Interfacial Stabilization of Zn anode in Mildly Acidic Aqueous Zn Batteries via Electrolyte Formulation

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Background

Introduction

Mildly acidic aqueous Zn batteries (AZBs) are promising as grid-scale energy storage systems due to high safety, affordability, and sustainability. However, AZBs still face persistent technical barriers at the interface of Zn anode; H_2 gas evolution, dendrite growth, and beyond.

Current Research Status

Among multiple strategies including electrode and separator engineering, electrolyte development is expected to provide solutions to a long-life AZBs. Various electrolytes have been developed to stabilize the Zn anode interface, simultaneously fulfilling the requirements of cost-effectiveness, high-performance. However, challenges still exist.

- ✓ Low utilization ratio of Zn anode (DOD < 10%)
- ✓ Low cycle number of full cell under high areal capacity.
- ✓ Some electrolytes have cost-related drawbacks.

Project Goal & Milestones (FY25)

Leveraging the fundamental understanding and technical capabilities accumulated through multiple years of DOE-OE projects on Zn batteries, PNNL aims to explore advanced electrolyte systems that can address the inherent challenges of conventional aqueous electrolytes. This effort is directed toward achieving key performance milestones as outlined below.

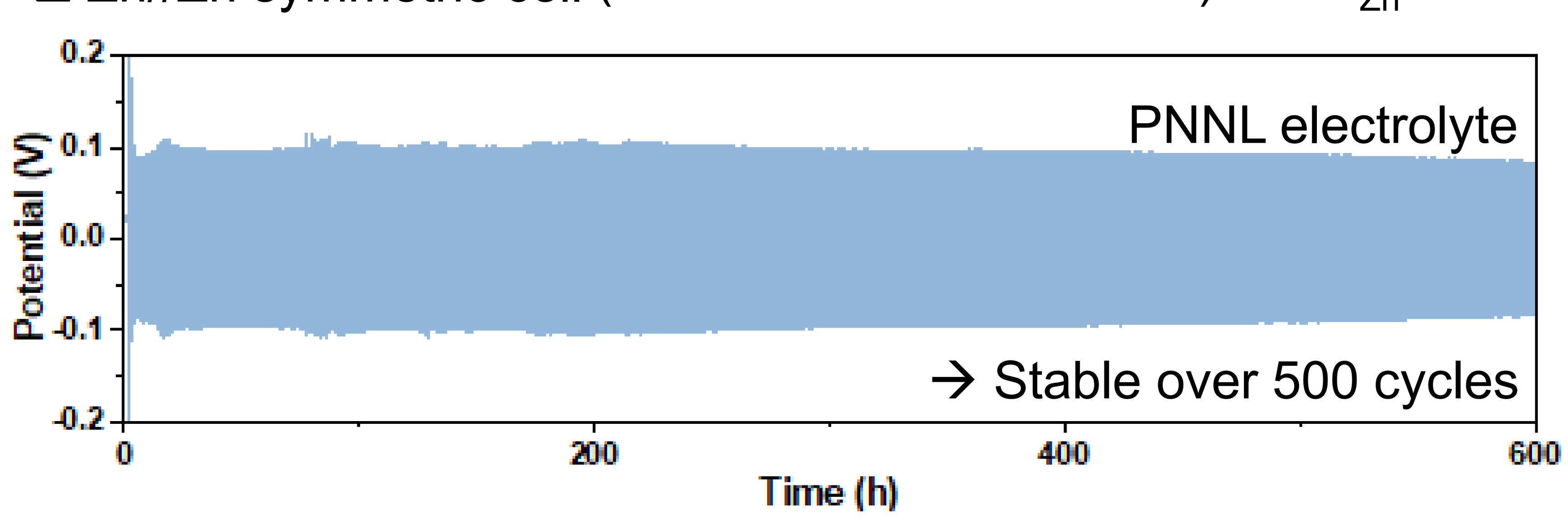
- ✓ Zn anode – over 500 cycles with a capacity of ~5 mA h cm^{-2}
- ✓ Full cell beyond Zn/MnO_2 with >2.5 mA h cm^{-2} and >100 mA h g^{-1}

