Solving Zinc Dendrite Formation on Anodes through Controlled Cation–Anion–Solvent Interactions

Dan Thien Nguyen,* David J. Bazak, Hannah F. Chang, Ajay Karakoti

Pacific Northwest National Laboratory

PROJECT PROFILE
Topic: Zinc & Lead Batteries | Vertical: Materials and Systems Innovation.
Strategic Pathway: **Grow:** Long-term expansion by enabling innovation, advancing new technologies, and building capacity for a future-ready electricity system.
Project start and finish: FY24-FY26

PROBLEM

AZB STATIONARY ENERGY STORAGE

- **Safer by design** — Nonflammable, water-based electrolytes reduce fire risk
- **Low cost & scalable** — Zinc is Earth-abundant, and widely available
- **High power & fast kinetics** — Aqueous ion transport enables superior rate performance

CURRENT TECHNICAL BOTTLENECKS

- **Zn dendrite** — Non-uniform plating/stripping, dendrite growth
- **Hydrogen evolution** — Parasitic water splitting, gassing
- **Material degradation** — Zinc corrosion Cathode dissolution
- **Stability limits** — Narrow "effective" electrochemical stability window

DESIRABLE TECHNICAL INNOVATIONS AND AREAS

- **Zinc metal** — Guide uniform Zn deposition to suppress dendrite
- **Electrolyte/ Additive** — Improve electrode reversibility, temperature stability
- **Cathode Materials** — Discovering new materials, new catalysts or electrode architectures
- **Separator Innovations** — Reducing the levelized cost of storage

THE VITAL ROLE OF ELECTROLYTE ENGINEERING

- **Interface engineering** — Stabilizes interface by forming robust interphases
- **Expanding electrochemical window** — Expanded electrochemical range for increased energy density
- **Operation range** — Excellent conductivity and functional across a broad temperature spectrum

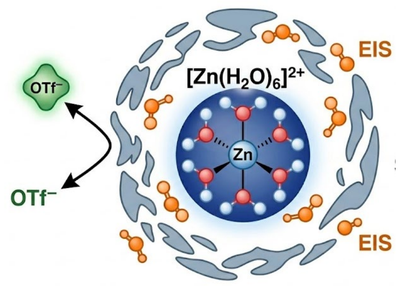
APPROACH

Approach: Bottom-up electrolyte design using an *ethyl isopropyl sulfone (EIS)* co-solvent to reshape Zn^{2+} solvation and disrupt water's H-bond network, widening the electrochemical stability window.

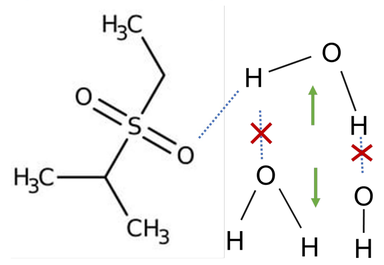
Why: Offers a low-cost, safe, and scalable route to zinc batteries without relying on expensive "high-concentration" systems.

Lab capabilities: Leverages Raman/FTIR/NMR, cryo-XPS, and advanced electrochemical characterizations to link molecular-scale solvation to full-cell performance.

Ethyl isopropyl sulfone



Exclusion of OTf^- anion from participation in the Zn^{2+} solvation

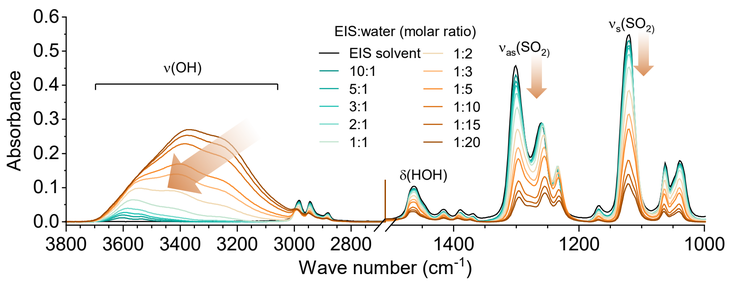


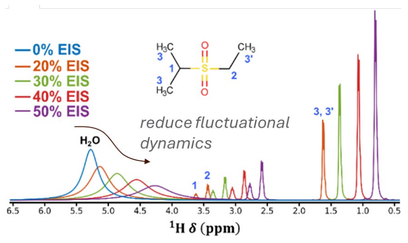
Restructuring the hydrogen-bond network and proton-transport

Best formulation: 1 M $Zn(OTf)_2$ in EIS:Water (40:60 vol.%)

