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Objectives and Relevance

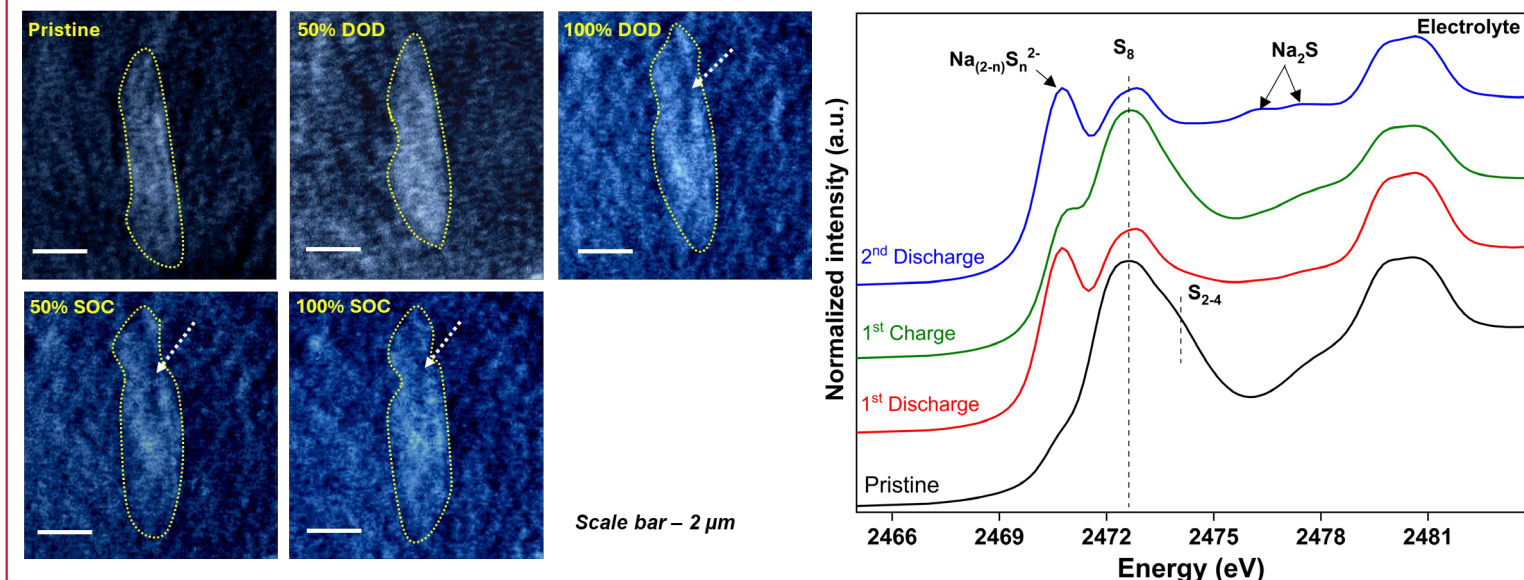
The SLAC-Stanford Battery Center aims to establish a research and demonstration program to accelerate the development of sodium-sulfur (Na-S) batteries by rationalizing, incorporating, and scaling storage chemistries based on earth abundant materials. One of the primary goals of the project is to develop and demonstrate room temperature Na-S batteries for grid scale energy storage. Working with other National Laboratories and industry partners the multi-year project aims at demonstrating Na-S batteries with energy density of 200 Wh/Kg and > 1000 cycles providing a viable alternative to Li-ion batteries in the grid space.

The proposed research aligns with DOE/OE energy storage mission as part of cost-competitive grid energy storage by simultaneously increasing energy/power density and reducing cost. The PI and team at SLAC aim to leverage collaboration existing within DOE/OE programs including STEER at SLAC-Stanford for TEA-LCA analysis, Grid Storage Launchpad (GSL) for testing and ROVI for model battery degradation and ageing to rapidly accelerate technology development for advancing ambient Na-S batteries.

Accomplishment I: Elucidating battery performance using multimodal X-ray characterization

(Manuscript to be submitted)

