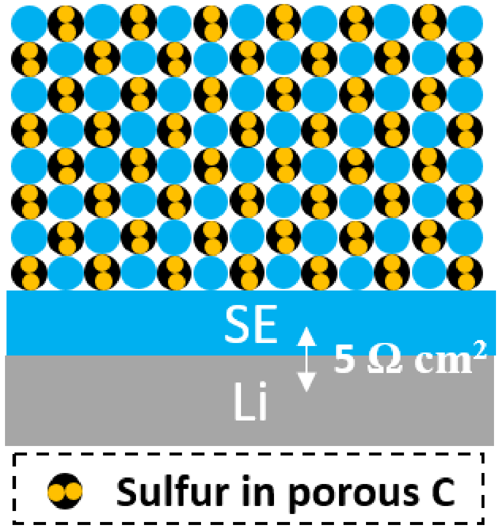
Why all-solid-state Li-S

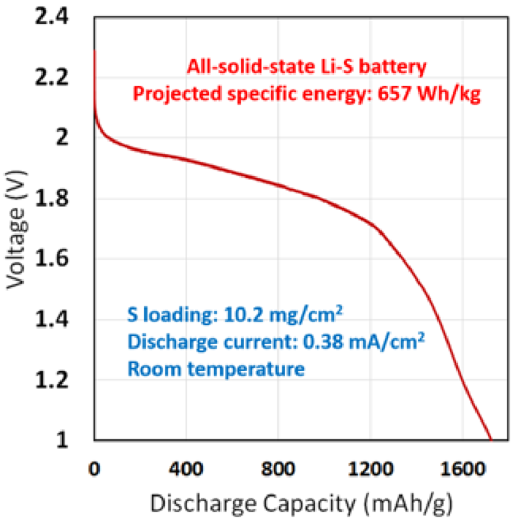
- SOA Lithium primary battery cathode: CF_x, 2.5 V, 865 mAh/g
- All-solid state-Li-S battery: 1.8 V, 1600 mAh/g

Challenge of sulfur as active material

- Low electronic conductivity, slow Li ion transport







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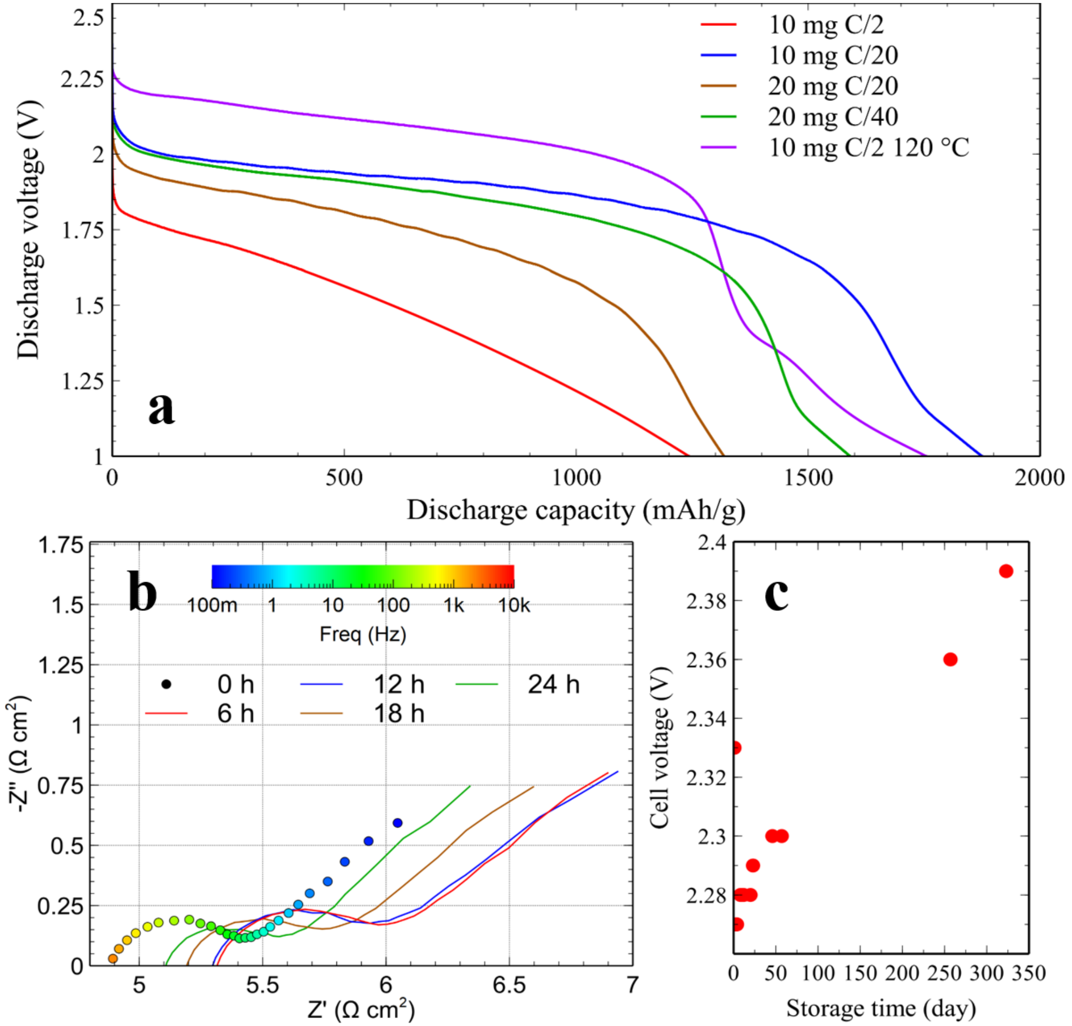
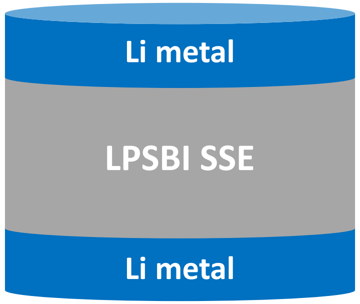
ASLSB performance



