

# Next-Gen Batteries from Fossil Fuel Precursors

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# Paul Scherrer Institute (PSI): A Quick Overview



## ETH Domain

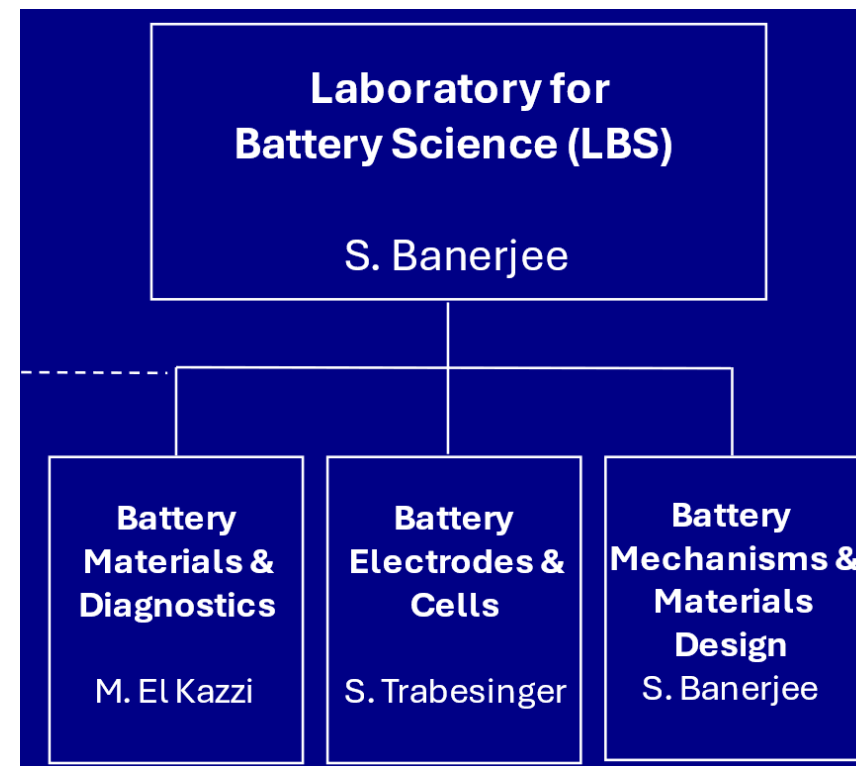


# Laboratory for Battery Science (LBS)



**VISION:** Our vision is to accelerate the energy transition through excellence in electrochemical energy storage research and innovation

**MISSION:** Our mission is to discover, design, and demonstrate advanced materials and electrochemical energy solutions for a sustainable energy future. We utilize and enhance cutting-edge experimental facilities to enable diversification of battery chemistries across a broad spectrum of applications. We educate a new generation of researchers to meet future needs of industry and society.





# Core Activities of the Laboratory for Battery Science



Research for high energy density, safer, *sustainable*, and long-lasting batteries!

## Materials & Electrode Design

- Design of active materials with emphasis on diversifying supply chains
- Advanced cathodes for high-energy Li-ion and Na-ion batteries including single crystals
- Negative electrodes with focus on Si/carbon composites and metal/alloy anodes
- Hydrocarbon-derived battery-grade structured carbon
- Hydrocarbon-derived additives, binders, and separators

## Interface Design

- Multifunctional additives for high-voltage Li-ion cathodes and metal anodes
- Coating, electrolyte and binder design for stable interphases
- Polymer multilayer and hybrid electrolyte interfaces
- Gas-evolution methodology development for interphase diagnostics

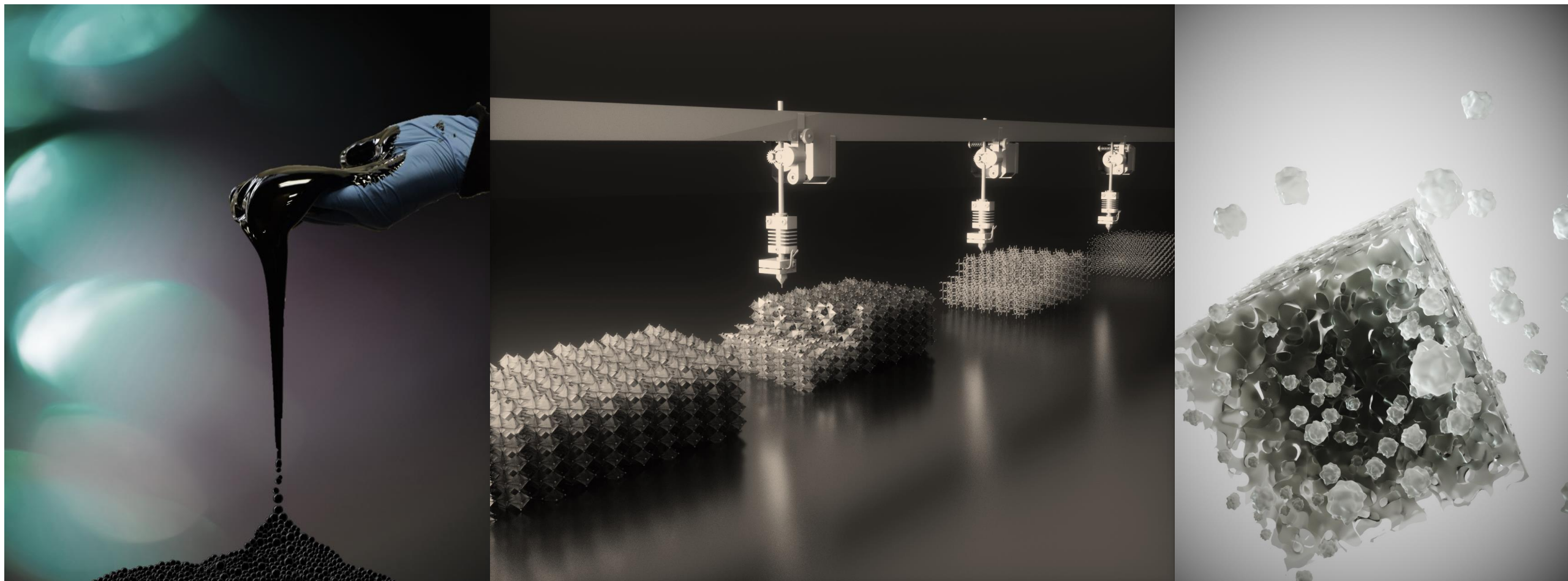
## Mechanisms, Failure Diagnostics, & Safety

- Mechanistic understanding of cell degradation and aging
- Cell aging and safety analytics and prognostics from electrode to battery management system
- SoC and SoH determination and cybernized batteries
- Post-mortem analysis and diagnostics

## Characterization Method Development

- Electrochemical methods
- Operando XRD, Raman, and FTIR
- Online Electrochemical Mass Spectrometry (OEMS)
- Electrochemical methods, Electrochemical Dilatometry
- Large facility operando methods for Neutrons, Muons, and X-rays



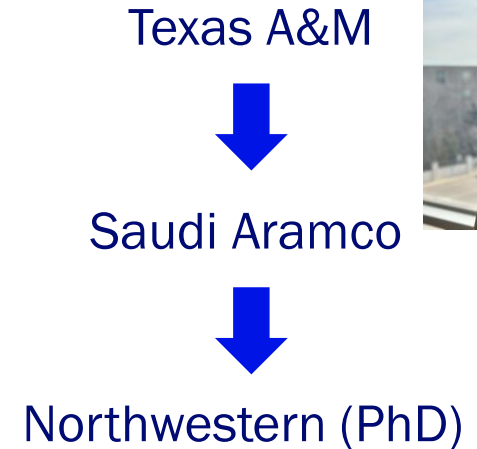


*to transform and upcycle fossil fuel fractions across diverse deposits –including low grade fuels and sulfur by-products -into battery grade carbon materials for next-generation technologies*