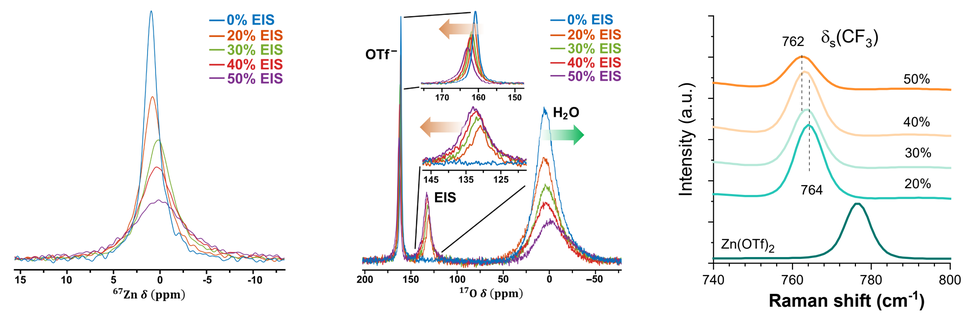
RESULTS

➢ Restructure the hydrogen-bond network

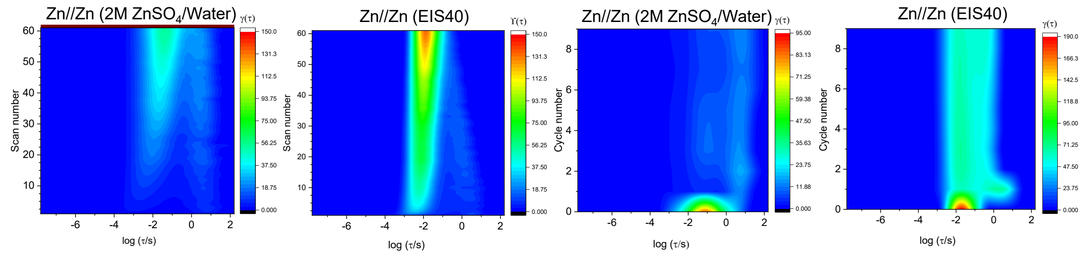




➢ Excludes OTf^- from participation in the Zn^{2+} solvation



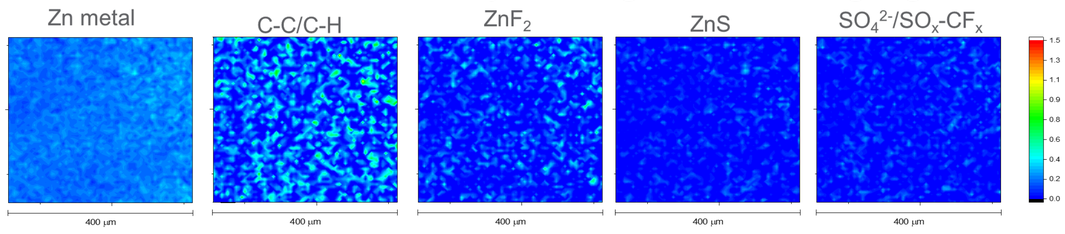
➢ Zn surface stabilized by a stable and uniform interphase



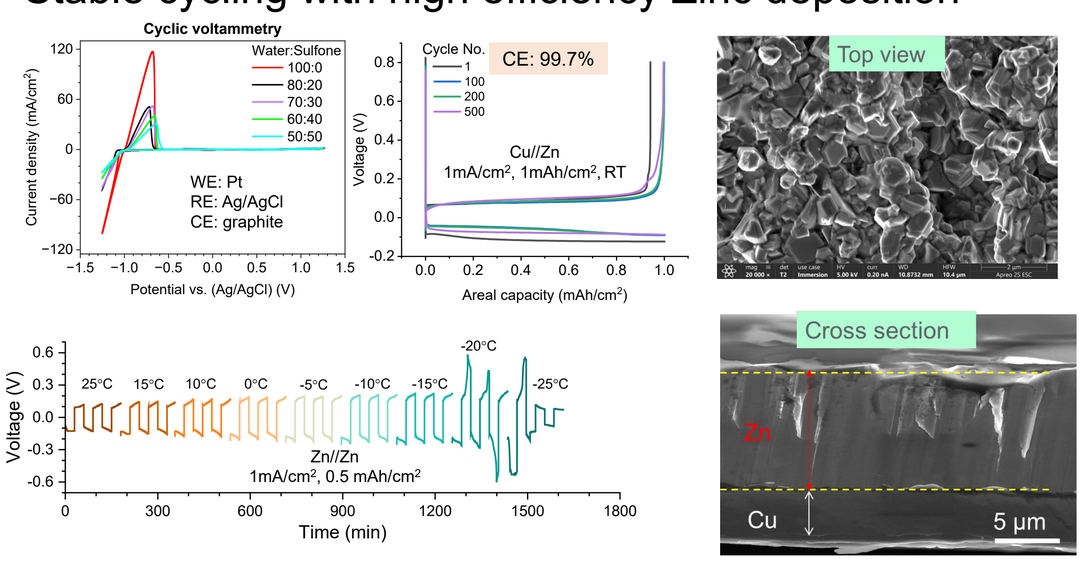
Stable chemical adsorption at the Zn surface with EIS40

EIS40 establishes a strong and stable interphase with cycling

➢ Uniform surface chemistry through XPS imaging



➢ Stable cycling with high efficiency Zinc deposition



CONCLUSIONS & IMPACT

- **Bottom-up electrolyte design:** Successfully reshapes Zn^{2+} solvation and disrupts water's hydrogen-bond network.
- **Achievement:** Solves key bottlenecks of AZBs without costly high-concentration "water-in-salt" formulations while enhancing cycling stability and safety.
- **Impact:** EIS40 electrolyte class is ready to advance the deployment of zinc batteries for long-duration grid energy storage.

FUTURE DIRECTIONS

- Deploy EIS-series electrolyte into Zinc –MnO_2 slurry batteries (final project deliverable).
- Advanced Zn-MnO_2 battery from TRL 3 to TRL 5.

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For additional information, contact:
Dan Thien Nguyen
thien.nguyen@pnnl.gov

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