- ❑ Rate performance
- ❑ Loading effect
- ❑ Operation at 120 °C
- ❑ Impedance at 120 °C for 24 h
- ❑ OCV over a year

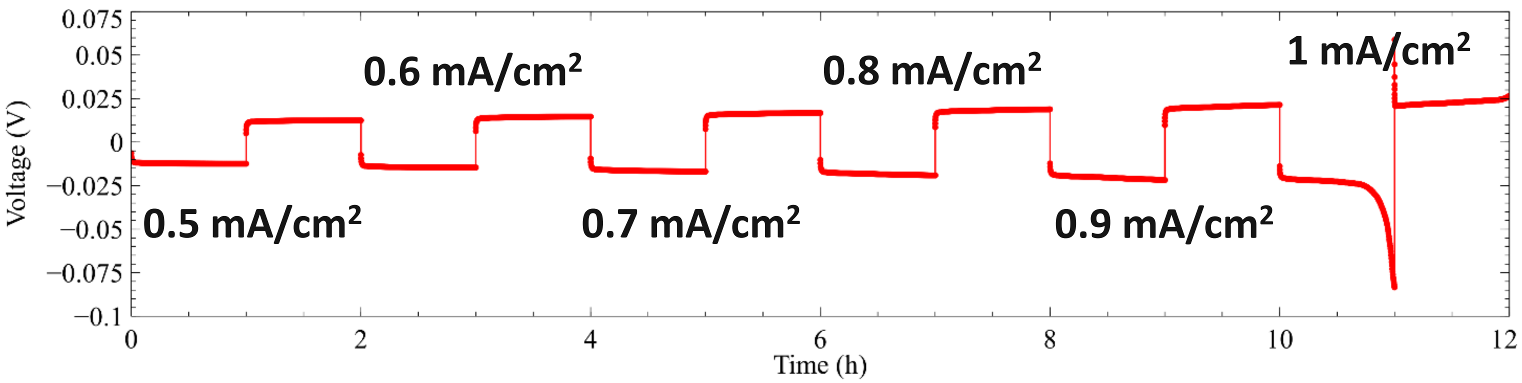
UDRI's proprietary.

All-solid-state rechargeable Li metal



LPSBI sulfide solid electrolyte

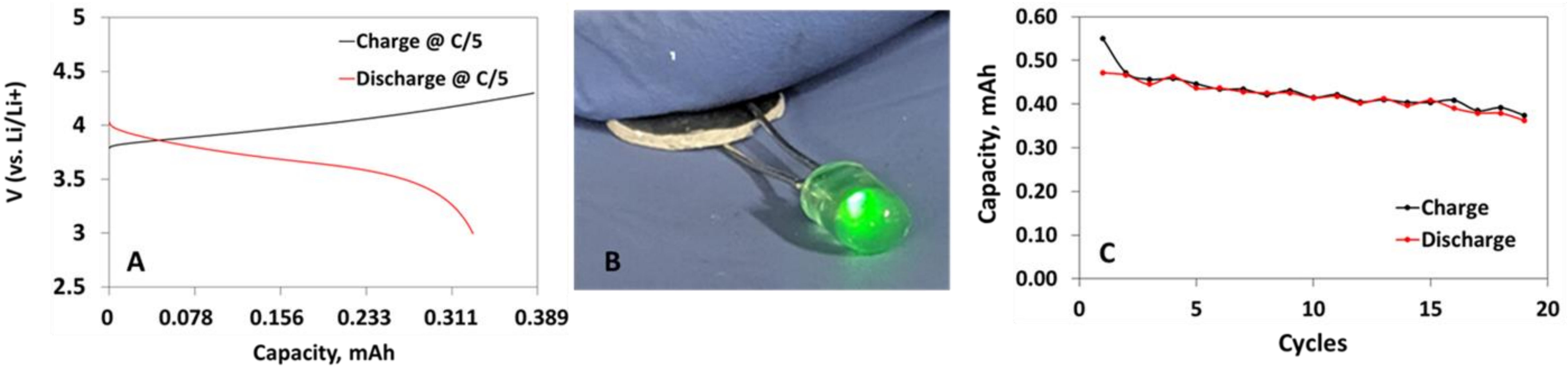
- High conductivity, stable interface with Li metal
- Densified by cold press (85% density)



Technical challenges

- Understanding failure of solid electrolyte
- Understanding stress evolution of Li metal
- Design a structure that mitigate Li stress, prevent SE failure

All solid state rechargeable lithium battery



Ongoing effort

- ❑ Improving Rate, cycling performance
- ❑ Cathode Loading effect
- ❑ Operation beyond 120 °C
- ❑ Impedance vs time beyond 120 °C
- ❑ OCV vs time beyond 120 °C

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UDRI's proprietary.

Summary

Solid State battery: the Future Battery, can provide

More energy!
More Power!
More cycle-life!
More safety!
Faster charge!
Lower Cost!

Funding Agencies / Acknowledgement

Ohio Federal Research Network (OFRN)