Approach

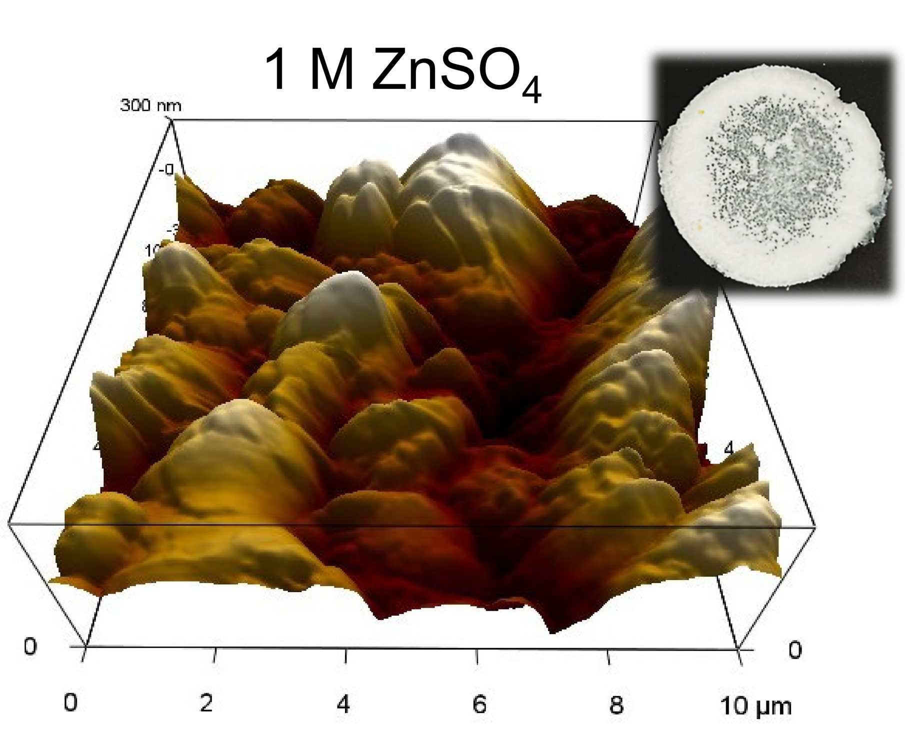
Design new electrolyte recipes to modulate the Zn/electrolyte interfacial properties including Zn deposition, electrolyte decomposition, and interphase gas evolution behavior.

Interfacial Stability of Zn Anode

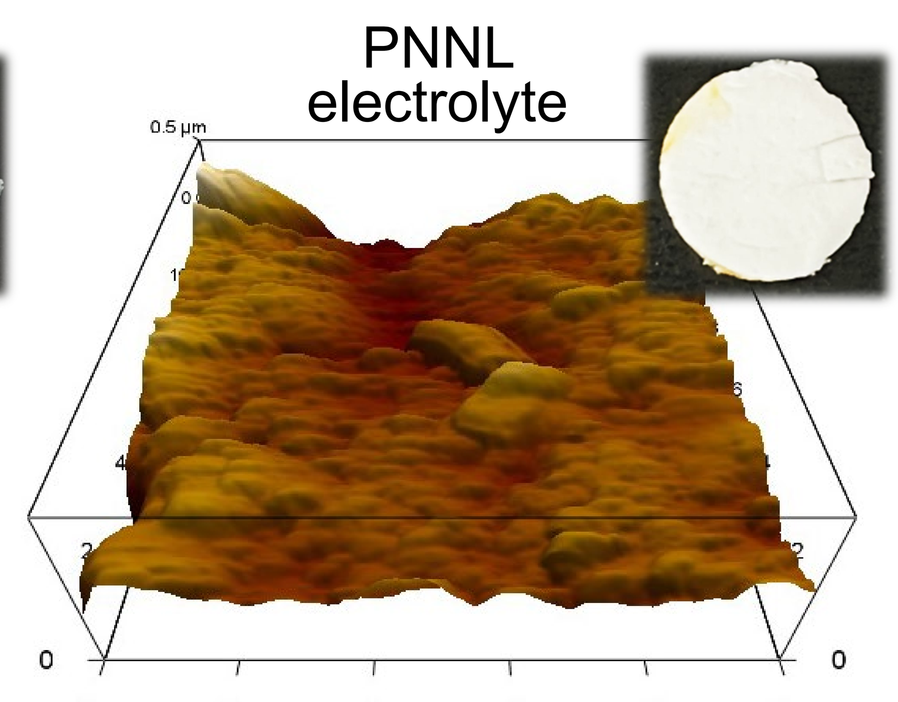
❑ Zn//Zn symmetric cell (10 mA cm^{-2} / 5 mA h cm^{-2}) DOD$_{Zn}$: 40%



