Safe, Low-Cost, High-Energy-Density Solid-State Li-Ion Batteries

Team:

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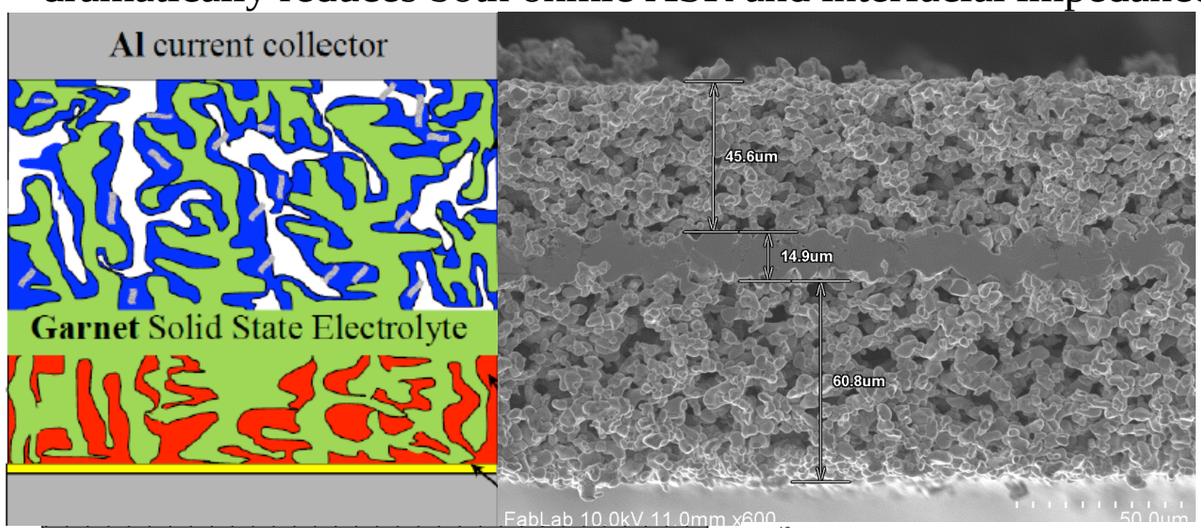
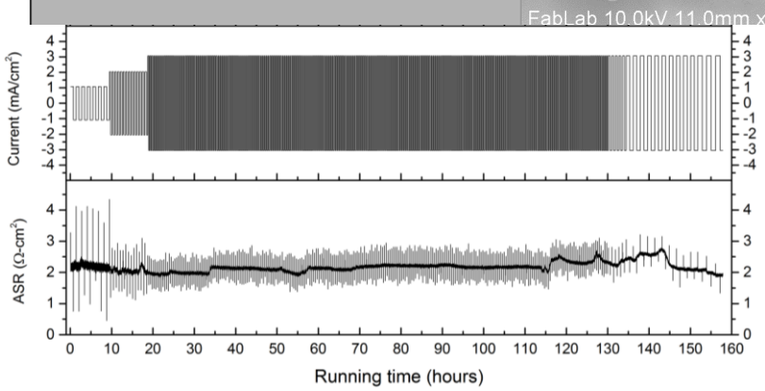
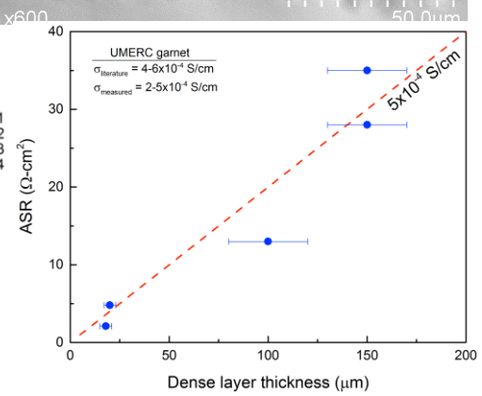
Technology Overview

- Eliminates battery flammability/safety issues
  - SSLIB's are intrinsically safe
- Eliminates thermal management requirements
  - no thermal runaway concern
- Hard ceramic electrolyte blocks dendrite propagation
  - allows for high capacity Li-metal anodes
- Wide electrolyte stability window (~6V)
  - allows for high voltage cathodes and high energy density
- Low-cost, thin-electrolyte, tri-layer structure
  - dramatically reduces both ohmic ASR and interfacial impedance







Current Status

- Demonstrated repeatable fabrication capabilities for ~15 μm thin dense garnet electrolytes
- Developed surface treatment that allows Li-metal wetting and pore filling of garnet with negligible interfacial impedance
- Achieved thousands of symmetric cell DC cycles and hundreds of hours at 3 mA/cm^2 up to ~100% DOD with no degradation
- Achieved extremely low ASR of 2 Ω cm^2 - far lower than conventional batteries
- No dendrites observed over multiple samples and Li-metal garnet interfaces
- Fabricated and demonstrated multiple solid-state Li-metal-anode battery chemistries, including with LCO and Sulfur cathodes
- Seeking interested partners and battery manufacturing companies for commercial scale-up

Project Statistics

Award Amount	**$890,379**
Award Timeline	**01/30/2014 to 03/31/2016**
Next Stage Target	**Commercially viable multi-cell prototype**
Collaborations Sought	**Battery manufacturing & commercialization partners**

