Mechanistic Insight and Optimization of Anode-Free Solid-State Batteries

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2025 Spring/Summer NASA Office of STEM Engagement (OSTEM) Internship Program

Advanced Materials and Processing Branch
NASA Langley Research Center

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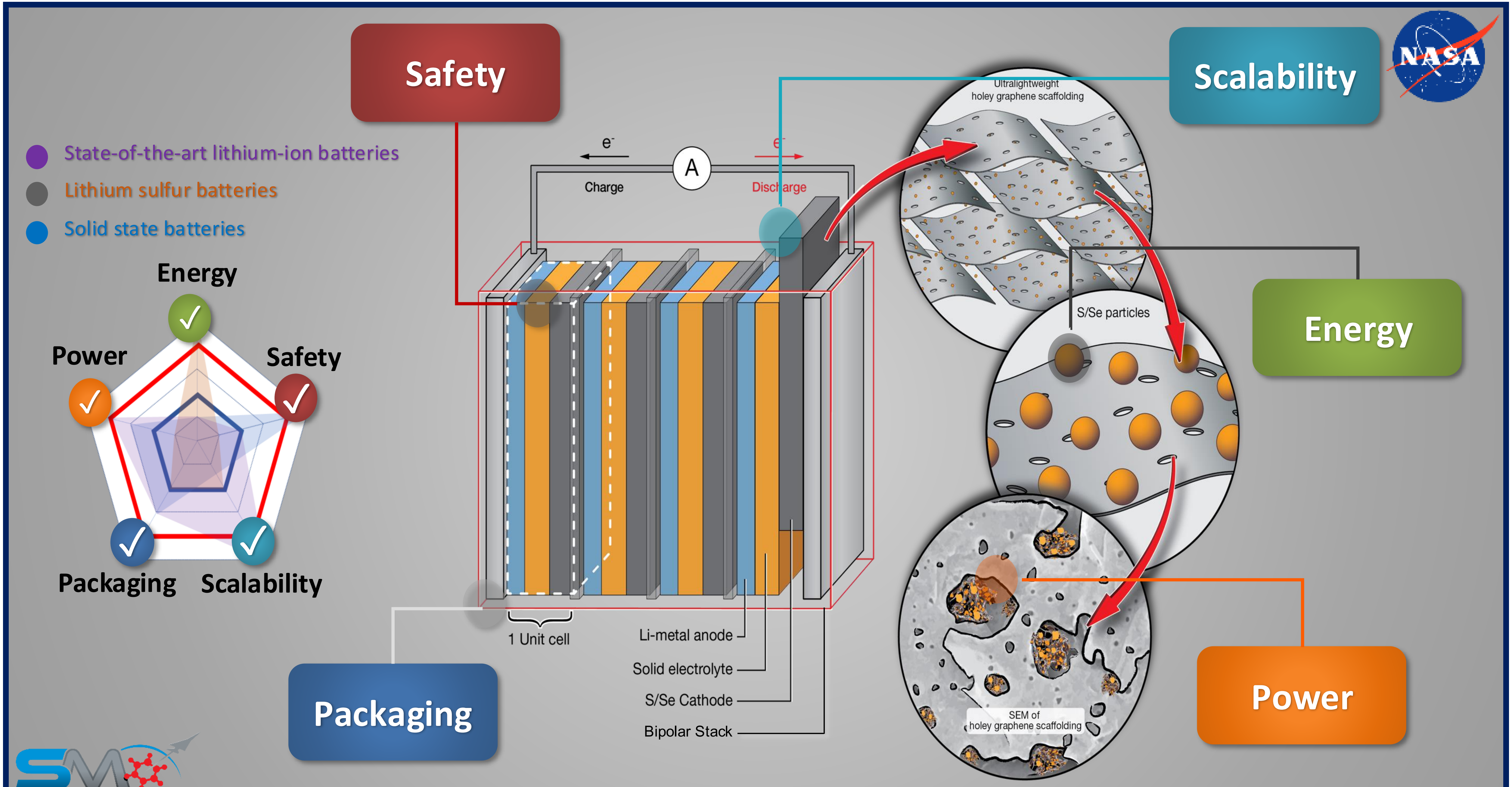
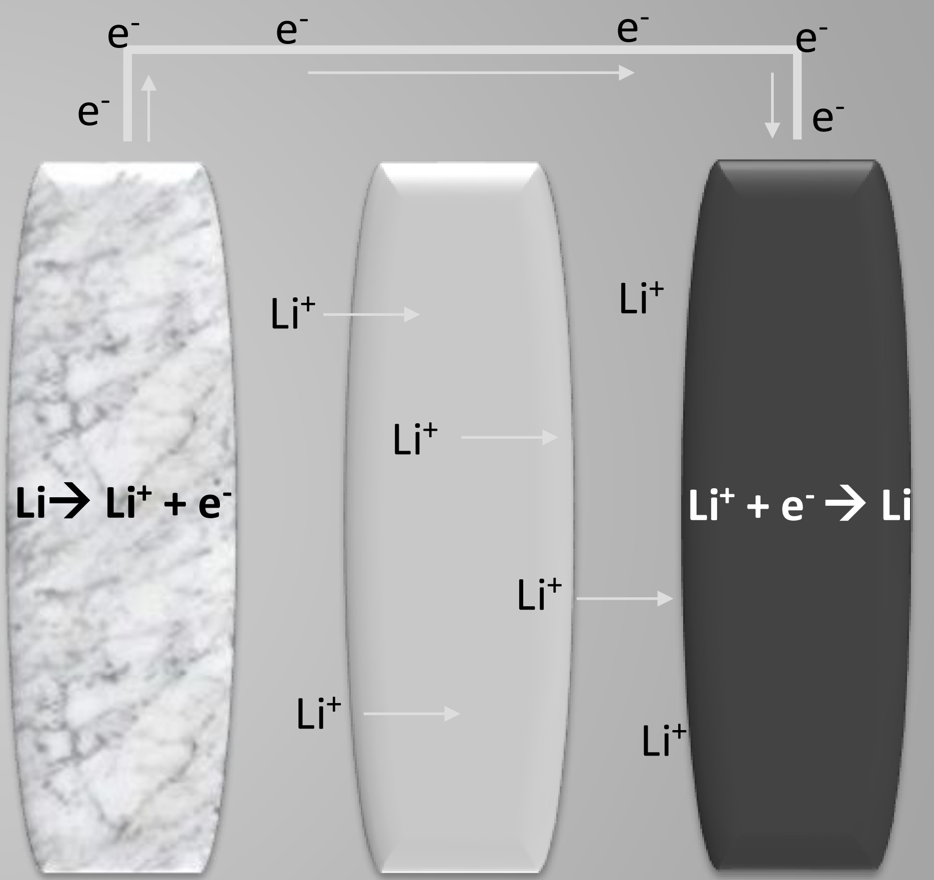
NASA Langley Research Center