❑ Atomic Force Microscope characterization of cycled Zn

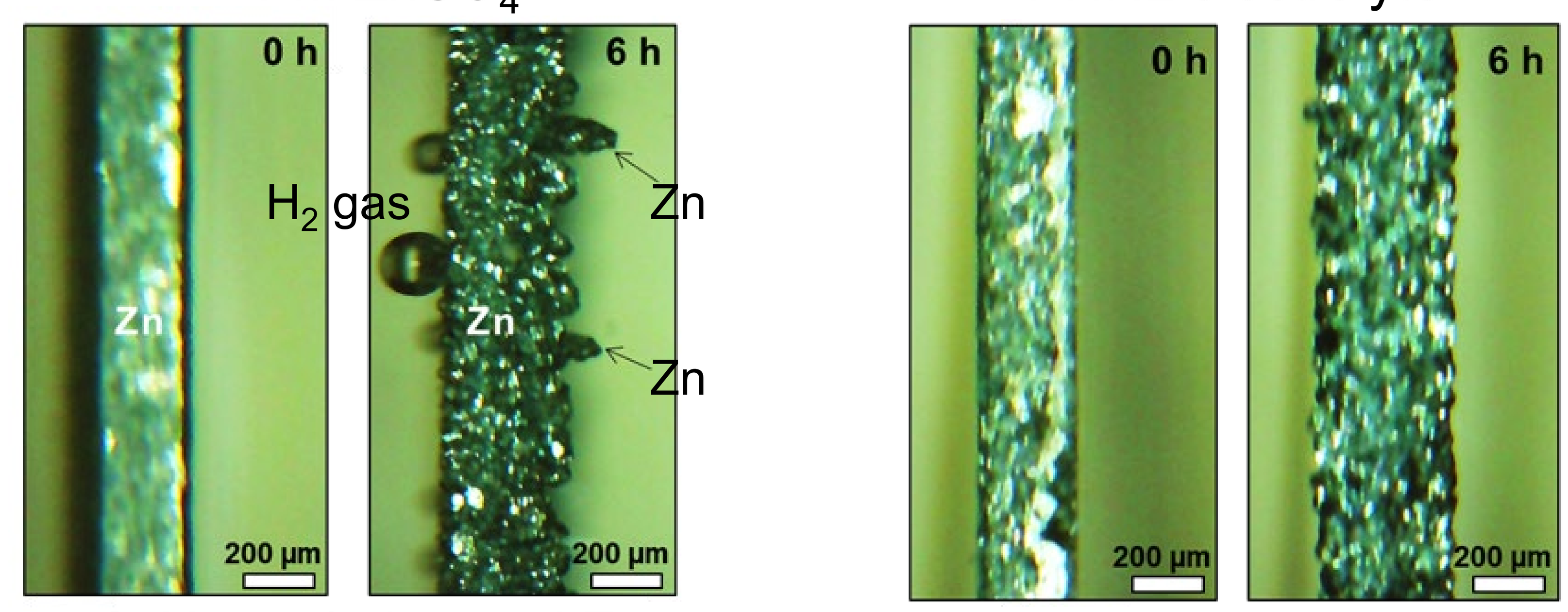


→ Very rough surface



→ Smooth Zn deposition

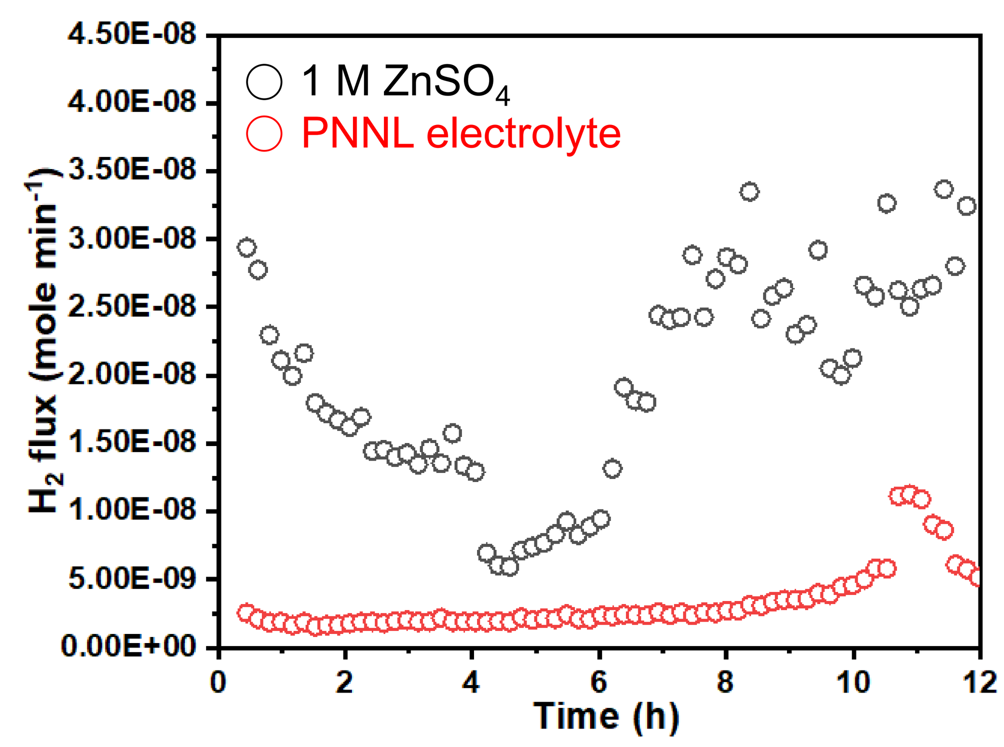
❑ *Operando* optical microscope imaging of Zn plating