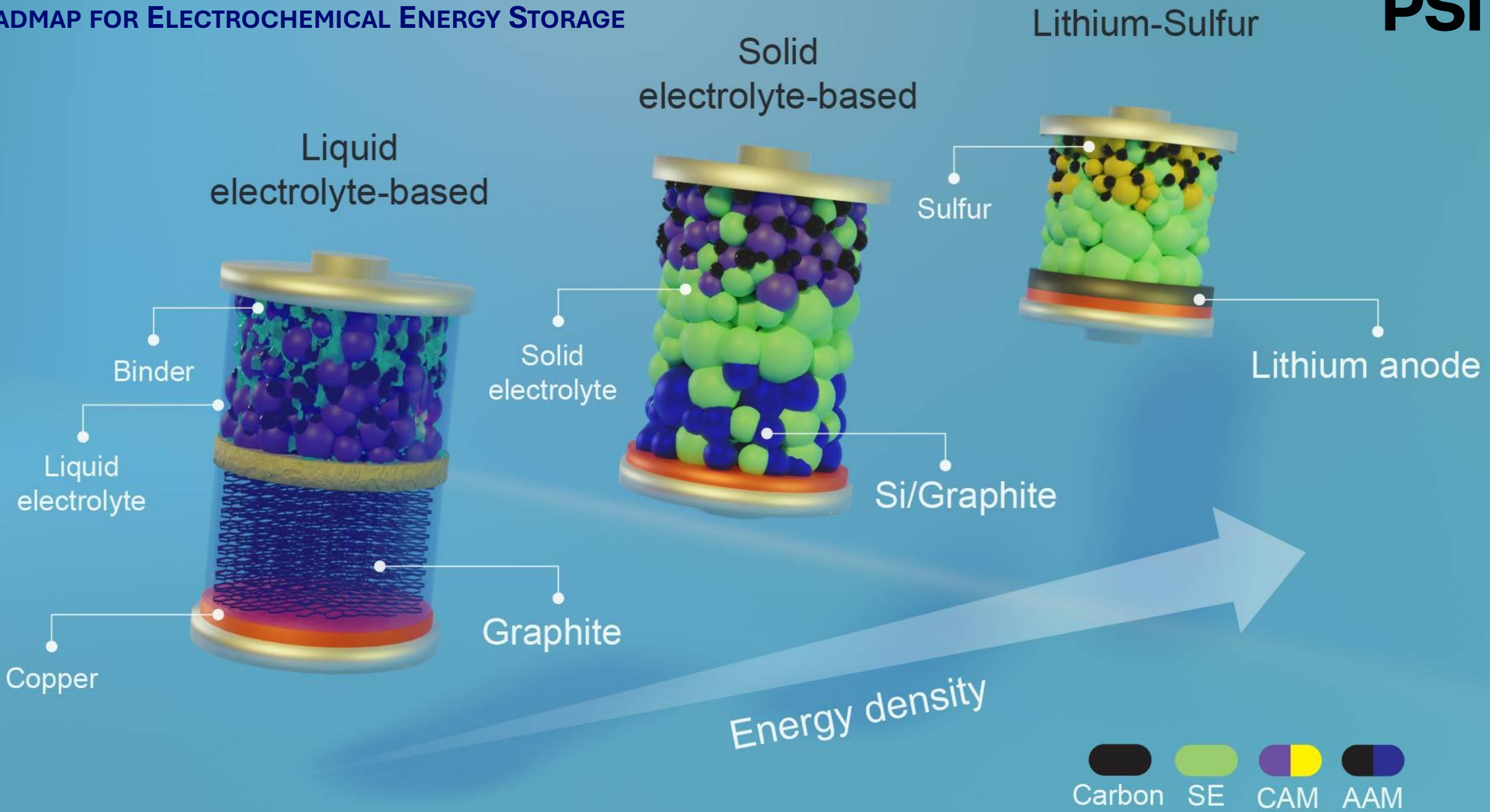
# Mechanisms of Collaboration



- Proof-of-concept projects to demonstrate viability
- Demonstrator projects at pouch cell level
- Embedding visiting scientists
- Collaborative supervision of Masters and PhD students at ETH Zurich
- Knowledge transfer
- Joint venture startups (Cenovus, PFP...)







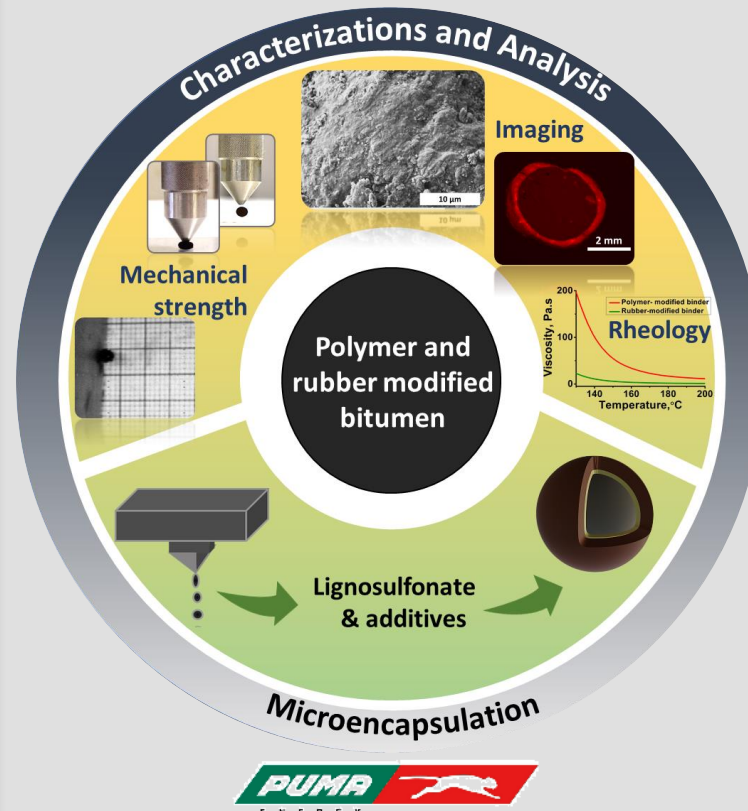
# ETH zürich Battery-Grade Carbon from Bitumen and Asphaltenes

## Bitumen and asphaltene-derived carbon microspheres

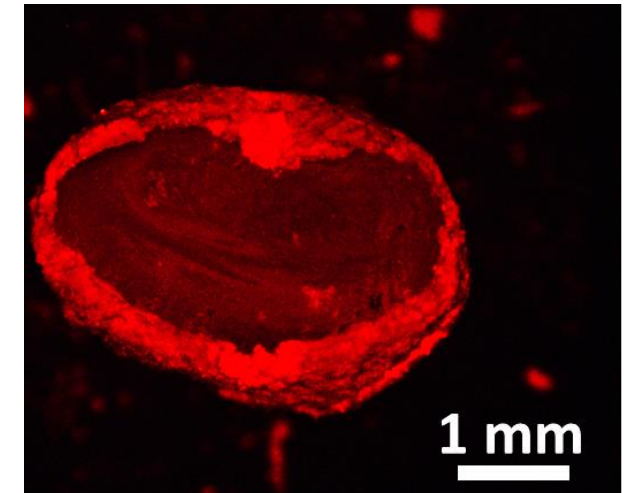
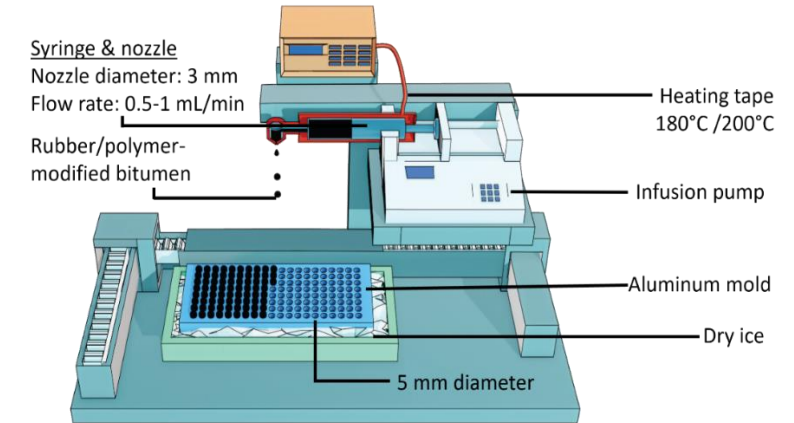


Patent Application No. US20220135885A1, Gupta, S., Anita., Banerjee, S., Zaheer, W. August 2022.  
 Anita., Zaheer, W., Jakhar, K., Antao, D.S., Gupta, S., Banerjee, S. *Fuel* **2021**, *302*, 121093.  
 Anita., Zaheer, W., Douglas, L., Sellers, D.G., Gupta, S., Banerjee, S. *Energy & Fuels* **2021**, *35*(8), 6576-6584.