SABERS: Solid-state Architecture Batteries for Enhanced Rechargeability and Safety

Battery Component Breakdown

- **Anode**- Electron and Ion source- usually Li
- **Electrolyte**- Bridge which allows ions to travel
- **Cathode**- Electron and Ion housing



Why Lithium Anodes Fail

Dendrite Formation
Uneven Li Plating

→

Thermal Runaway
Internal Short Circuit

→

Mechanical Instability
Volume Expansion

→

Capacity Fade
Loss of Active Li

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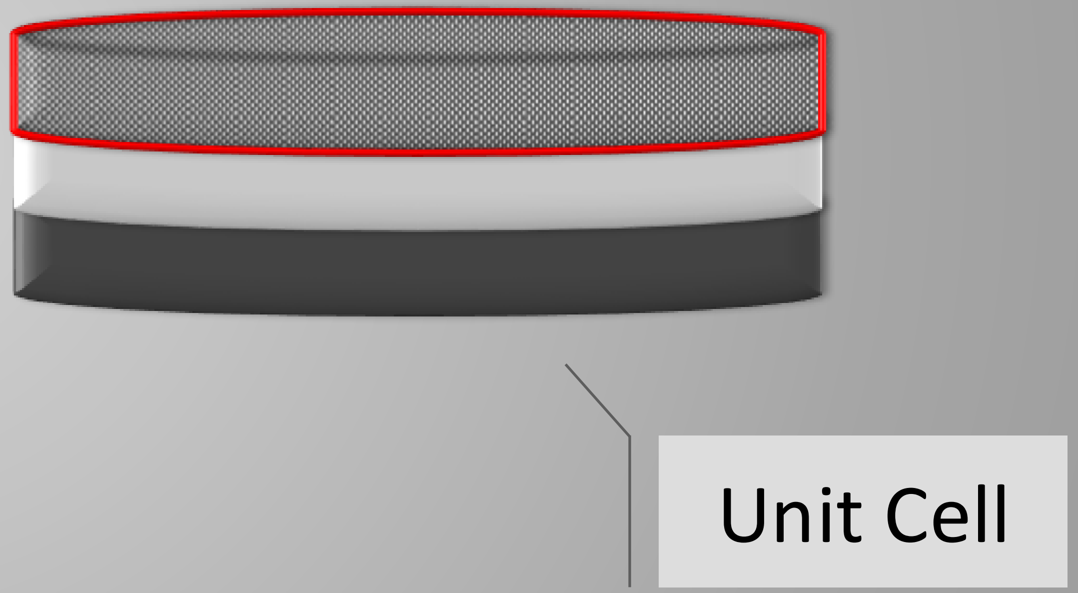
Anode-Free Solid-State Battery

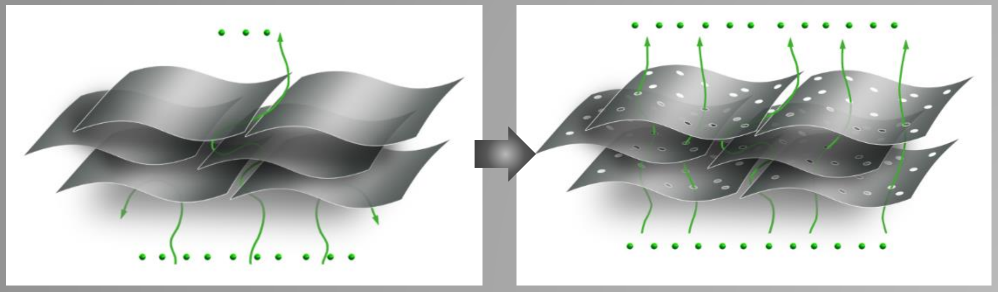
- **Cathode-** Li stored in transition metal oxide framework instead of Li Chip