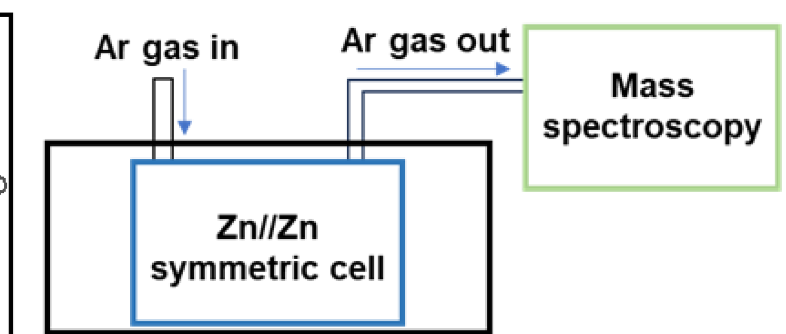


→ H_2 evolution and Zn dendrite formation

→ Suppressed H_2 evolution and smooth Zn deposition

❑ *In situ* gas release behaviors during Zn plating/stripping



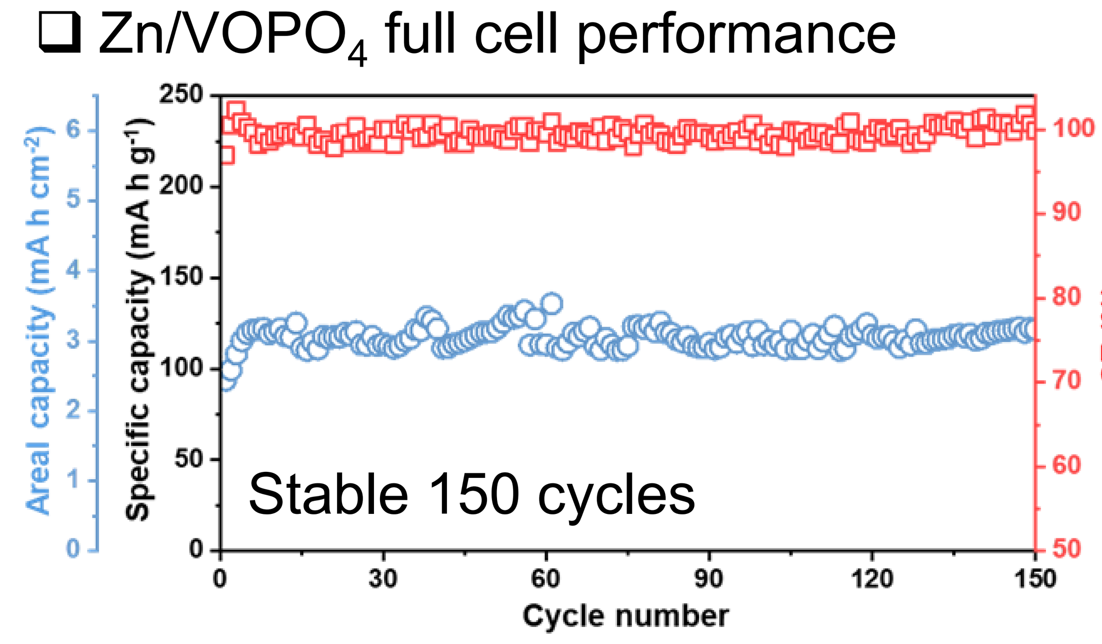


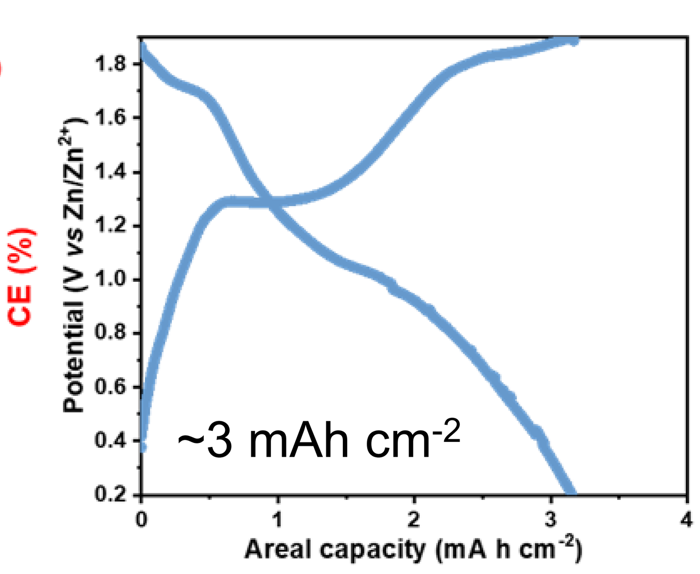
Lower H_2 gas flux

→ Inhibited gas release with the new electrolyte recipe

