Soft Shorts and Other Pernicious Problems in Zn-Ion Battery Research

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PROJECT PROFILE
Topic: Zinc & Lead Batteries | Vertical: Materials and Systems Innovation | Strategic Pathway: Grow
Project start and finish: FY25-FY26

PROBLEM

Zinc batteries are a promising technology for grid-based energy storage.

- Inexpensive, nontoxic, nonflammable, US-based supply chains
- Incorporation into the grid will improve reliability and is important for emerging technologies (*e.g.* AI data centers)

Currently, zinc batteries use alkaline electrolytes, but mildly acidic electrolytes may enable better reversibility at higher capacity (increased energy density and cycle life).

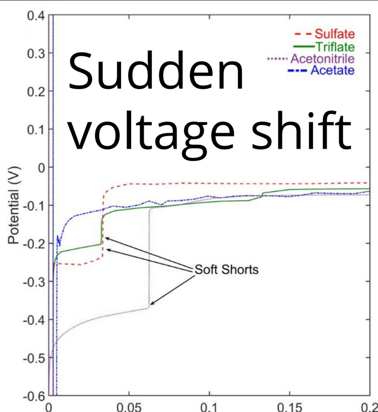
Precise mechanism of cycling (such as role of ZHX) is unclear in these electrolytes. Recent reports[1] have also shown that common test-designs (*e.g.* symmetric cells) may predict higher performance than can be achieved due to soft shorting.

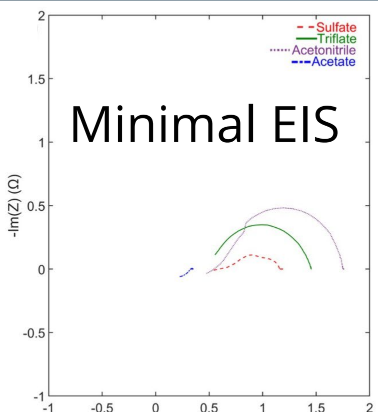
APPROACH

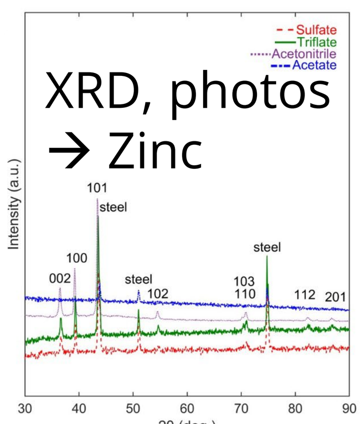
Zinc symmetric and asymmetric cells with various electrolytes are studied to understand the extent of soft shorting in the testing space.

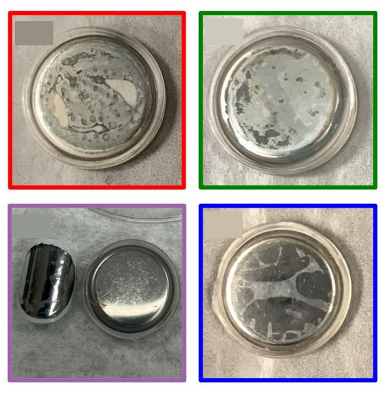
Cryogenic femtosecond laser cross-sectioning with SEM-EDS, which was developed at Sandia National Labs and recently demonstrated for Li-ion coin cells for the first time[2], is applied to understand the interphases that form in Zn-ion batteries.[3]