- **Solid Electrolyte-** Allows Li^+ to travel through cell

- **Anode Place Holder-** Housing for Li

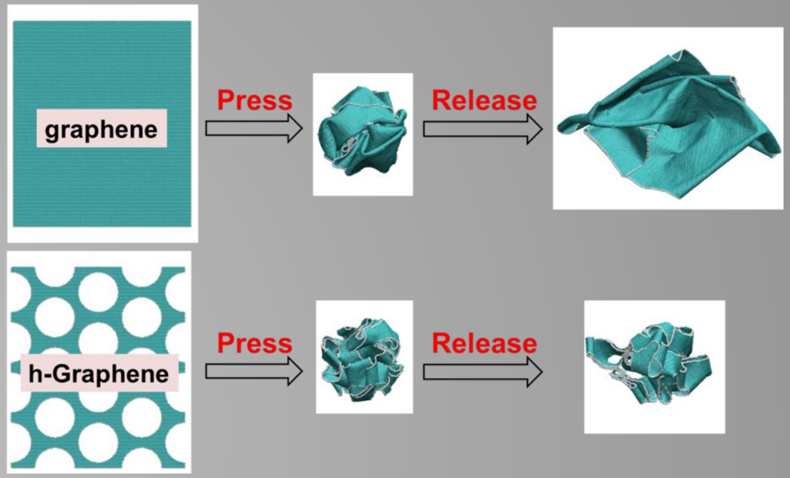


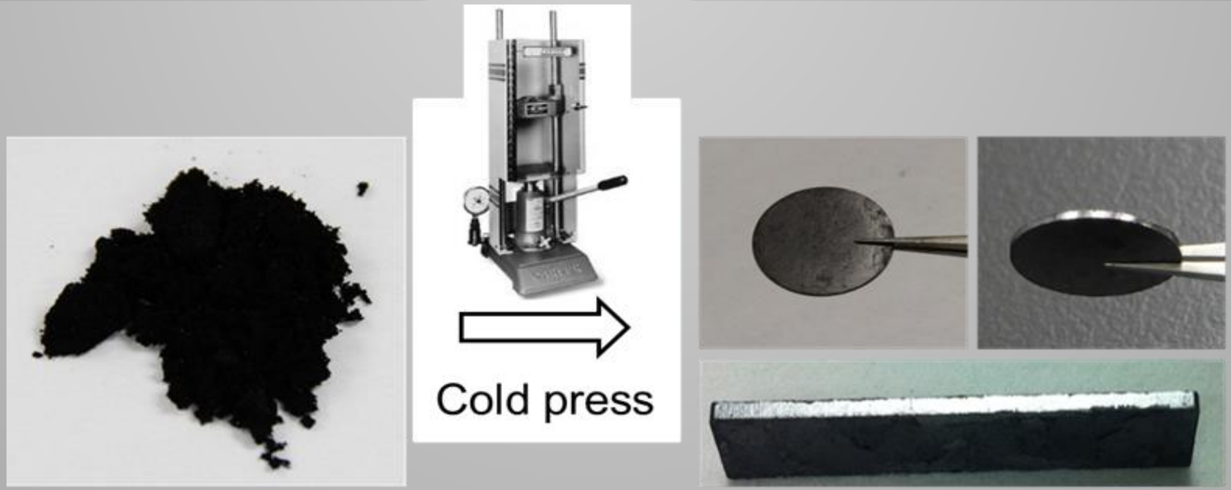
Holey Graphene: Always Saves the Day



Intact Graphene

Holey Graphene





ACS Nano **2014**, *8*, 8255. *ACS Nano* **2017**, *11*, 3189. (In collaboration with Prof. Liangbing Hu)

Tuning Lithium Deposition

Lithiophilicity
Surface Affinity

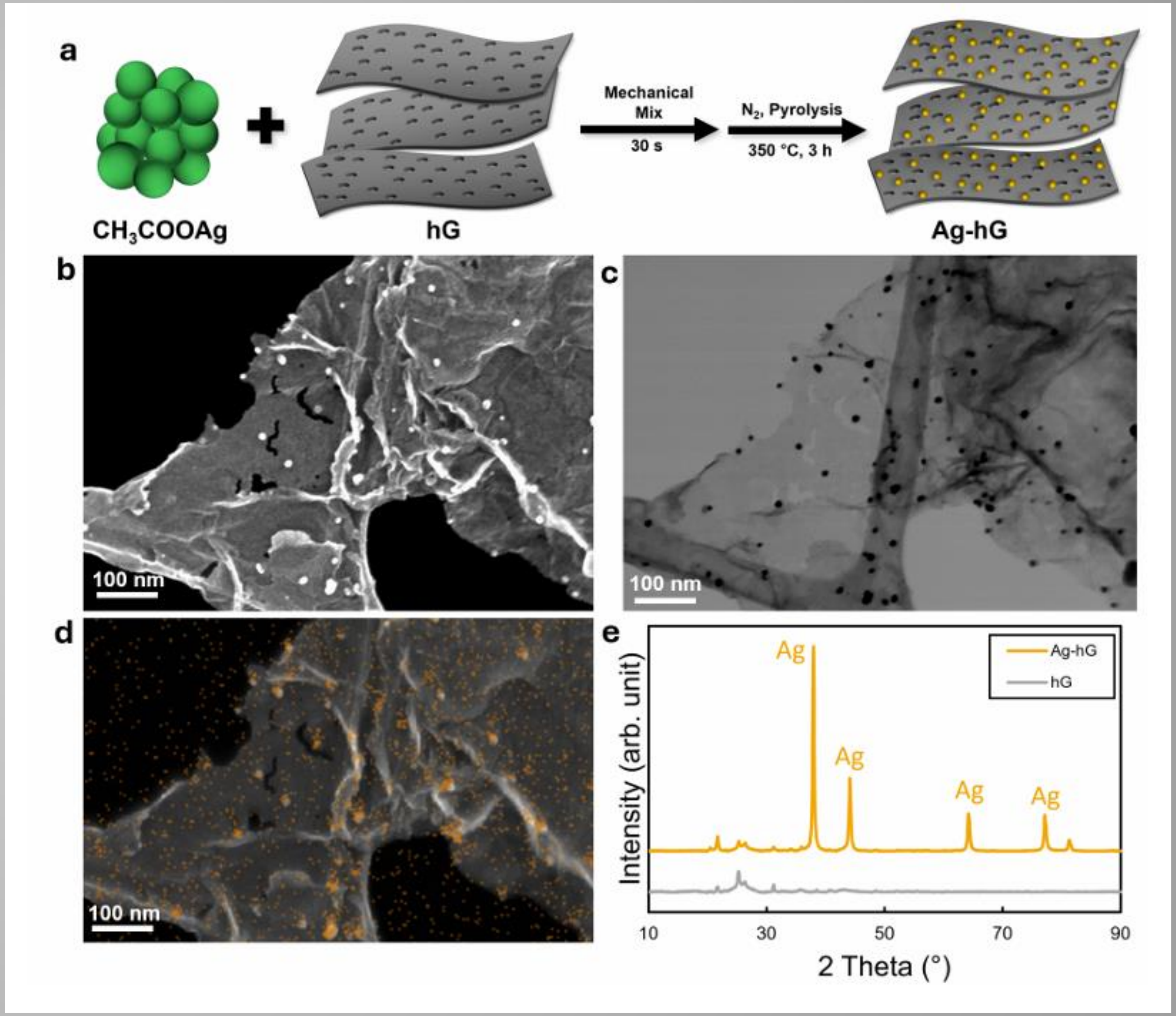
Nucleation Overpotential
Energy Barrier

Ion Transport
Mobility

Silver-Holey Graphene (Ag-hG)