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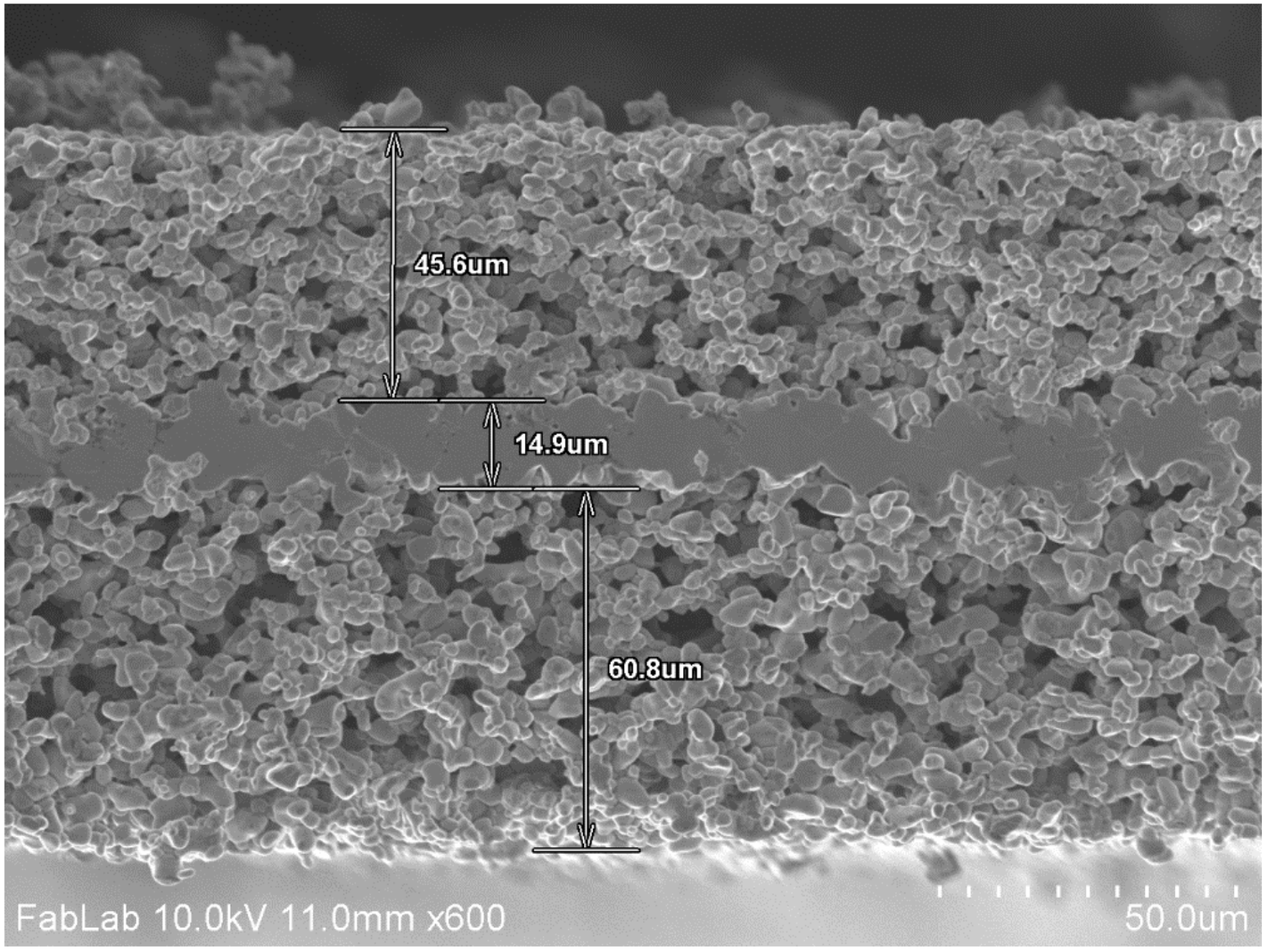
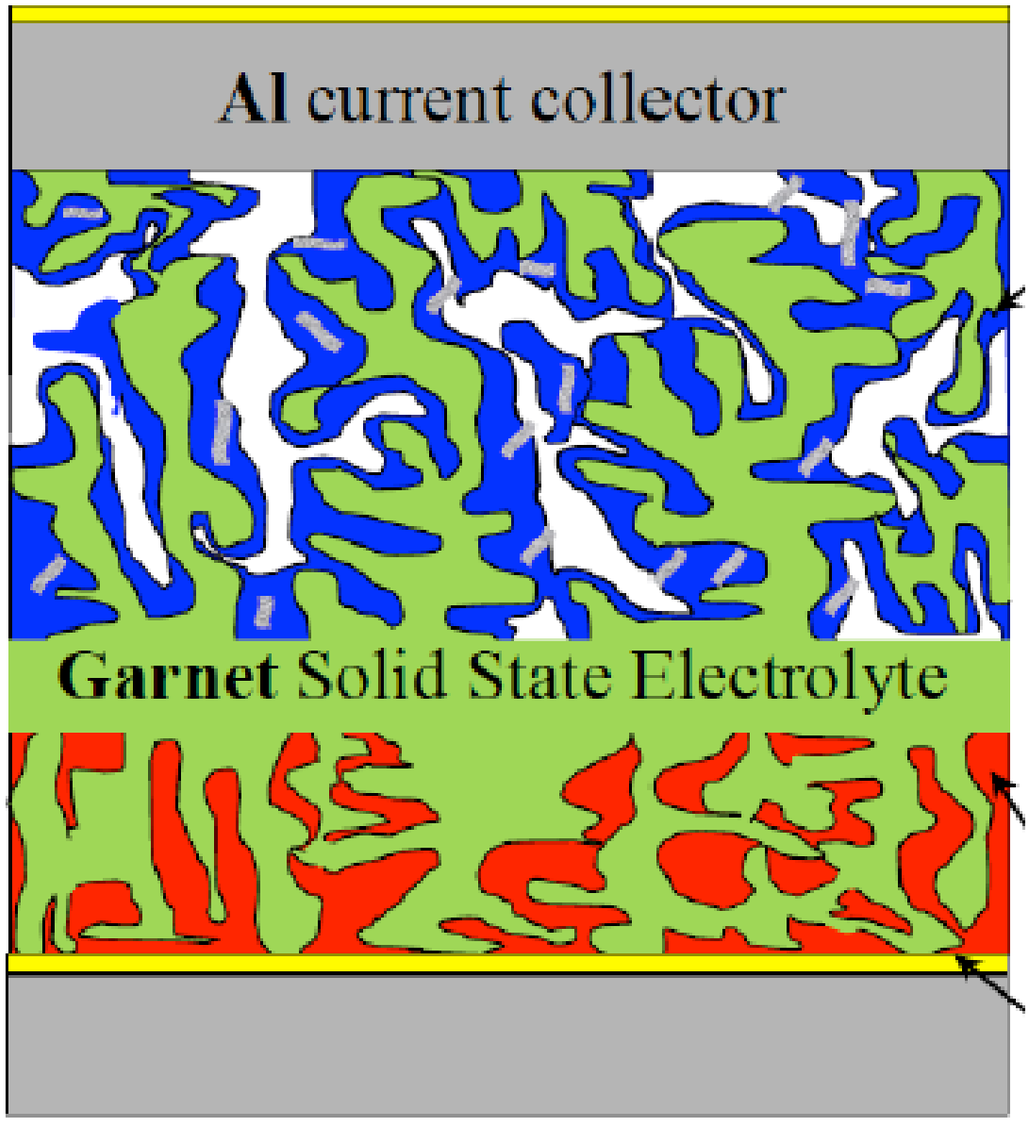
storage + ion systems