## Rubber-modified bitumen as a porous carbon precursor

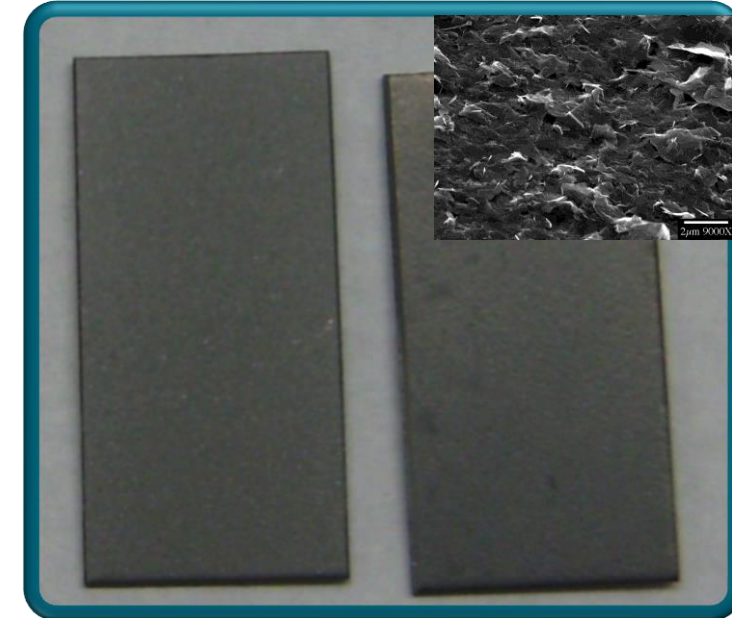
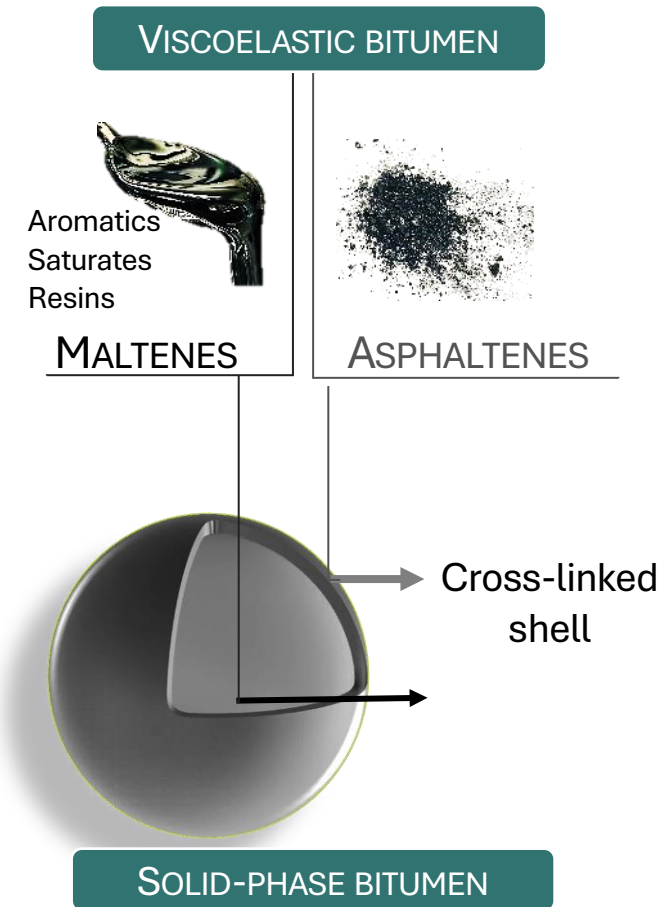
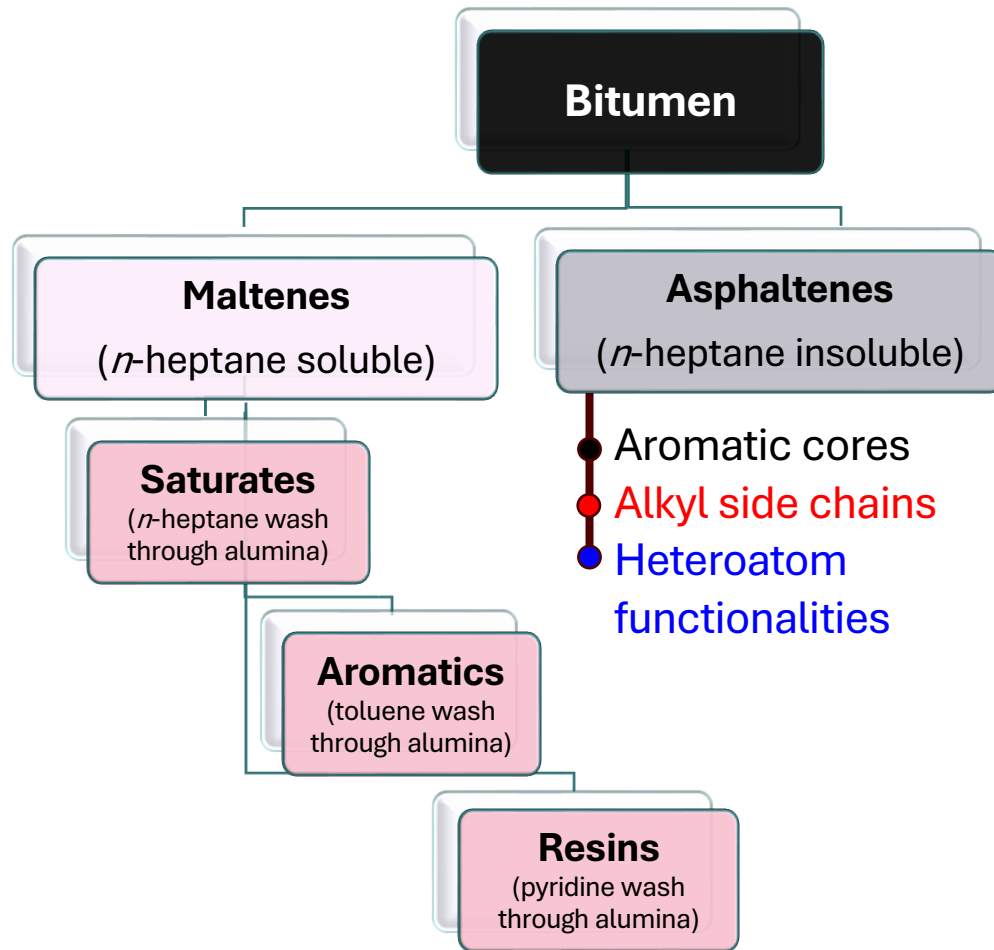


Disclosure ref. 6219TAMU23, Anita., Denneman, E., Banerjee, S. 2023.  
 Anita., Rivera-Gonzalez, N., Liu, G.W., Antao, D.S., Denneman, E., Banerjee, S.