The Ag-hG hybrid material:

- Facile, solvent-free preparation
- Ag nanoparticles <20 nm
- Metallic Ag nanoparticles supported on hG sheet surfaces



"Dry Compressible Anode Interlayer Design Enabling All Solid-State Batteries at Low Stack Pressure."
Jason S. Packard, Yi Lin* et. al. , *ACS Appl. Energy Mater.* **2026**, DOI: 10.1021/acsaem.5c02931

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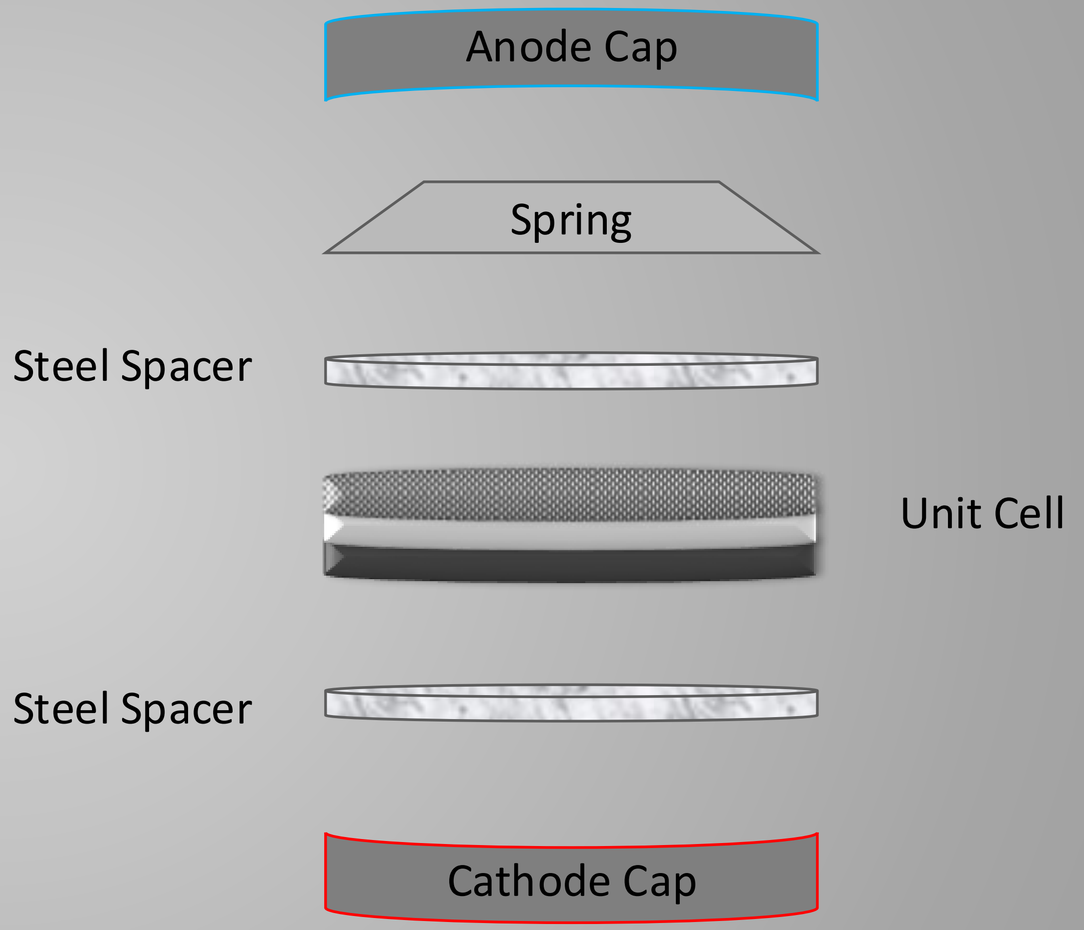
Anode-Free Li-NMC Battery

- **Cathode**- NMC (Lithium Nickel Manganese Cobalt Oxide)
  - Li stored in transition metal oxide framework instead of Li Chip
- **Electrolyte**- LPSC (Li_6PS_5Cl)
  - Allows Li^+ to travel through cell

Anode Place Holder- Ag-hG

- Ag metal inside hG to act as anchor points for Li^+



"Anode-free" = "Reservoir-free" (i.e., no pre-existing and excess metallic Li)