Solid State Li Battery (SSLiB)

Successfully fabricated thin ~15 μm dense supported garnet electrolytes

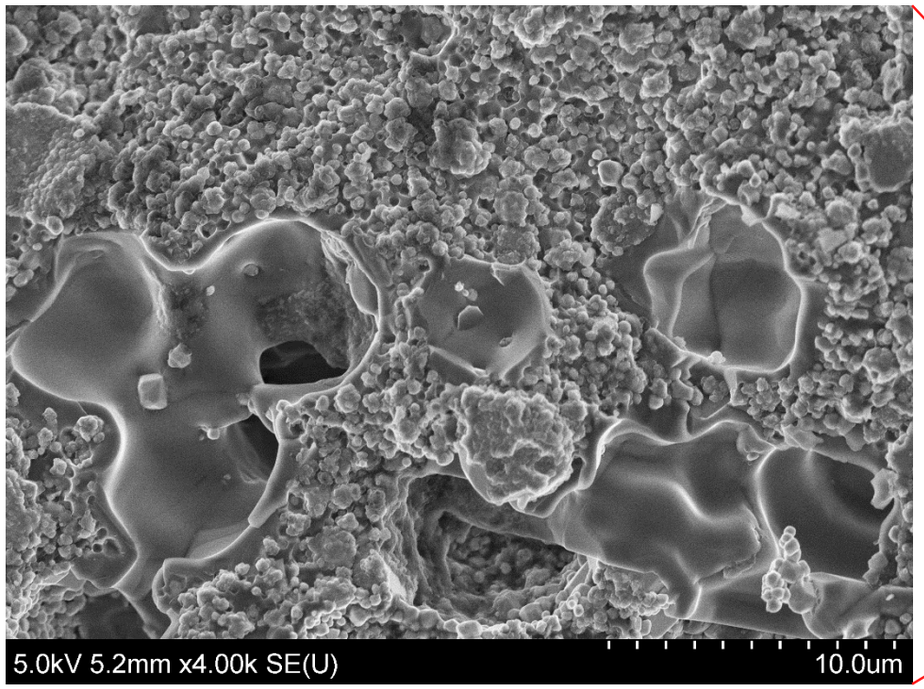


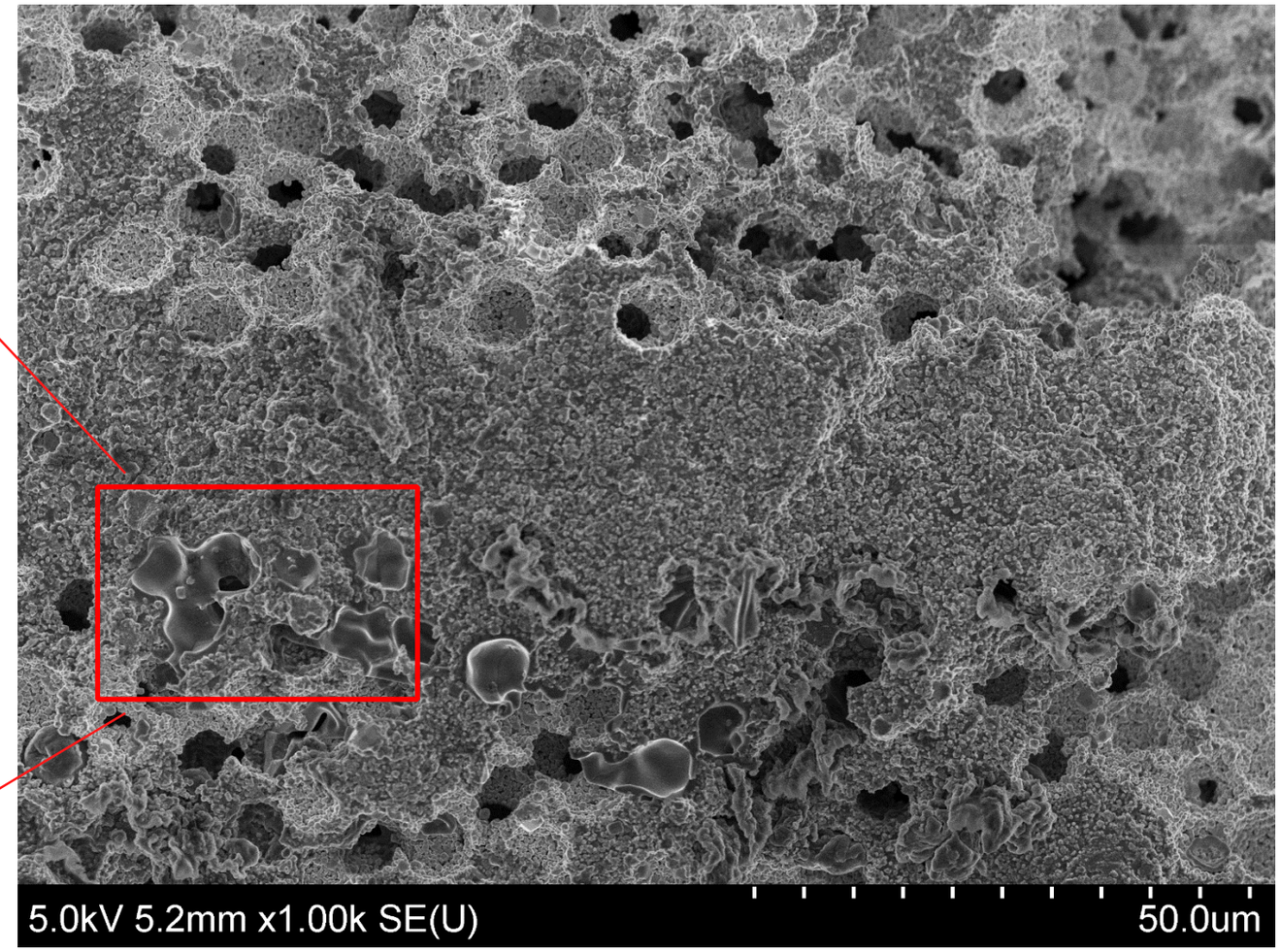


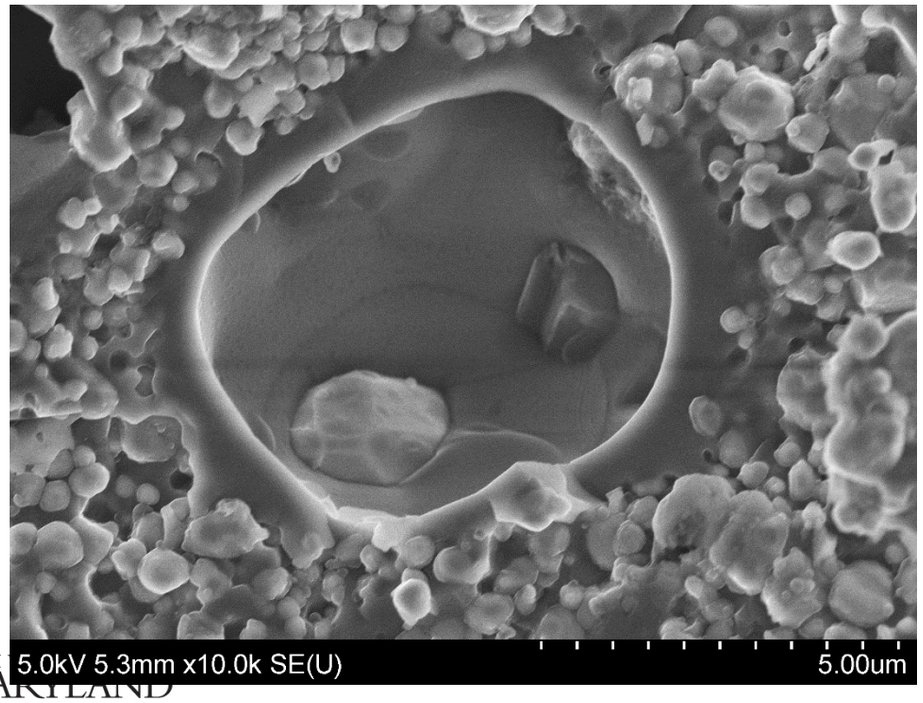
- Thin dense central layer has low ASR and blocks dendrites
- Porous outer layers provide structural support and can be infiltrated with electrodes to provide large electrolyte/electrode interfacial area