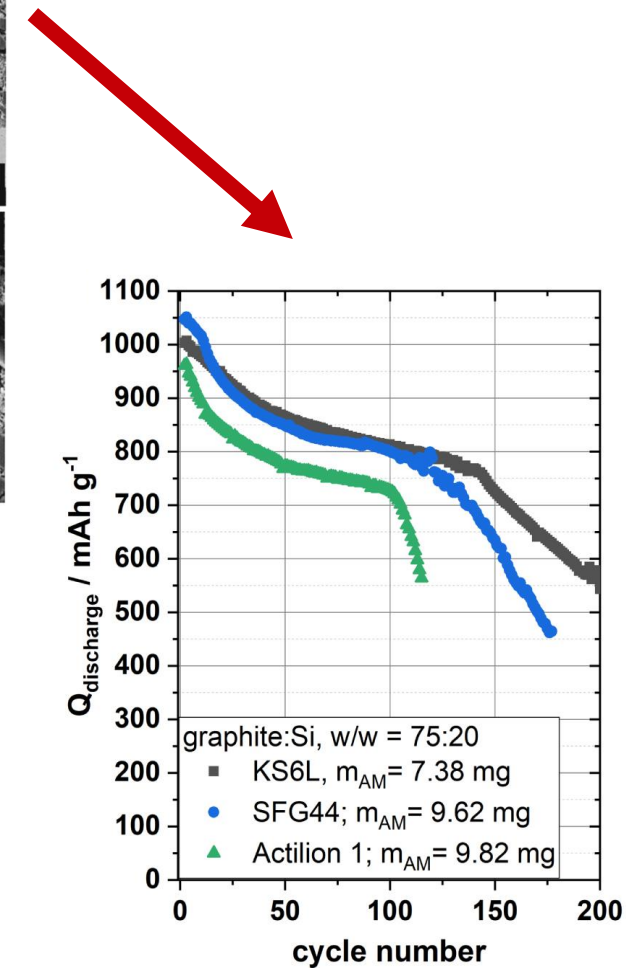
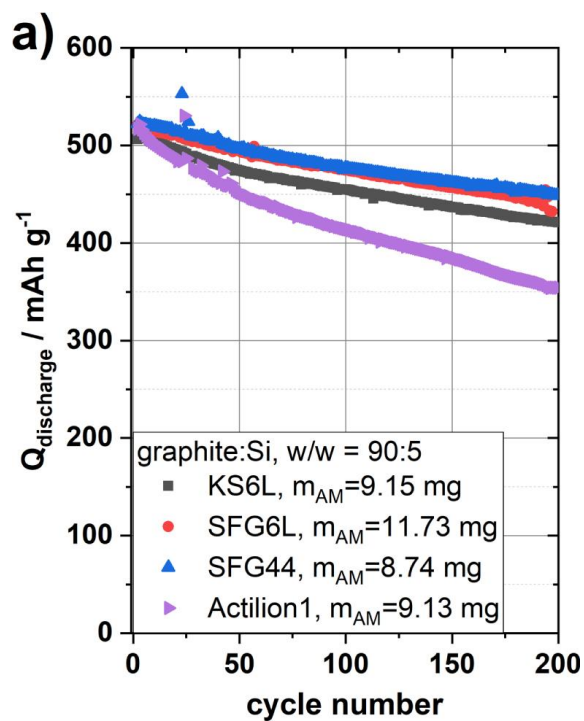
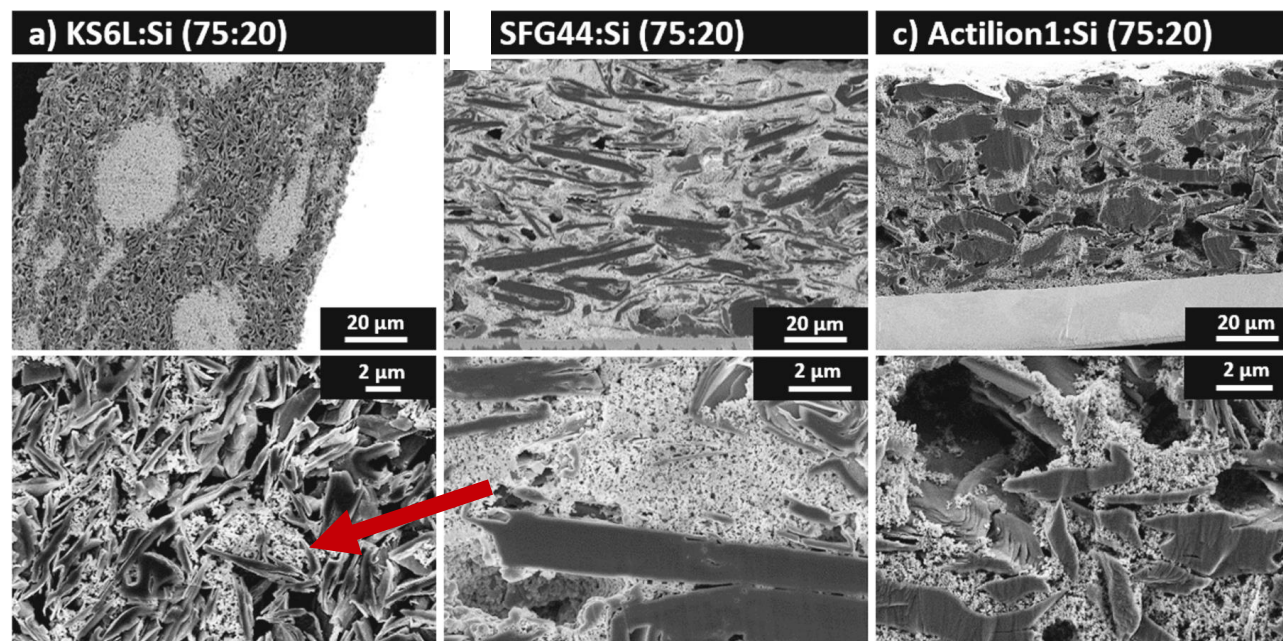




# Viscous Oil Graphitization & Flue Gas Solidification to Obtain Battery-Grade Carbon



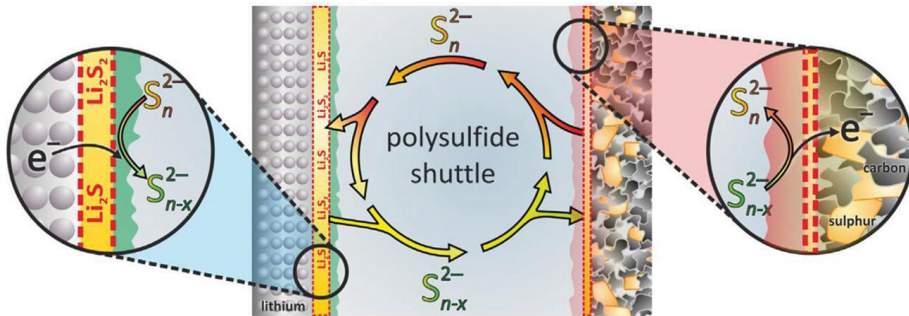
# Electrode design – Graphite/Si containing anodes