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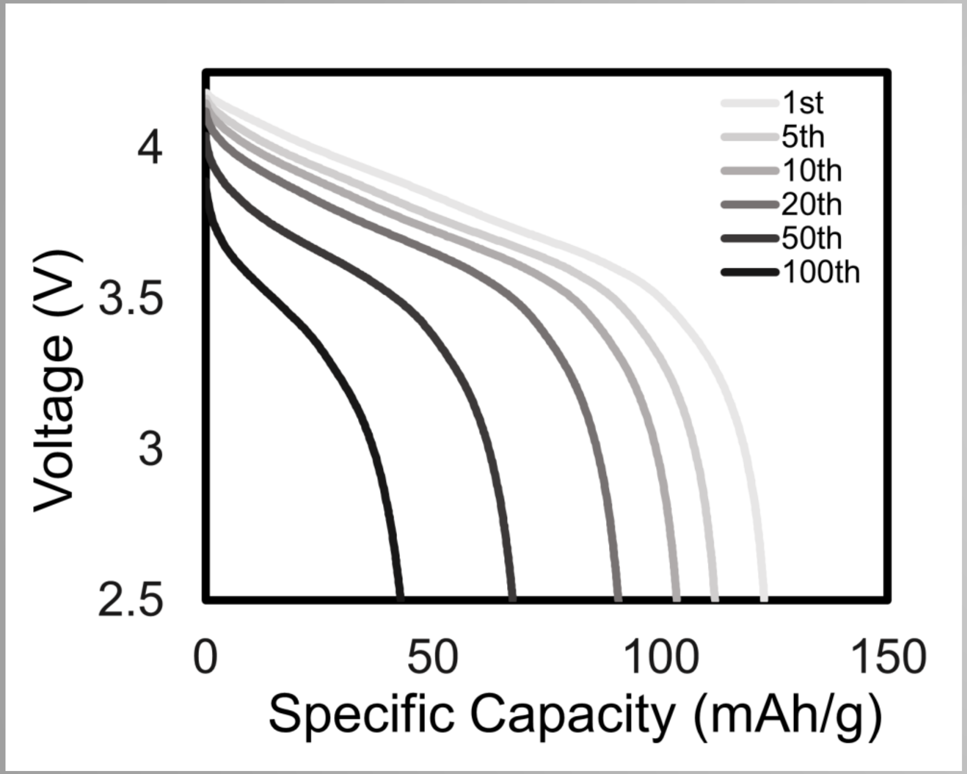
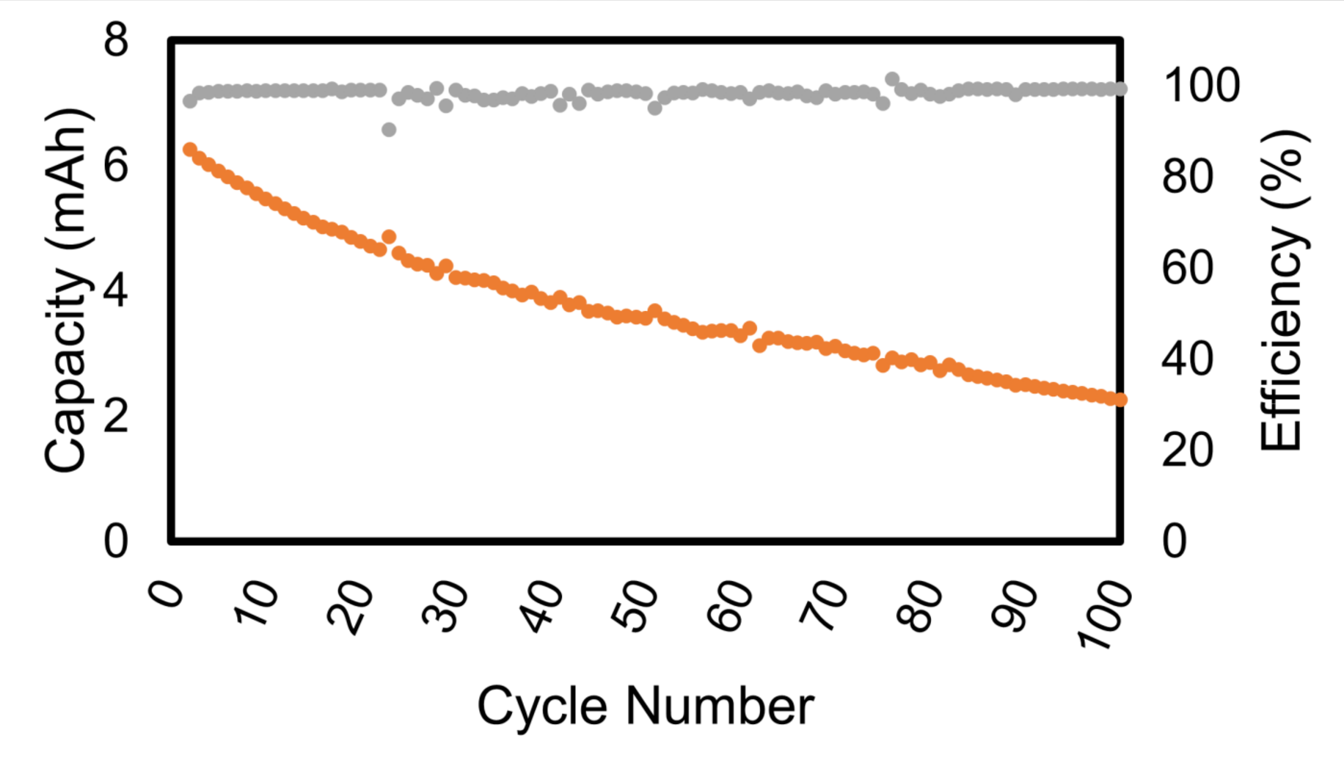
Cell Cycling Performance





- **<u>Cell architecture</u>**: 64mg NMC Cathode at 30mg/cm^2 active mass loading, 90mg LPSC, 8mg 1:3 Ag-hG as anode housing.
- **Cycling conditions:** First charge at C/10 (1.062mA), then cycled at C/5 (2.124mA).