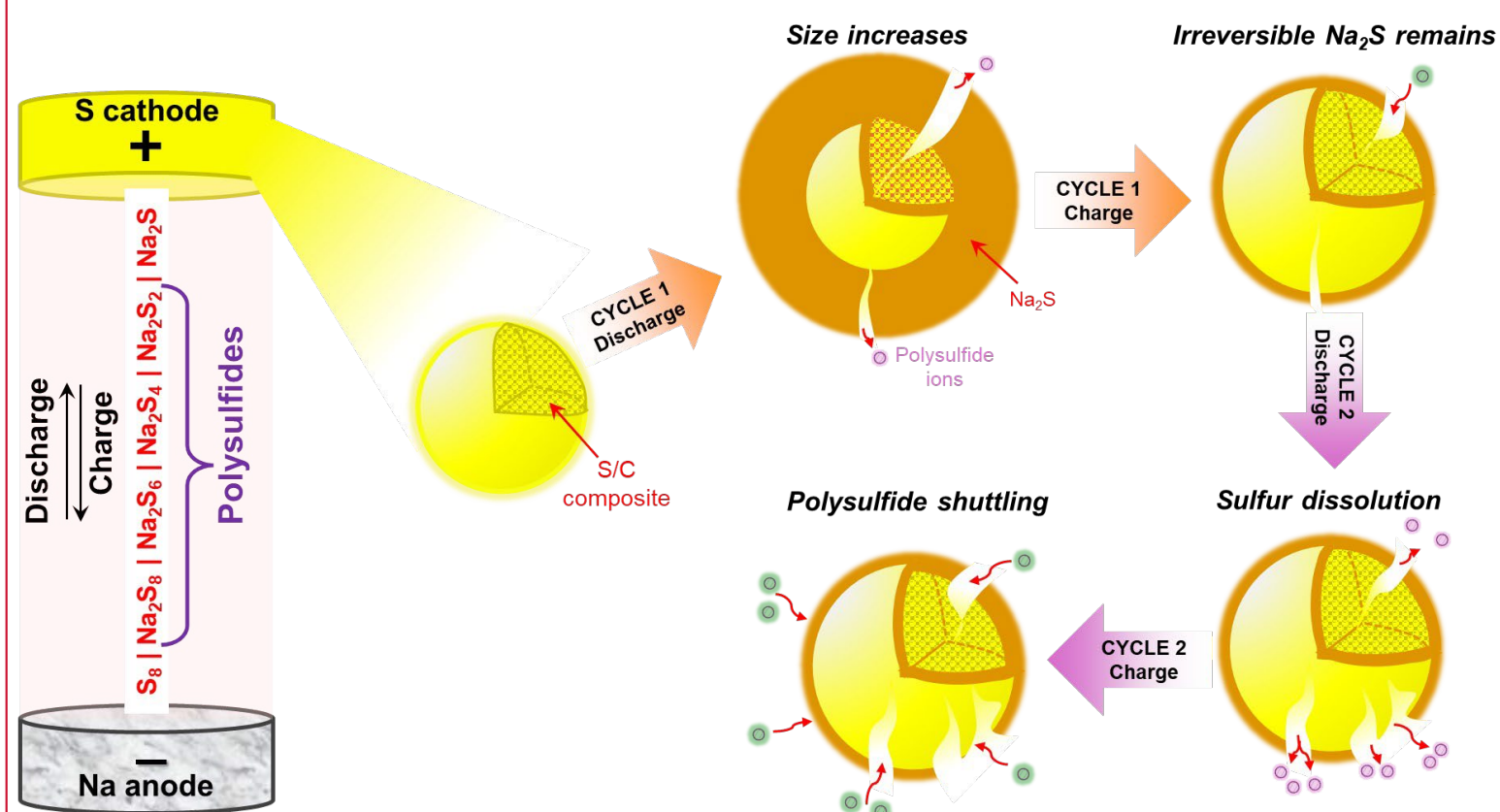
We visualized the spatial and chemical evolution of the sulfur cathode during cycling using operando X-ray microscopy and spectroscopy. Our findings enable the rational design of sulfur cathodes for high-performance Na-S batteries.



Visualizing sulfur volumetric dynamics using operando transmission X-ray microscopy; tracking polysulfide shuttling and chemical evolution using X-ray absorption spectroscopy.

During the first discharge, $S_8 \rightarrow Na_2S$ conversion happens and is accompanied by the irreversible volume expansion, as shown in the operando Transmission X-ray Microscopy measurements.

S K-edge X-ray absorption spectroscopy revealed polysulfide ion dissolution (liquid) from elemental sulfur (solid) and its shuttling between the cathode and anode in consecutive cycles, resulting in poor efficiency and severe capacity decay.