Li Infiltration: SEM after Cycling

More Li present on side after cycling

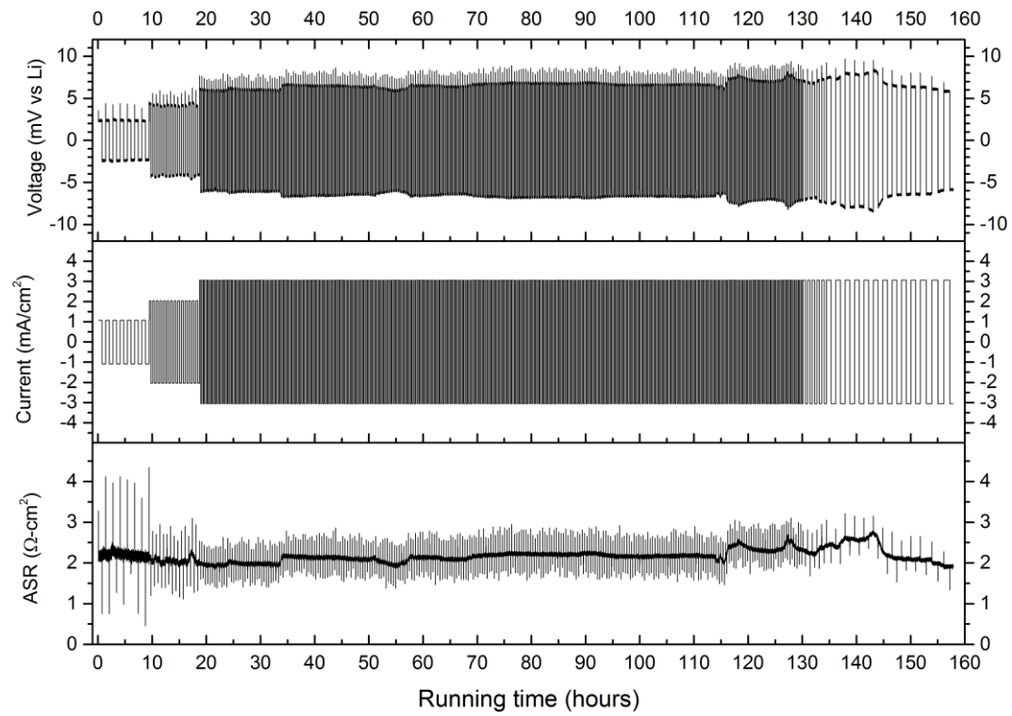






- Solved Li-metal/garnet interface issue:
  - Li wets garnet and fills pores
  - Negligible interfacial impedance
- No dendrites observed over multiple samples and Li-metal garnet interfaces