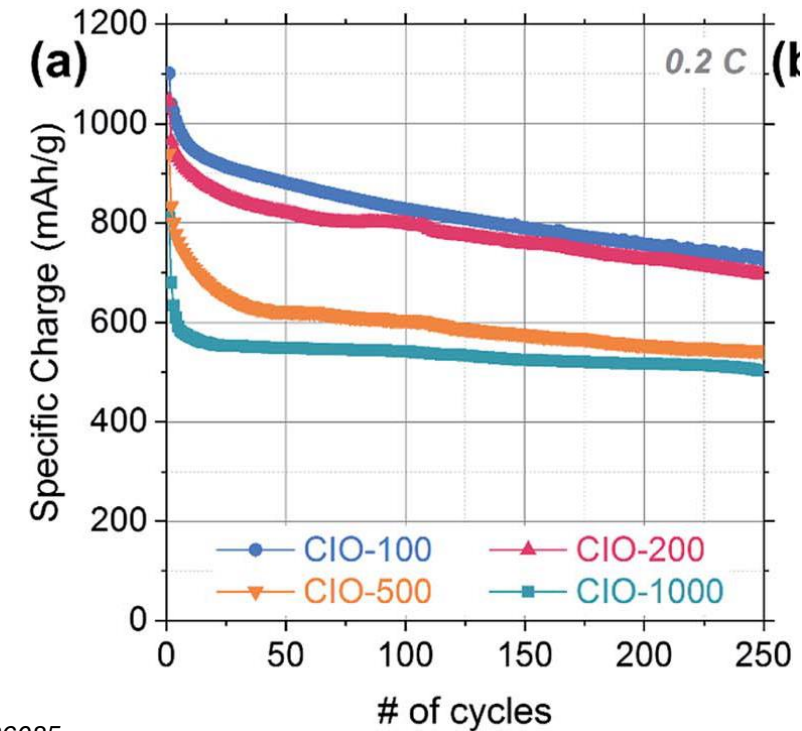
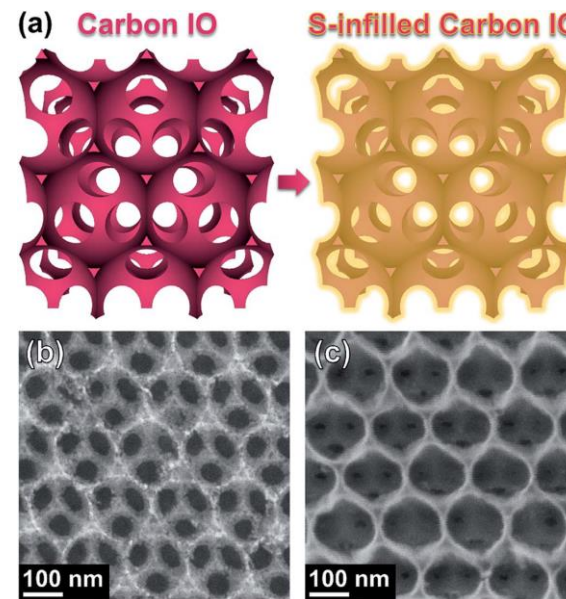
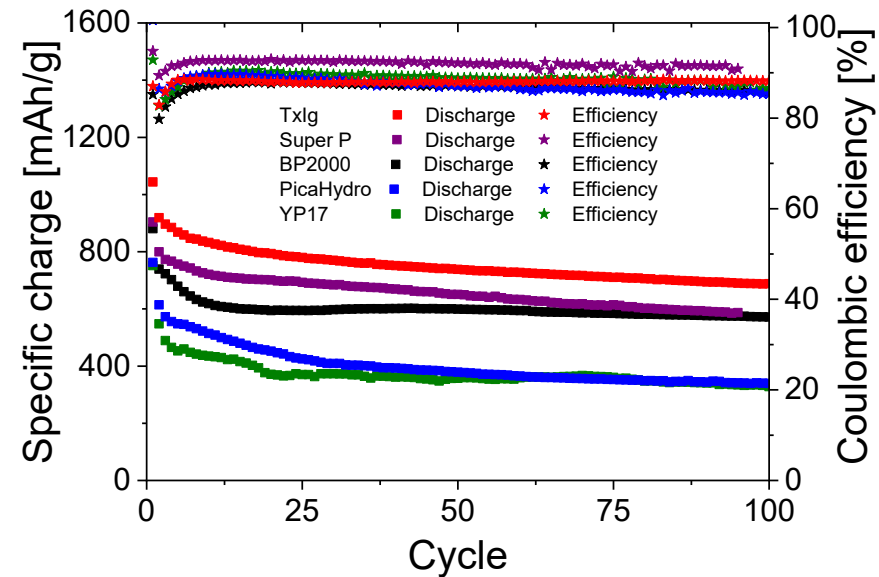
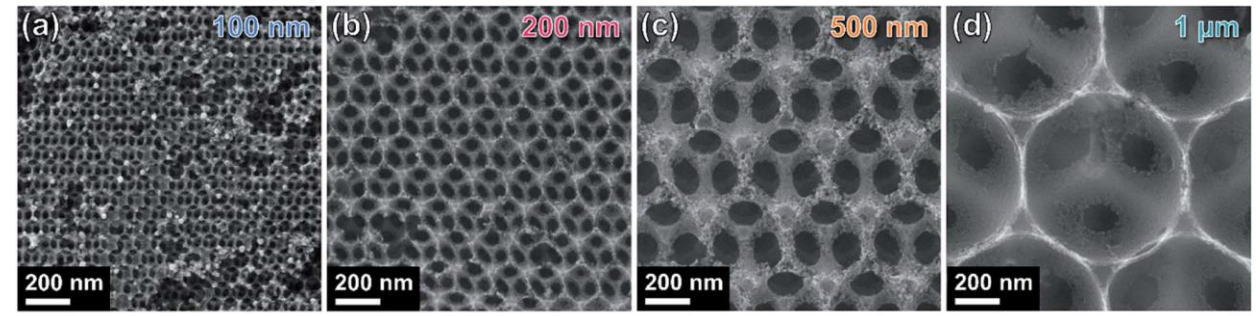


# Carbon Matrix Effect – Li Sulfur batteries

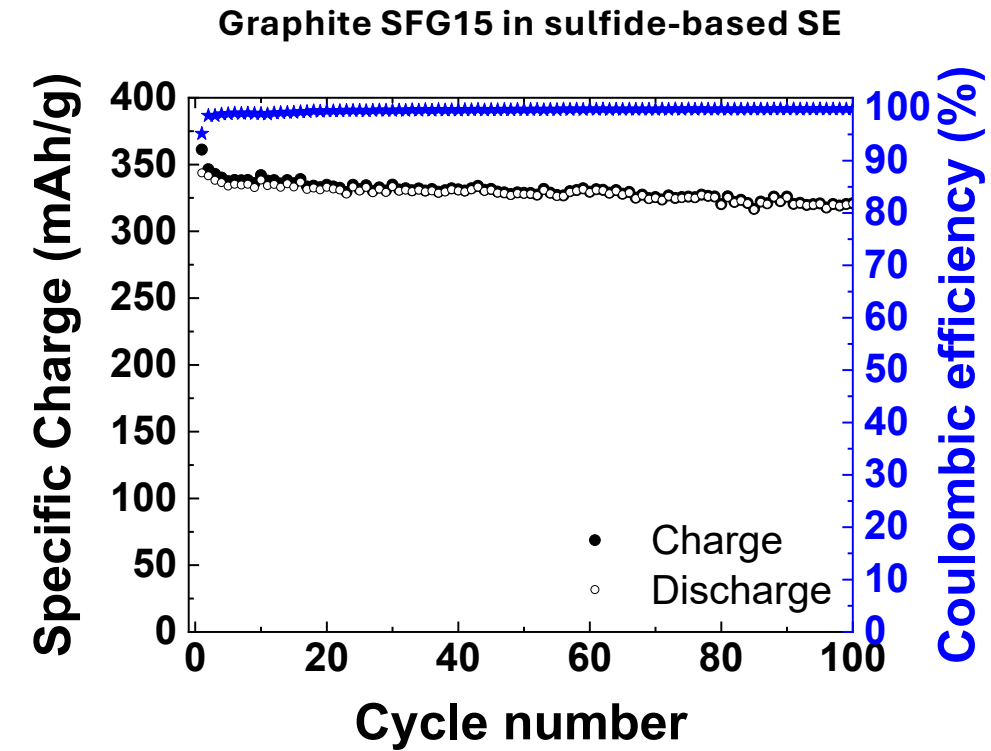
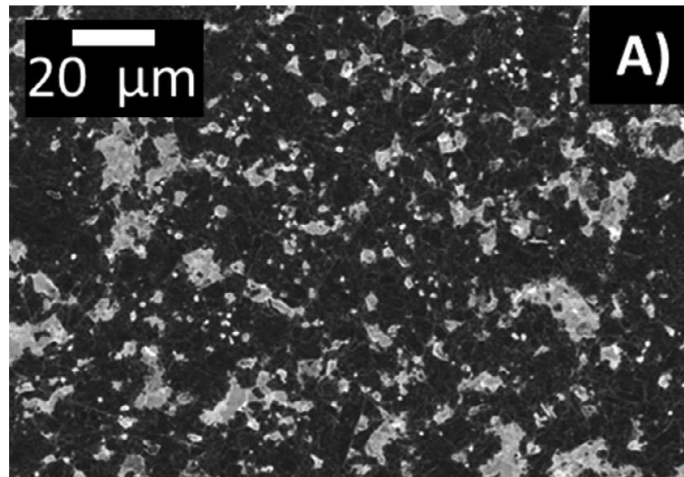
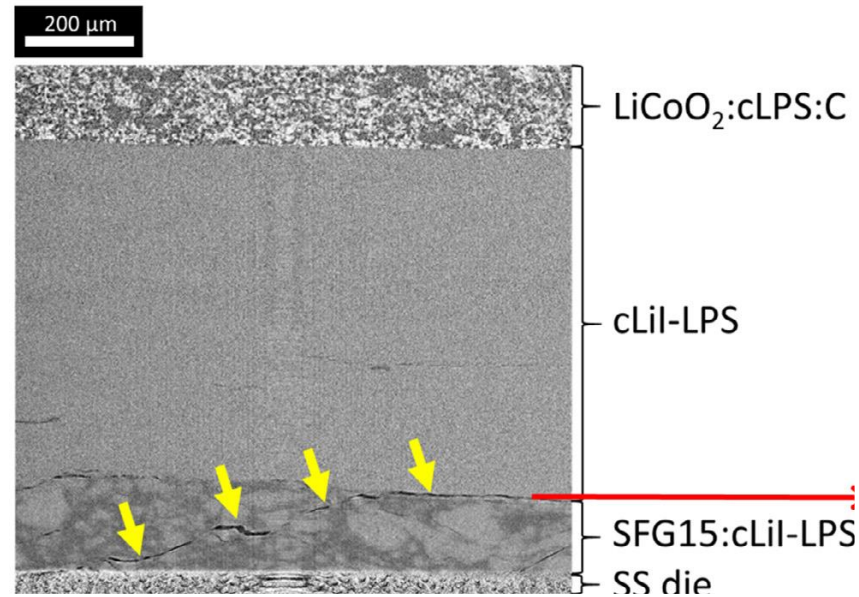
## Importance of sulfur host structural



