Zinc Sulfur Systems for Low Cost Safe Long Duration Energy Storage

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PROJECT PROFILE

Topic: Zinc Batteries | Vertical: Materials & Systems Innovation

Strategic Pathway: **Grow**

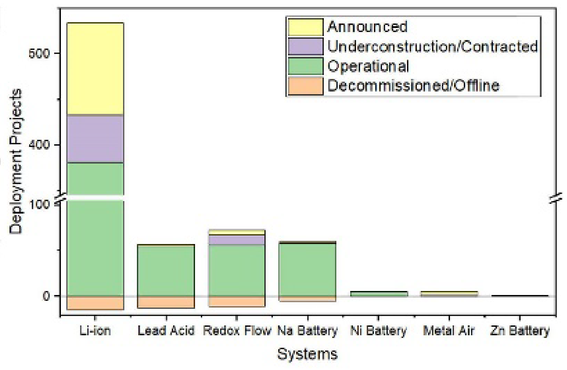
Project start and finish: FY26-FY28

PROBLEM

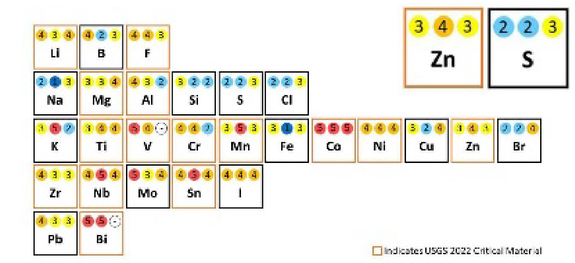
Lithium-ion batteries dominate the current market for grid scale battery energy storage systems (BESS) but are a source of continuing concern due to flammability, cost, and supply chain limitations.

~80% of in-construction and operational BESS are based on Li-ion technology.

Older technologies (lead acid, NaS) make up the largest non-Li-ion systems, but many are being decommissioned.



Garrett P. Wheeler, Lei Wang, Amy C. Marschilok. Beyond Li-ion Batteries for Grid-Scale Energy Storage. *Elements in Grid Energy Storage*. **2022**, ISBN: 9781009030359. Publisher: Cambridge University Press. Editors: Babu Chalamala, Vince Sprenkle, Imre Gyuk, Ralph D. Masiello, Raymond Byrne.



Key	Value #1: Combined Global Supply Chain Indicator — World Reserves	Years to Economic Depletion	HHI (market concentration)	Value #2: Combined Domestic Supply Chain Indicator — U.S. Reserves	Percent Reliance on Net Imports	Value #3: Combined ESI Indicator — Disability Adjusted Life Year [DALY/MT]	Terrestrial Ecosystem Damage (Species year/MT)
1 pt.	>1 billion MT	>1 million years	<1500	>1 billion MT	Net Exporter	NA	<NA
2 pts.	>1 billion MT	>100,000 years		>10 million MT	<50%	<0.01	<0.001
3 pts.	>100 million MT	>1000 years	<2500	>1 million MT	<75%	<0.1	<0.01
4 pts.	>10 million MT	>100 years		>100,000 MT	<90%	<0.5	<0.1
5 pts.	<10 million MT	<100 years	>2500	<100,000 MT	>90%	<1	<1

To avoid mistakes of the past, supply chain and societal implications of new batteries should be considered early during technological development.

Identifying a diverse slate of potentially abundant materials is a critical first step for satisfying future battery energy storage system needs.

V.L. Putsche, J. Pattany, T. Ghosh, S. Atnoorkar, J. Zuboy, A. Carpenter, E.S. Takeuchi, A.C. Marschilok, K.J. Takeuchi, A. Burrell, M.K. Mann, *Front. Sustain.*, **2023**, *4*, 1287423.

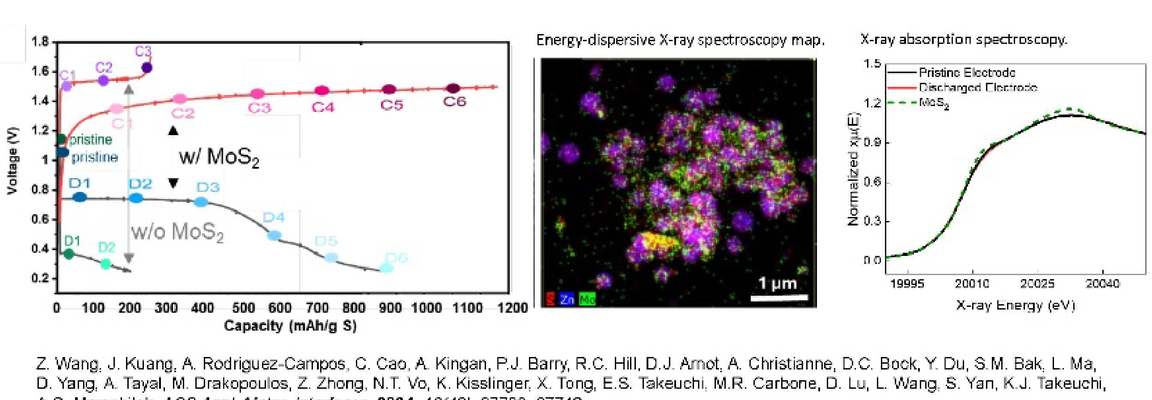
APPROACH

This program is investigating aqueous zinc sulfur (Zn/S) batteries for low cost safe long duration energy storage based on sustainable materials.