RESULTS

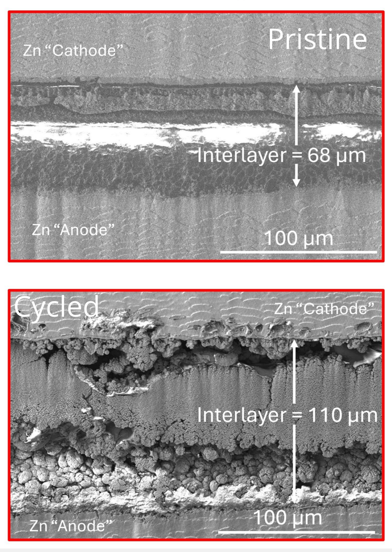




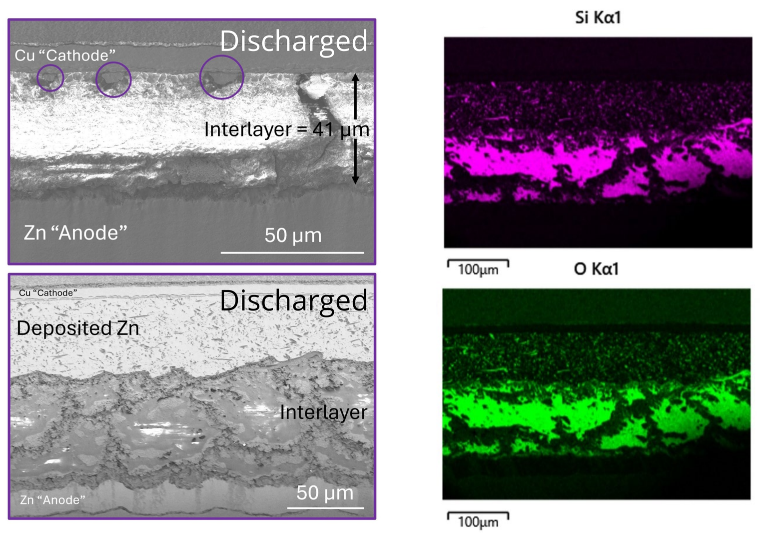




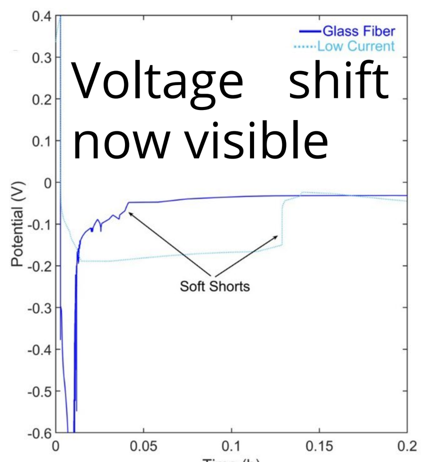
Zinc/steel cell data: quick shorting (except for acetate?)

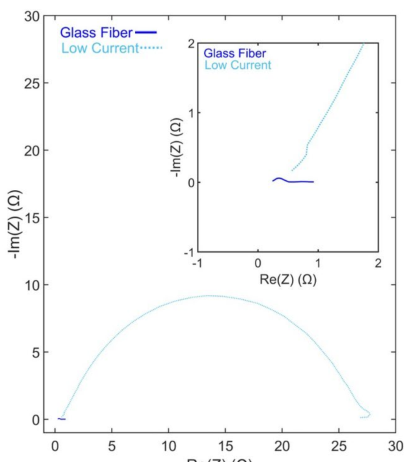


CryoFIB reveals considerable corrosion with sulfate electrolyte – even as built



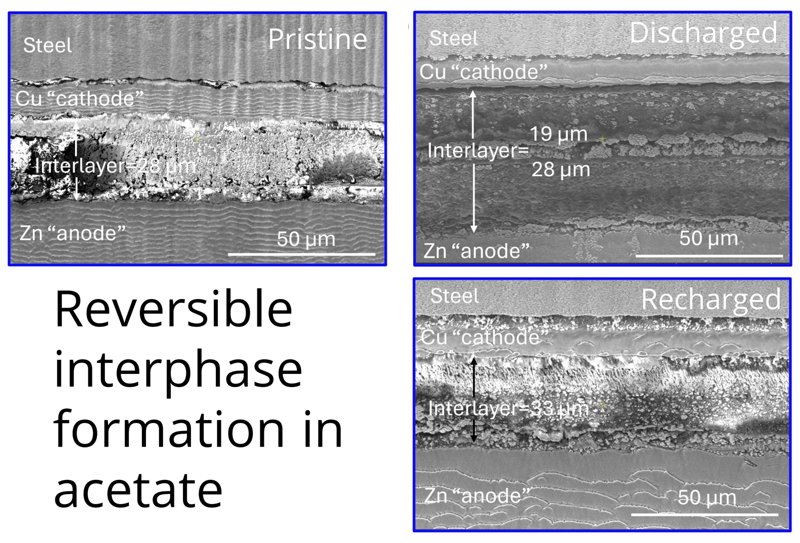
Channels in separator after discharge → Soft shorting visualized with cryoFIB



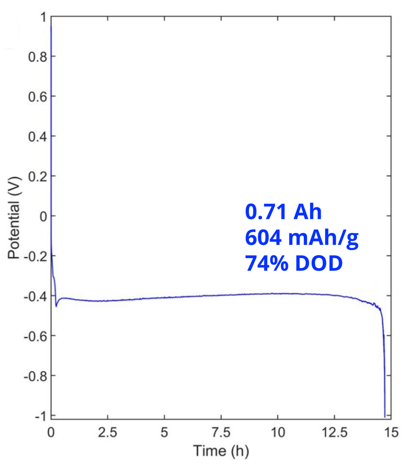


Soft shorting now detectable for acetate. Soft shorting can occur quickly, transience may "fool" EIS.