M. R. Busche, et al., *J. Power Sources* **2014**, 259, 289.



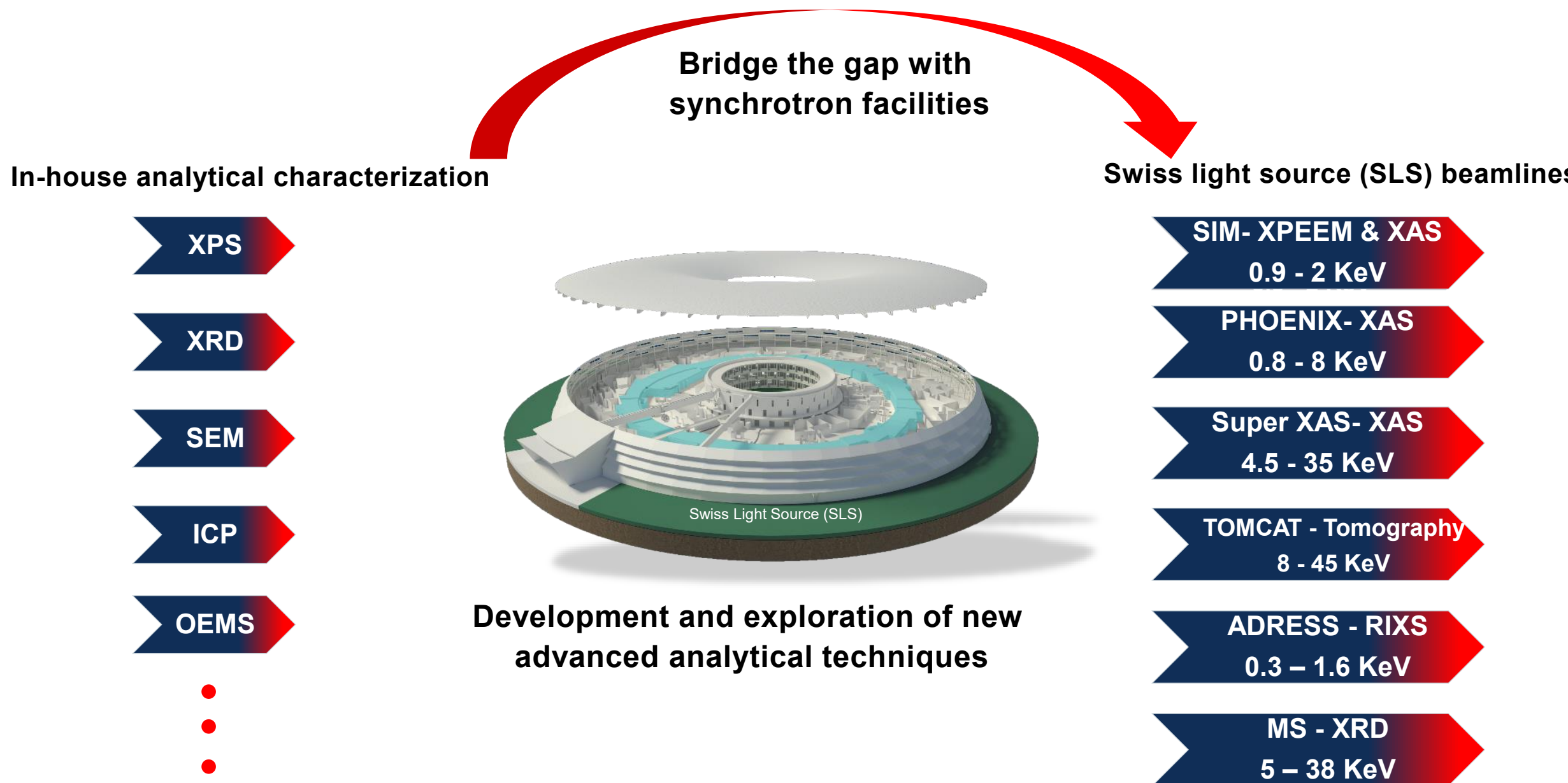
# Graphite cycling performances in all-solid-state battery



Laura Höltzsch et al., *J. Electrochem. Soc.* **167** 110558 (2020)



# Advanced *ex-situ* or *operando* techniques at PSI



## PSI Facilities

## Large scale/ SLS & SINQ





# PSI's capabilities bridging battery chemistries, scales, and formats



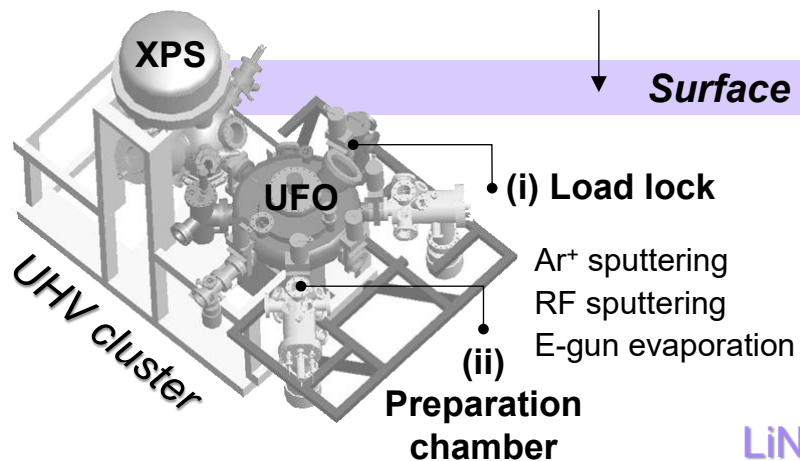
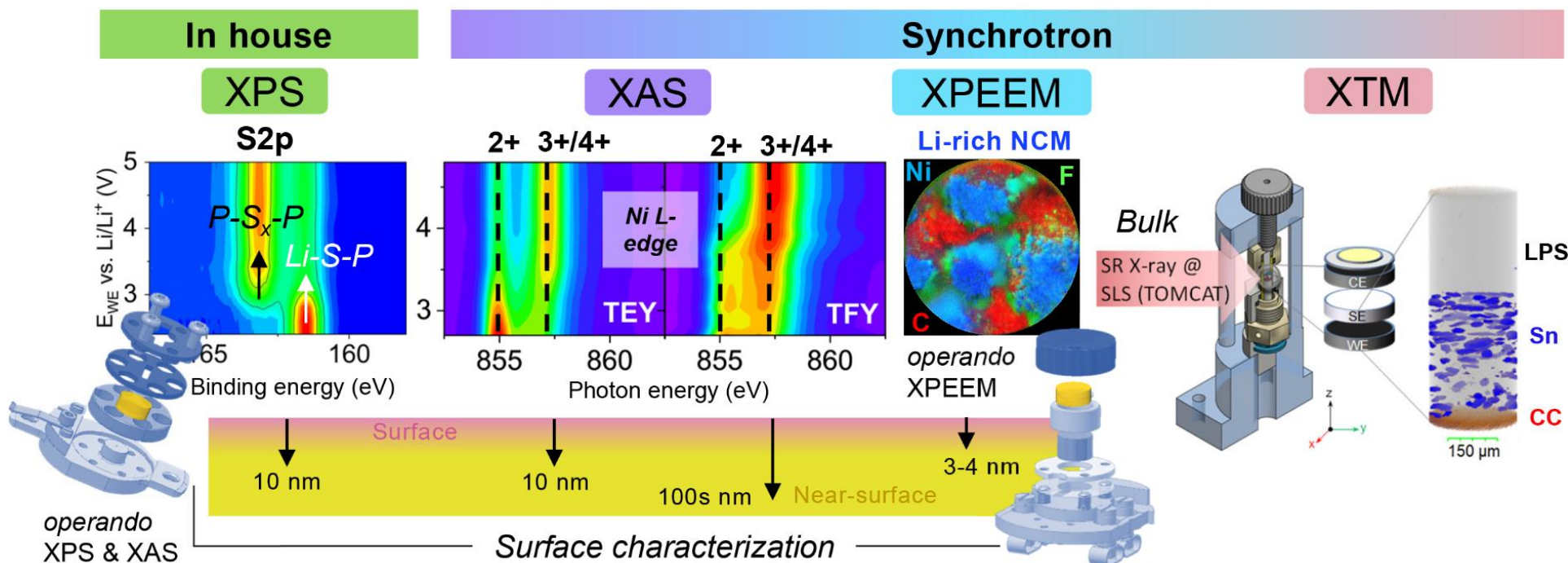
Cycling  
performance