Anode	Active Material Cost
Zinc	$3/kg
Lithium	$80/kg

Cathode	Theoretical Specific Capacity	Active Material Cost
Sulfur	1675 mAh/g	$0.6/kg
LFP	170 mAh/g	$12/kg
NMC811	197 mAh/g	$30/kg

Recent results from our DOE Basic Energy Science program have shown MoS_2 to be an effective catalyst for the Zn/S reaction, lowering the overpotential for Zn + S ⇌ ZnS conversion (L), serving as a surface site for ZnS reduction product formation (C), without any change in Mo oxidation state (R).



Z. Wang, J. Kuang, A. Rodriguez-Campos, C. Cao, A. Kingan, P.J. Barry, R.C. Hill, D.J. Arnot, A. Christianne, D.C. Bock, Y. Du, S.M. Bak, L. Ma, D. Yang, A. Tayal, M. Drakopoulos, Z. Zhong, N.T. Vo, K. Kisslinger, X. Tong, E.S. Takeuchi, M.R. Carbone, D. Lu, L. Wang, S. Yan, K.J. Takeuchi, A.C. Marschilok, *ACS Appl. Mater. Interfaces*, **2024**, *16(49)*, 67730–67742.

This DOE OE program is focused on three tasks:

Task 1 Optimize electrode composition and formulation

Task 2 Optimize electrolyte composition including the role of additives

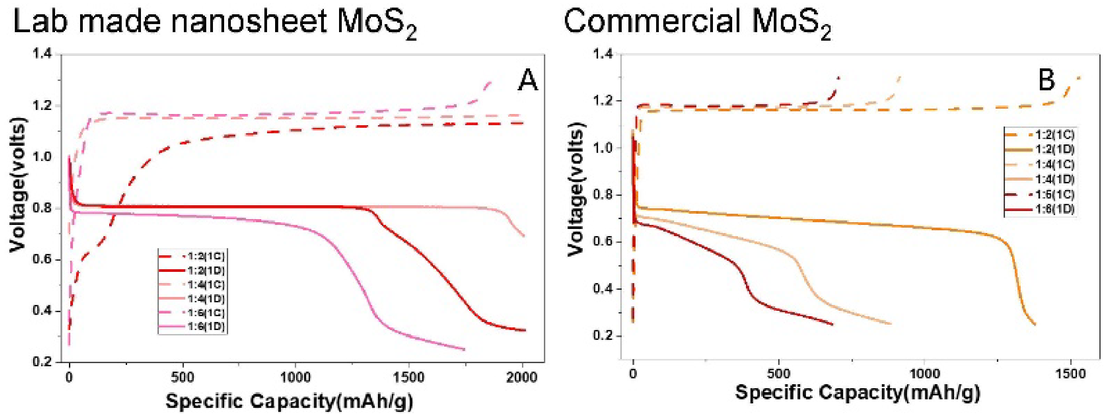
Task 3 Scale up the selected cell to demonstrate viability in a larger form factor