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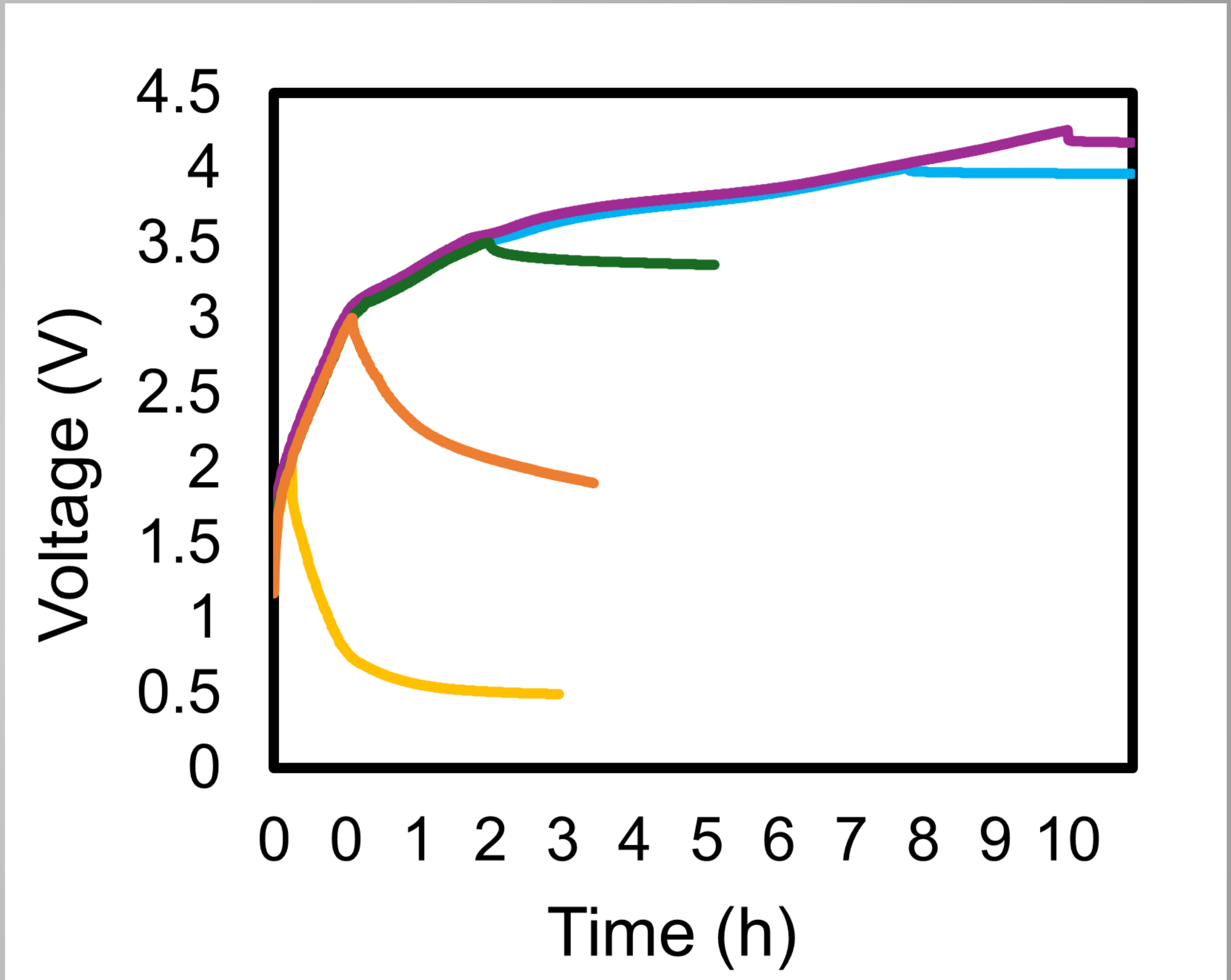
Voltage Relaxation Indicates Interfacial Stabilization



Testing voltage relaxation behavior at various points of charging voltage.