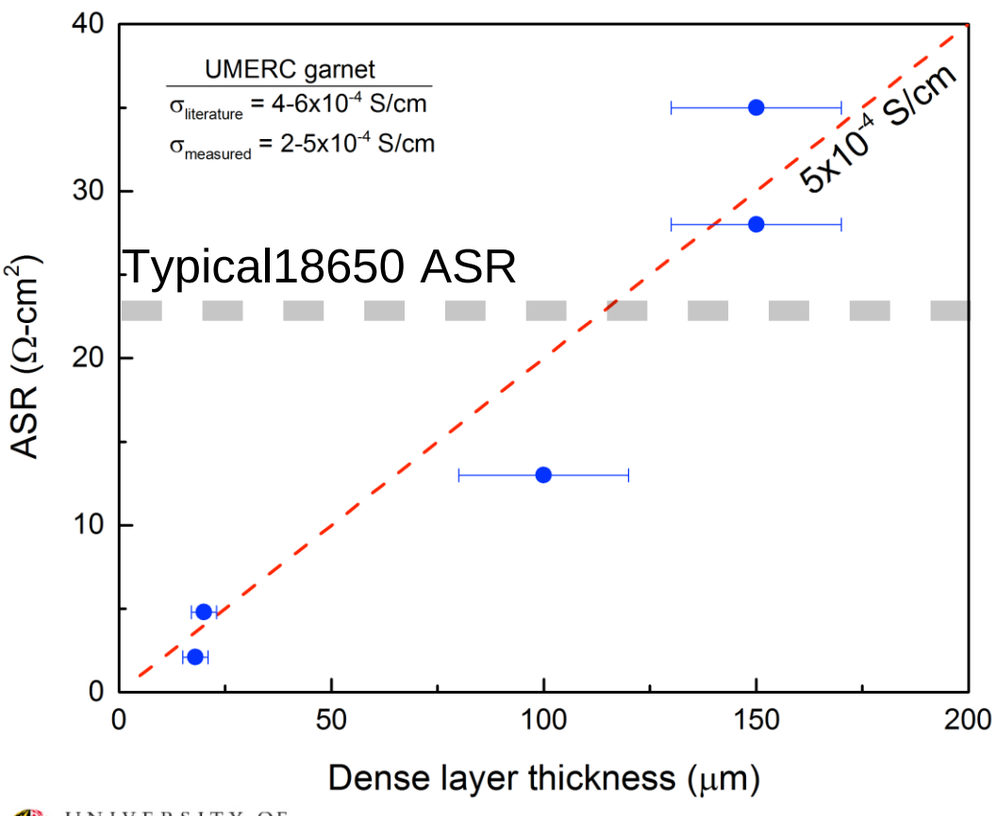
Li Cycling of Tri-Layer Garnet

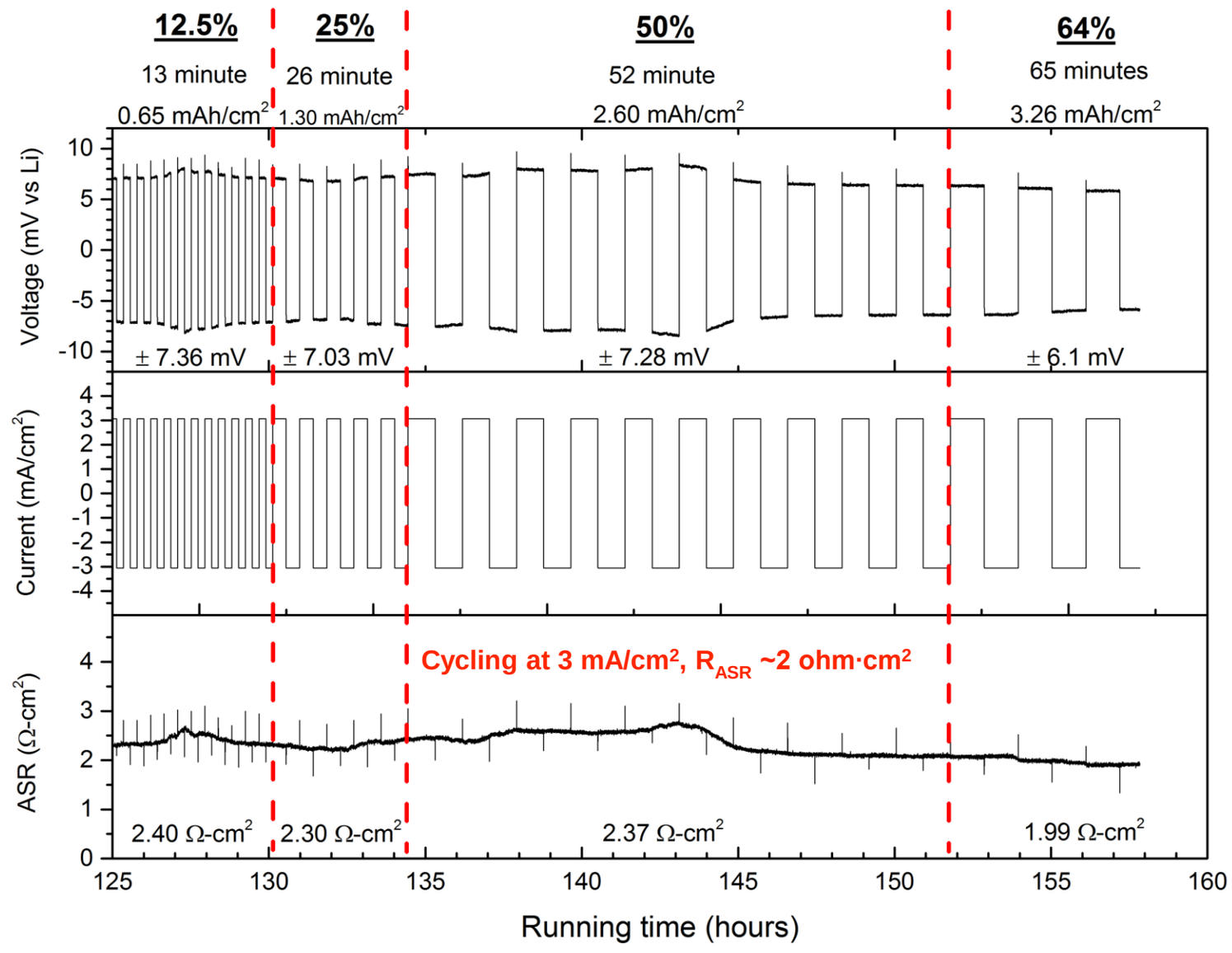


Stable plating/stripping cycling for high Depth of Discharge

No degradation or performance decay

Dramatically lower ASR than conventional batteries