3 year program, $300 K – end September 2028

RESULTS

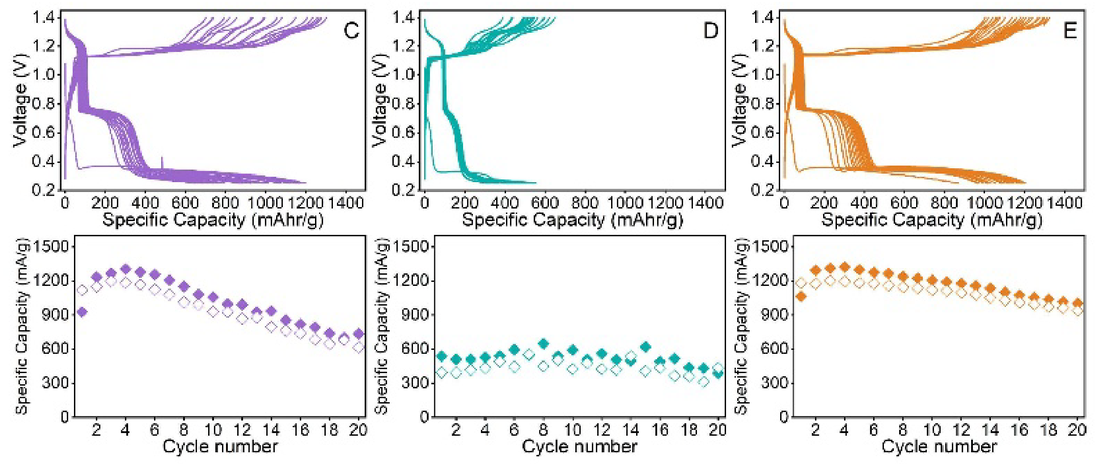
Task 1. Electrode composition

Lab made nanosheet MoS_2 — Commercial MoS_2



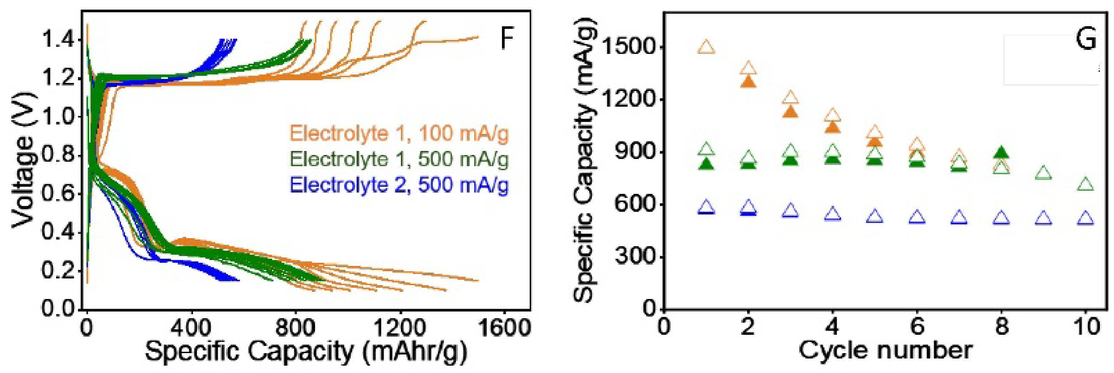
Task 2. Electrolyte composition

Coin cells, Various electrolyte compositions

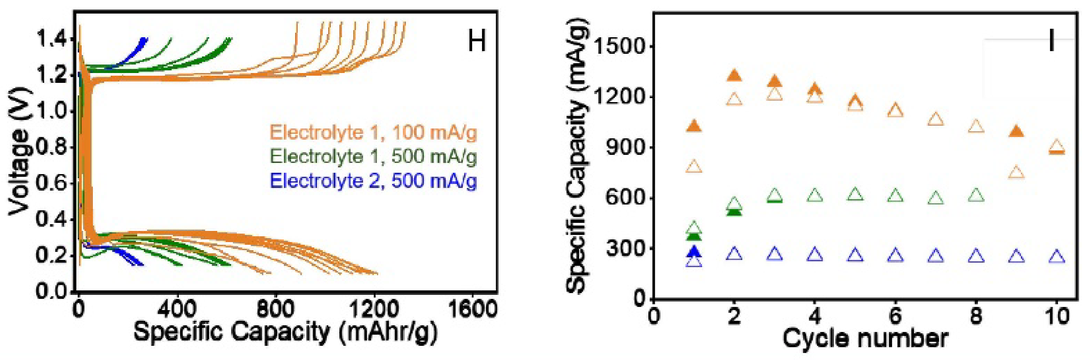


Task 3. Transition to larger form factors

Pouch cell, Lab made nanosheet MoS_2



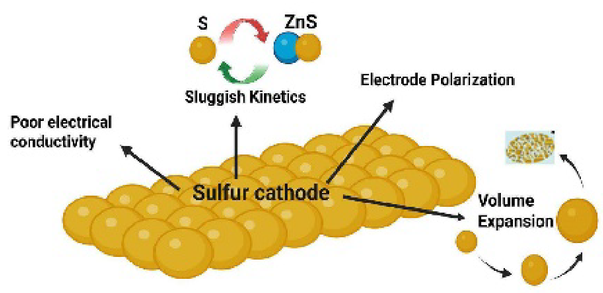
Pouch cell, Commercial bulk MoS_2



CONCLUSIONS & IMPACT

By overcoming the sluggish kinetics, and poor electrical conductivity of the sulfur electrode, we can achieve a safe, low cost, long duration energy storage energy storage system.

Optimizing the electrode composition and electrolyte will be critical.



FUTURE DIRECTIONS

- Investigate lower cost battery components.
- Understand impact of formation cycling on long term battery behavior.
- Define optimization in terms of tradeoffs of cost and functionality.

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