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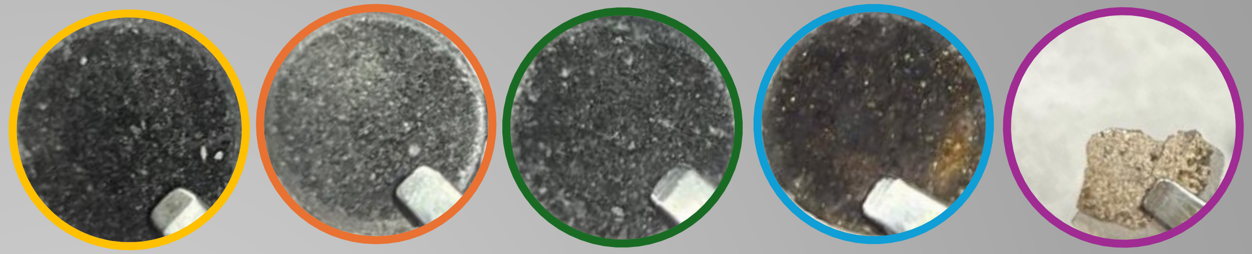
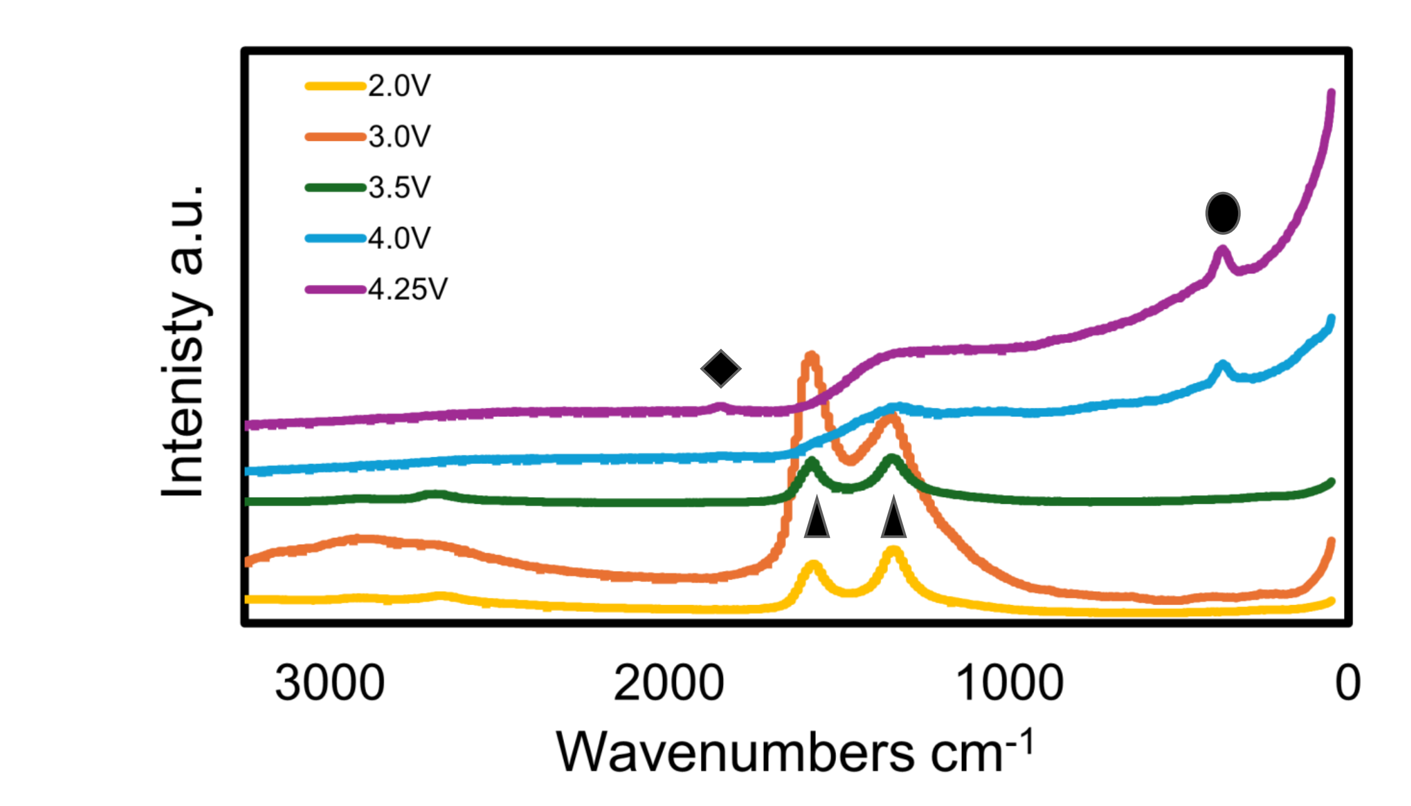
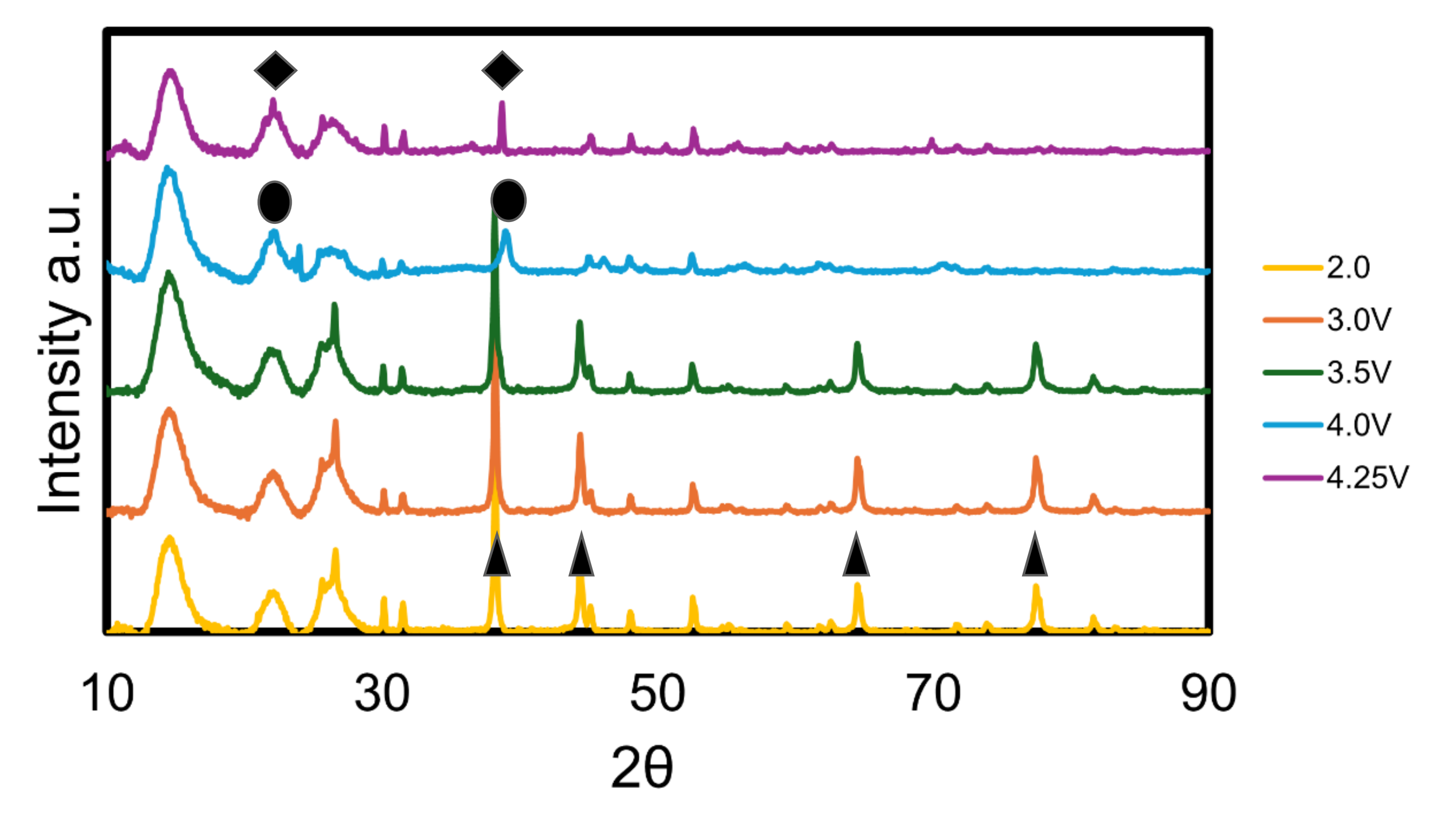
Li-Ag Alloy Formation