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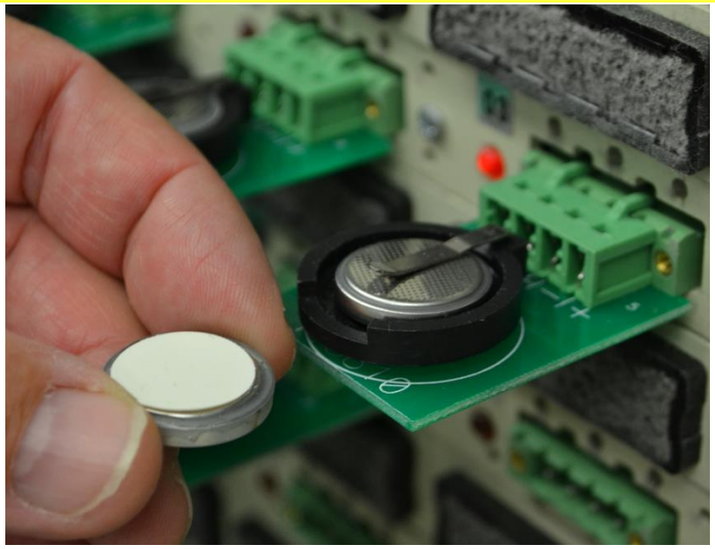
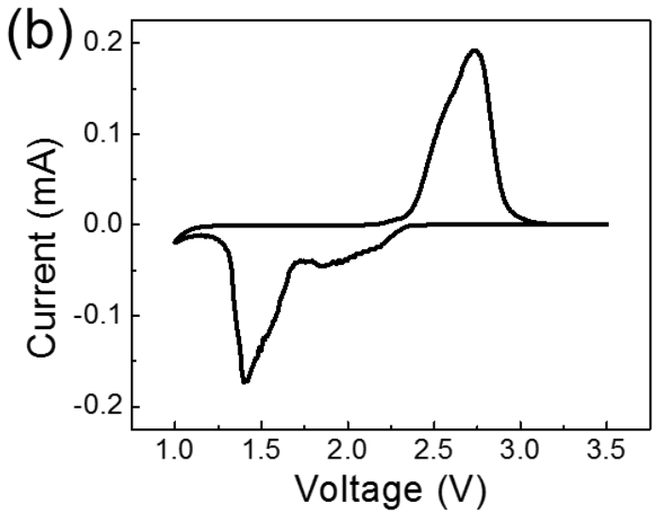
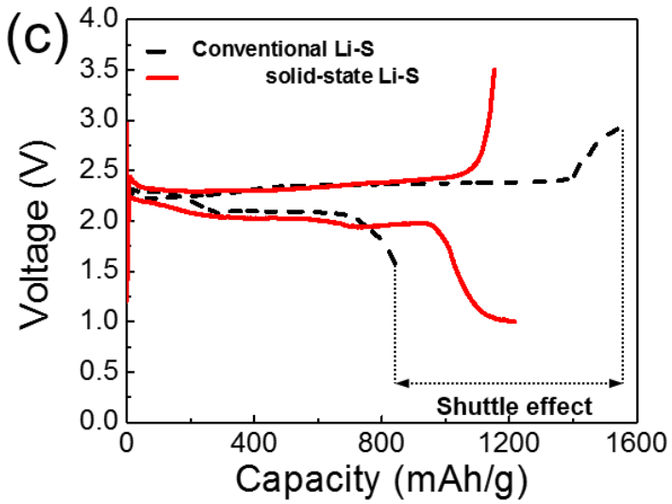
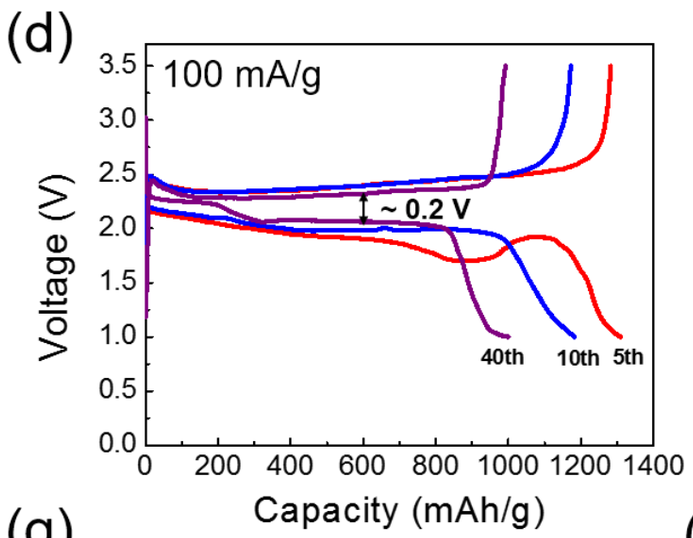
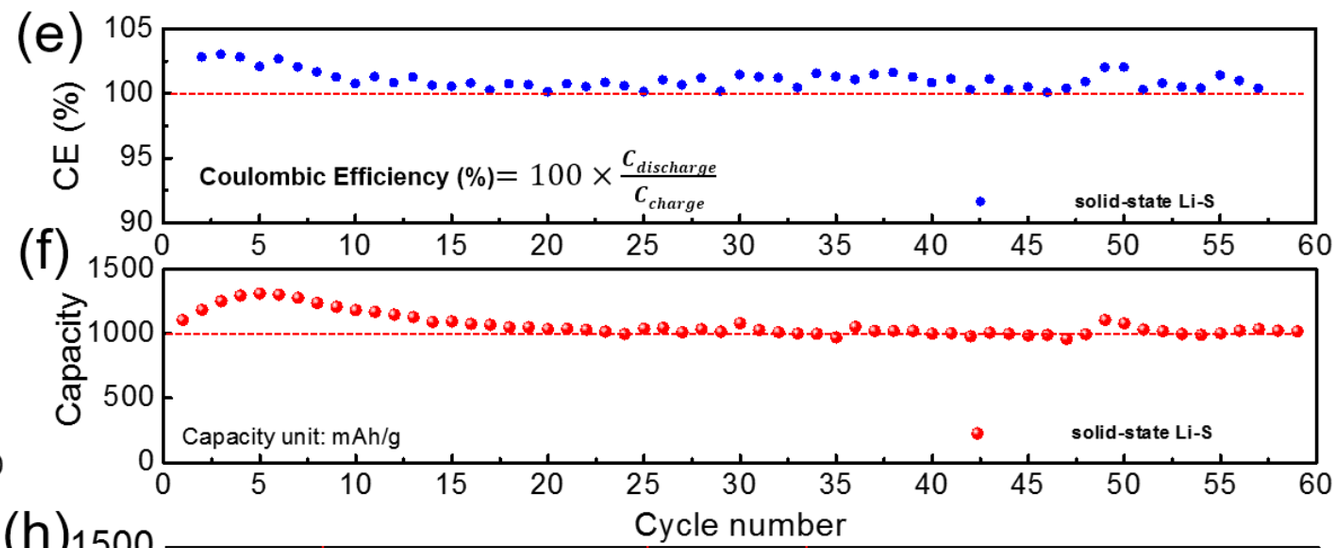
Solid State Li_{metal}/Garnet/Sulfur Battery