Custom-made cells:

**Generation 1**

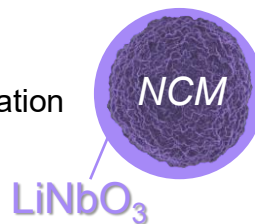


**Generation 2**

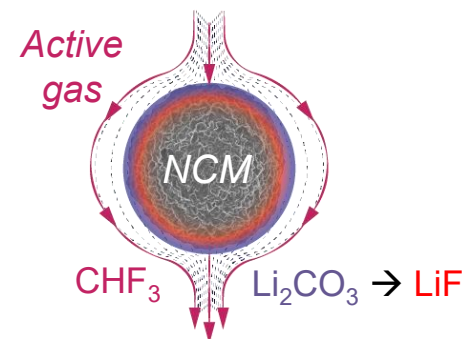


**Surface engineering**

Sol-gel  
coating

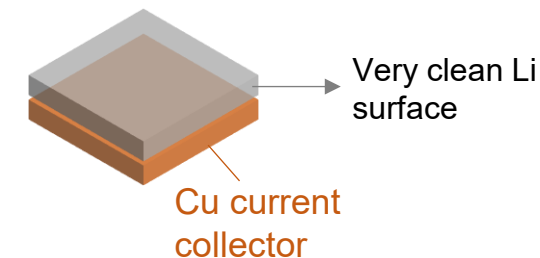


Gas flow reaction

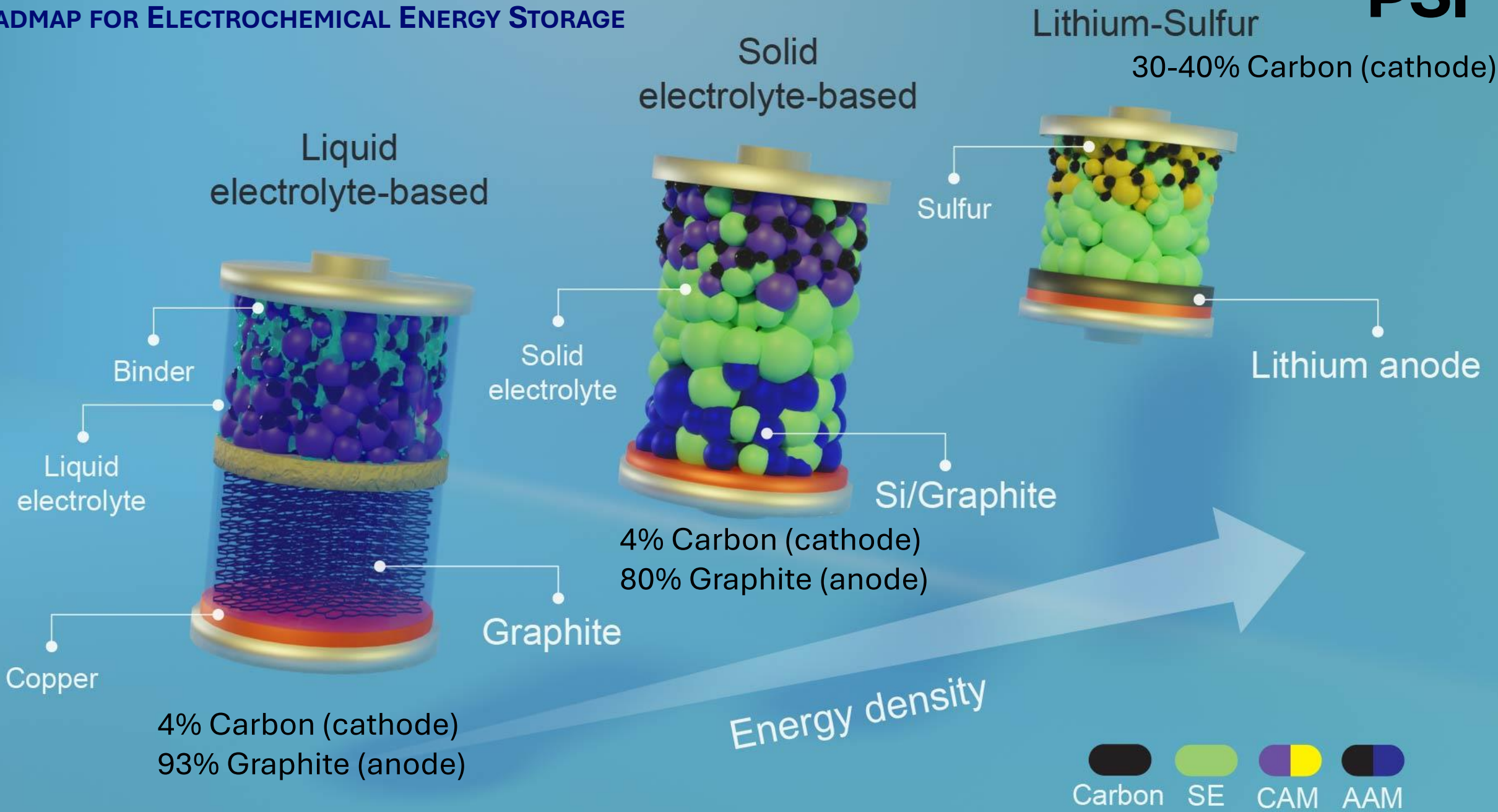


**Li evaporation**

Thin Li films



ROADMAP FOR ELECTROCHEMICAL ENERGY STORAGE

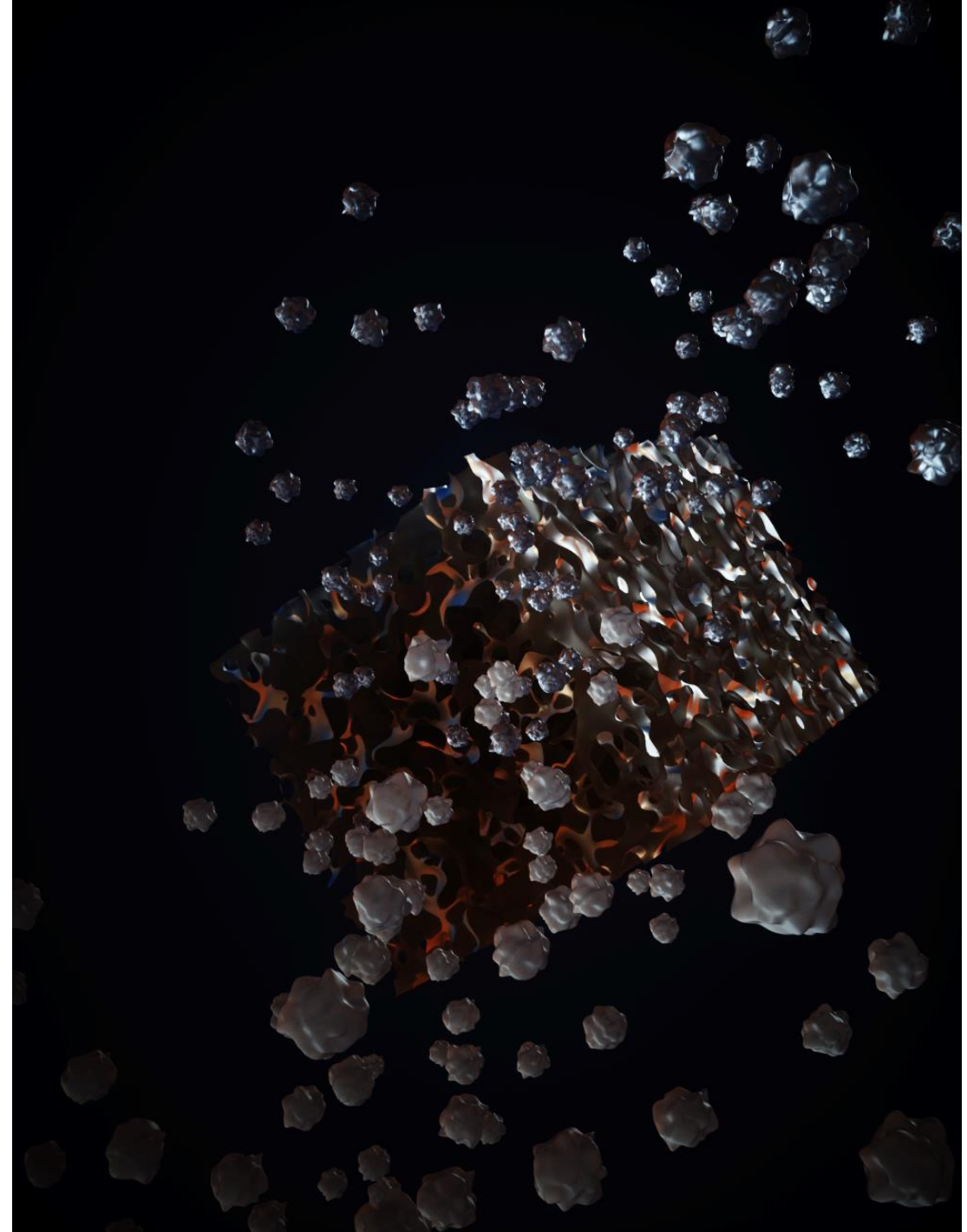




# Core Pitch

*LBS will transform and upcycle fossil fuel fractions across diverse deposits –including low grade fuels and sulfur by-products into battery grade carbon materials for next-generation technologies*

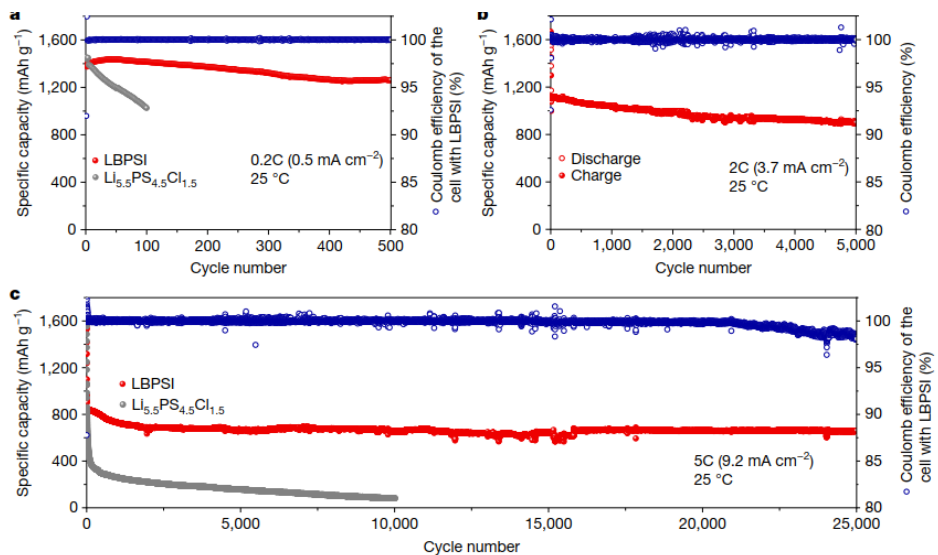
- Carbon additive for cathode and anode active composite
- Graphite and hard carbon for lithium and “beyond lithium” technologies