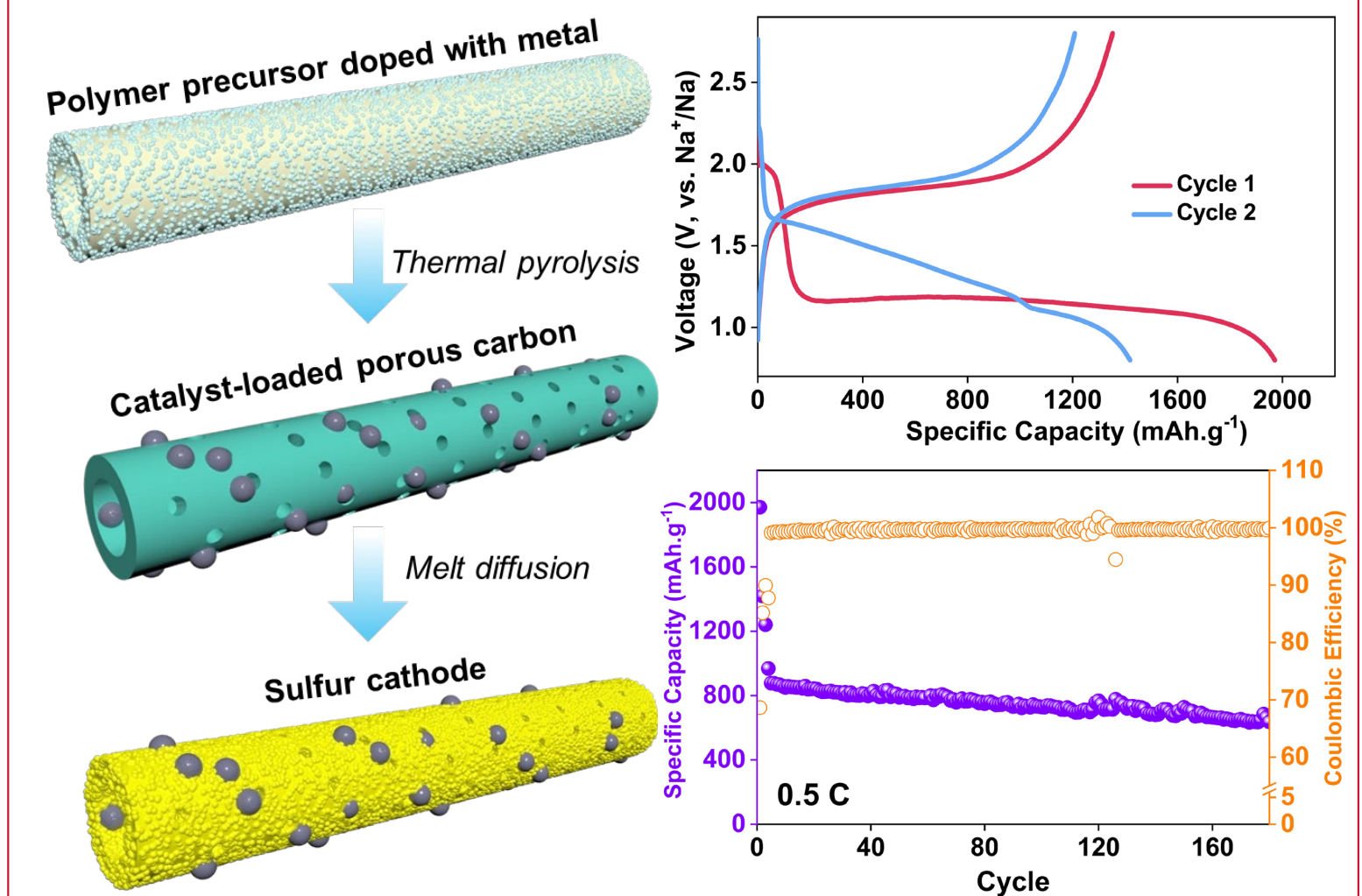
Schematics of the sulfur conversion as elucidated by X-ray tools during cycling.

Accomplishment II: Efficient sulfur host design for high specific capacity and long-cycle life Na-S batteries

(Manuscript under preparation)

We developed a novel carbon material with a highly microporous structure and a high surface area. Low-cost and earth-abundant metal atoms were doped at low atomic percentages as electroactive sites around pores to enhance the sulfur redox kinetic performance.

The resulting efficient carbon host, impregnated with 60 wt.% sulfur, exhibited a high efficiency (99%) and excellent discharge specific capacity (700 mAh.g⁻¹) after 100 cycles.



Synthesis procedure of polymer precursor doped with low-cost electrocatalyst metal, followed by sulfur impregnation; charge-discharge profiles of the first two cycles and the cycle life of the efficient carbon host over 180 cycles.

Project Status

Milestone	End Date	Status
Milestone-1: Establish baseline room temperature Na-S battery performance for techno-economic analysis	3/31/2025	Completed
Milestone-2: Develop and scale up the synthesis of non-noble nanomaterials for Na-S batteries	6/30/2025	Completed
Milestone-3: Design high specific capacity (800 mAh/g), high energy density (200 Wh/Kg), and long cycle life of 200 cycles Na-S batteries at low cost	9/30/2025	On track
Milestone-4: Develop and scale up fluorinated electrolytes for Na-S batteries	12/31/2025	On track

On-going and Proposed Work

- **Materials innovation** to boost the Na-S battery performance for grid energy storage.
- Cell design remodeling and efficient engineering to incorporate the **high-loading sulfur cathode**.
- **Machine-learning-accelerated** electrolyte development for high performance Na-S batteries.
- Utilize the **Grid Storage Launchpad** to validate high-performance Na-S batteries at scale.

Acknowledgment

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