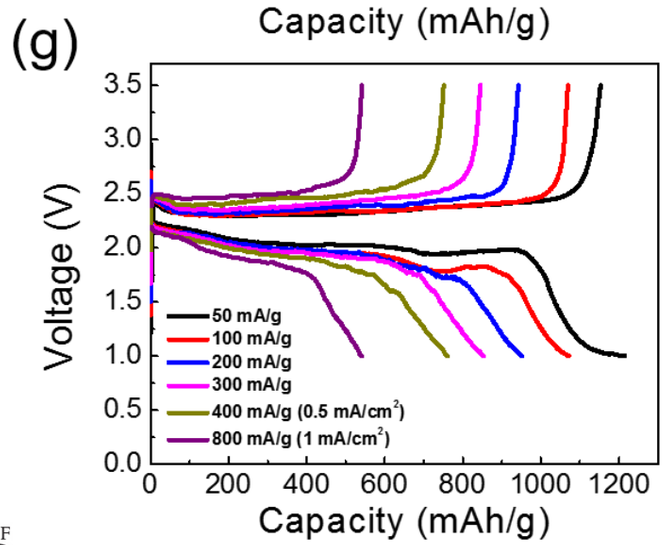


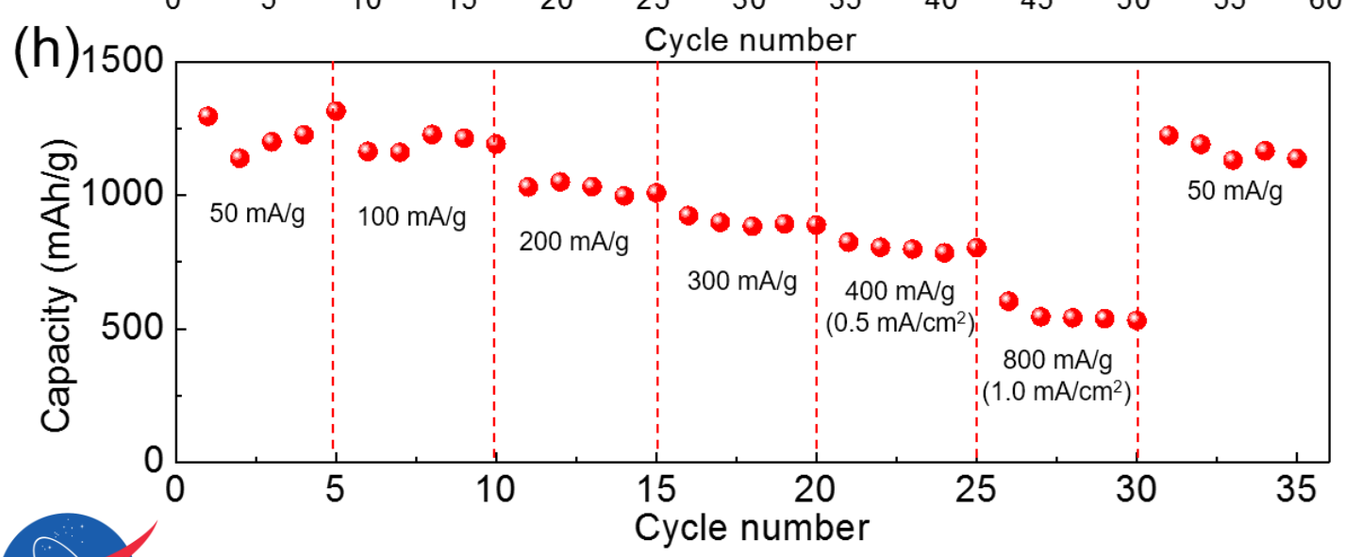












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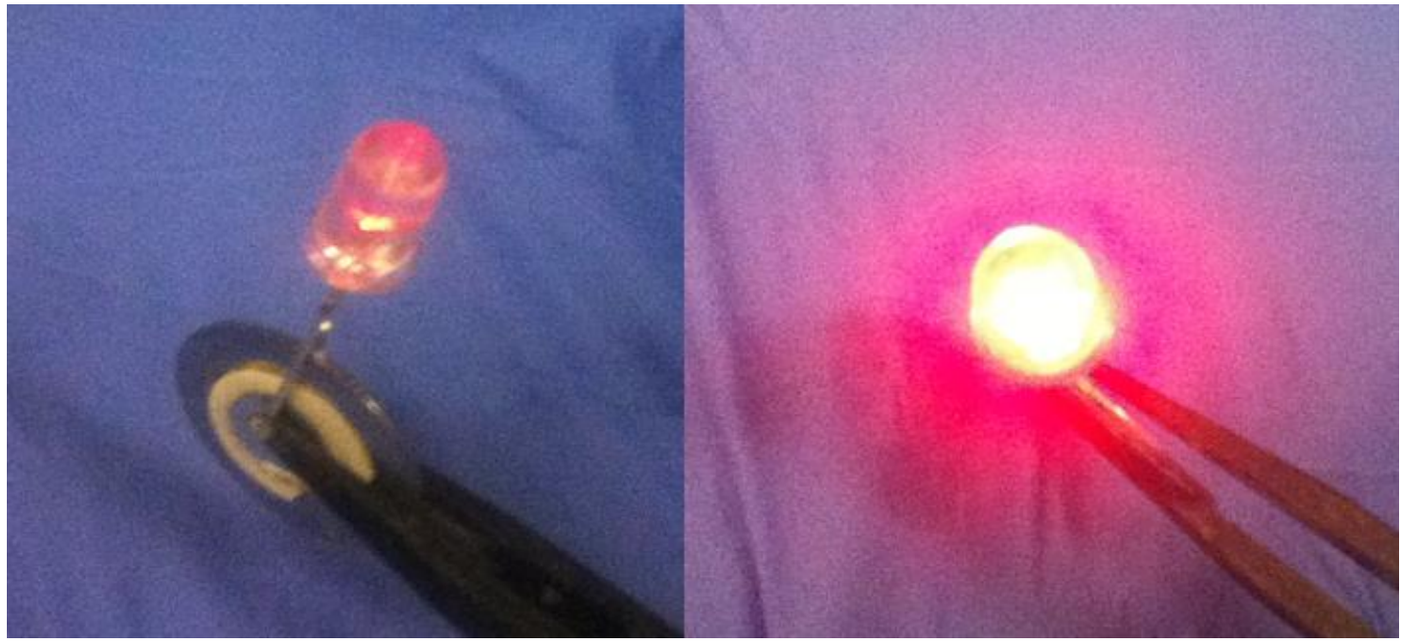
Game Changing, Advanced Energy Storage - Phase 2 Awarded

All Solid State Battery

First All Solid State Li-Ion Battery (SSLiB) with high capacity Li_{metal} anode



Major Accomplishments:

- Achieved Garnet electrolyte with RT conductivity ~1 mS/cm
- Verified Garnet electrolyte is stable from Li metal up to 6 V
- Demonstrated scalable fabrication of Garnet electrolyte by tape casting
- Porous-dense-porous triple layer successfully fabricated
- Infiltrated Li metal anode and high voltage cathode in porous Garnet
- Developed low interfacial impedance surface treatment for Garnet electrolytes
- Demonstrated high current and high cycle rate of Li metal with Garnet without degradation
- Demonstrated all solid state battery with various cathodes and Li metal anode

Lessons Learned:

- Solid state interfacial impedance and stability can be dramatically improved by compositional and microstructural modification
- Multi-layer Garnet structures can be fabricated with scalable methods without sacrificing conductivity
- However, optimization of processing conditions was much more difficult than initially thought