- Graphite/silicon composites with tailored mesoporous carbons
- Next-generation matrix for Li/S and Na/S as well as Li/air



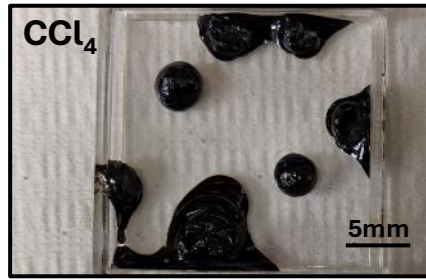
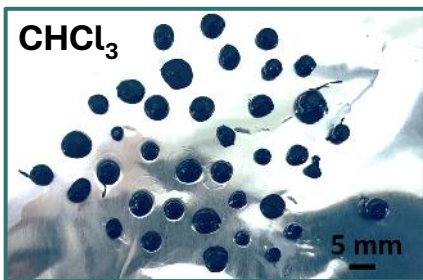
# Long term collaboration project on sulfur all-solid-state battery embedding fossil-fuel-derived carbon



## All-solid-state Li-S batteries with fast solid-solid sulfur reaction

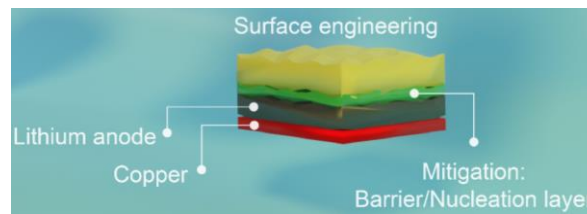
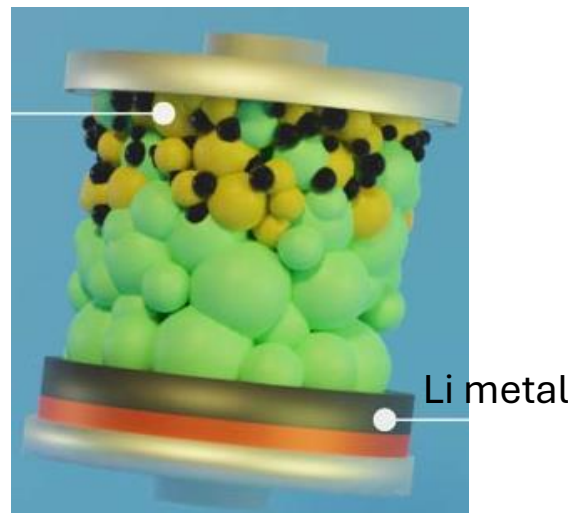


Huimin Song, *Nature* volume 637, pages846–853 (2025)

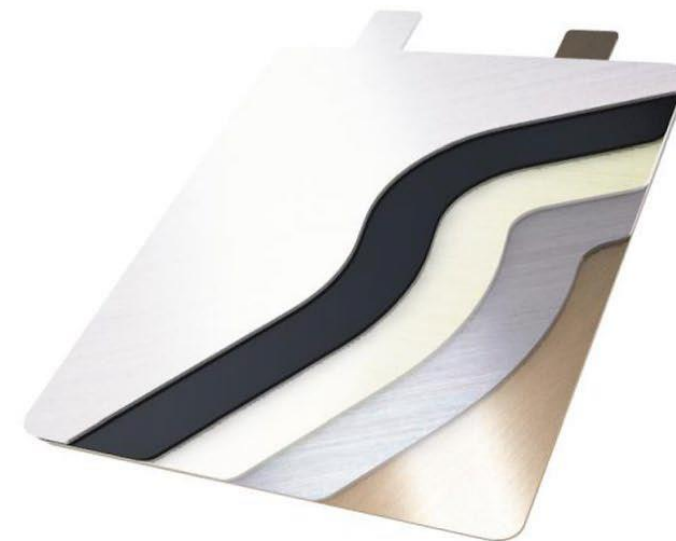


## Reproduce the excellent performance

**Fossil fuels and sulfur by-products provided by Aramco**



## Pouch cell demonstrator



Yong-Gun Lee et al., *Nature Energy* volume 5, pages299–308 (2020)

Textured carbon and sulfur from fossil fuel fractions