RESULTS *cont.*

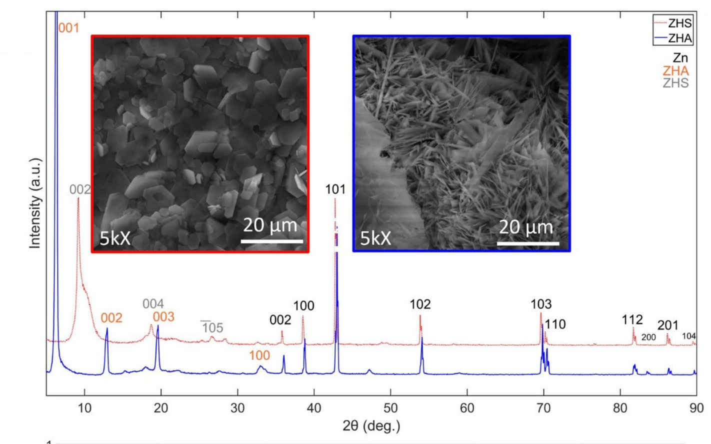


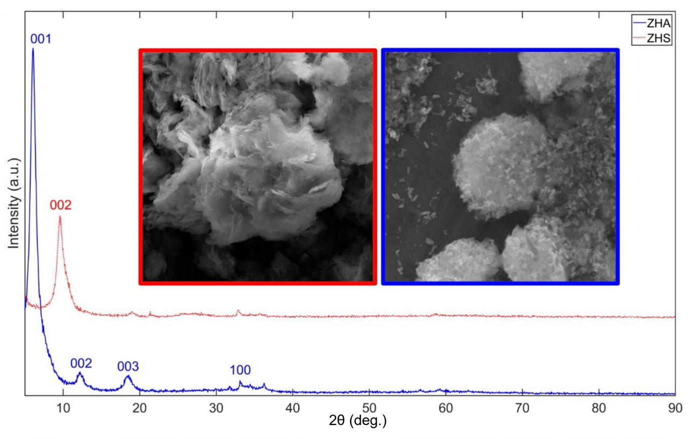
Reversible interphase formation in acetate

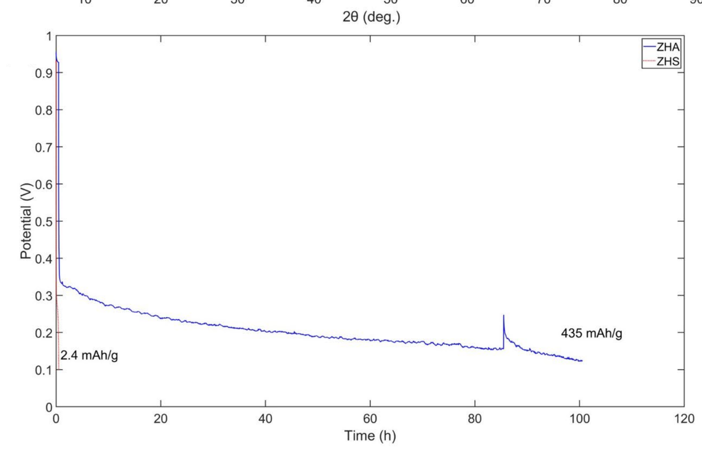


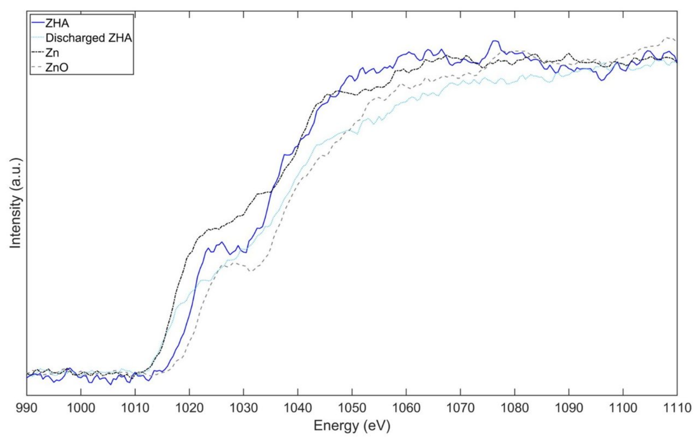
Acetate can plate zinc with significant separation suggesting potential for re-design

Gassing occurs, stops if cell shorts









ZHA/ZHS can form *in situ* or through synthesis. ZHA can be reduced *vs* zinc while ZHS cannot.

CONCLUSIONS & IMPACT

Soft shorts represent a major, and understudied, problem and this work further highlights their severity:

- Soft shorts may occur near instantaneously
- Transient nature means even EIS detection can be challenging
- They may also hide problematic gassing behavior

Reversibility of ZHX species is anion dependent which has significant implications for electrolyte engineering.

Properly understanding symmetric cell results is critical for using those results to inform larger-scale studies. These findings suggest that physical verification of zinc transport through mass balance is a best practice for verifying symmetric cell performance. CryoFIB shows great promise in the direct observation of soft shorts.

FUTURE DIRECTIONS

Best practices identified are being implemented in the new Storage Innovations project which plans to use extensive symmetric cycle testing to identify beneficial levels of pressure for performance.

The structure and electrochemical reversibility of different ZHX materials, associated with common electrolytes, is being investigated through an ongoing project.

References

(1) Li, Q. and Zhi, C. *et al. Joule*, **2022**, *6*, 269-279.
(2) Jungjohann, K. L. and Harrison, K. L. *et al. ACS Energy Lett.* **2021**, *6*, 2138-2144.
(3) Quilty, C. D. and Lambert, T. N. *et al. In review.*

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