Raman spectroscopy and optical photographs suggested Li-Ag alloy forms when the cell was charged to ~3V

Li-Ag Alloy Formation

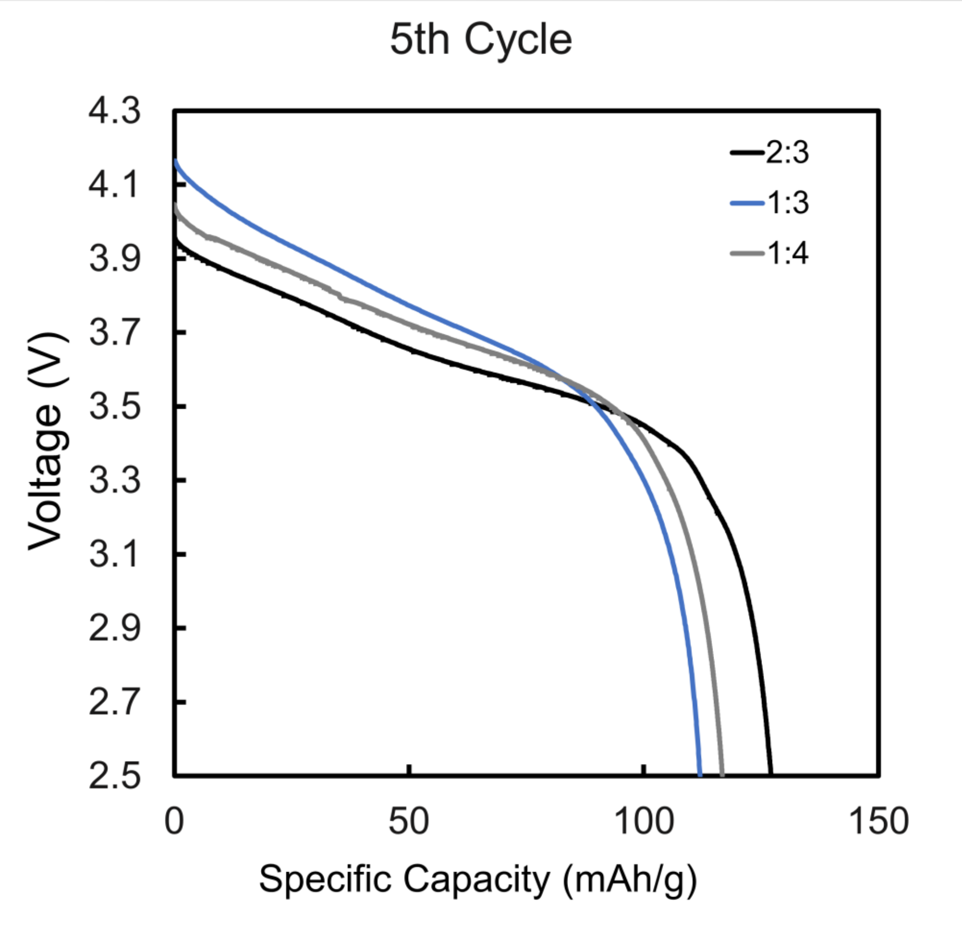


X-Ray diffraction (XRD) data further supports Li-Ag alloy formation

Discharge Retention

Ratio	5th Cycle	20th Cycle	% Lost
1:3	112.0076	90.7575	18.97%
2:3	127.1402	118.4091	6.87%
1:4	116.7614	86.7234	25.73%

Ag:hG ratio at 2:3 was found to be optimal for cycling stability.



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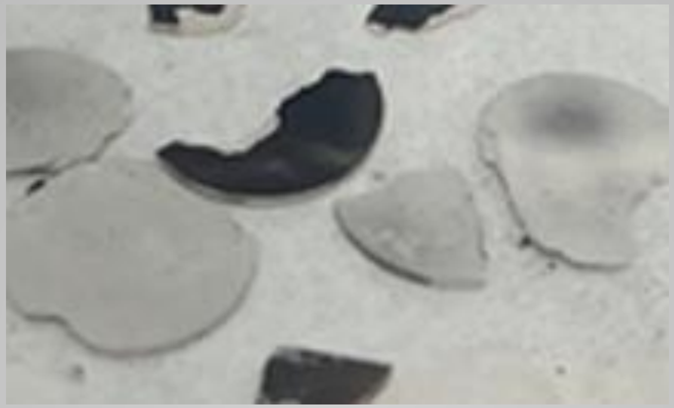
Lab Success… Manufacturing Reality

2:3

First Place

Good performance, moderate processability



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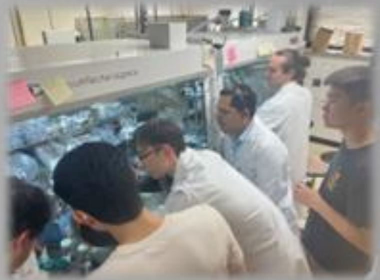
People's Choice

Moderate performance, good processability

"Dry Compressible Anode Interlayer Design Enabling All Solid-State Batteries at Low Stack Pressure." Jason S. Packard, Yi Lin* et. al. , *ACS Appl. Energy Mater.* **2026**, DOI: 10.1021/acsaem.5c02931

Acknowledgements

- Dr. Lin
- SABERS Team
  - Especially Sean and Marion
- Arkansas Space Grant



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