Full Cell Performance

❑ Zn/$VOPO_4$ full cell performance

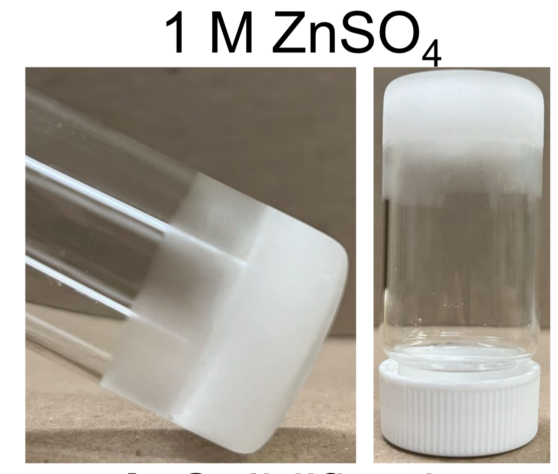




Wide Working Temperature Range

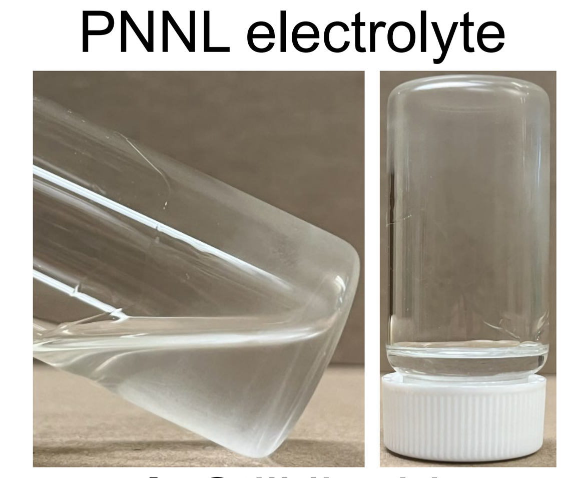
At -20 ℃

1 M $ZnSO_4$



→ Solidification

PNNL electrolyte



→ Still liquid

Alignment

This project is accelerating the development and testing of a new energy storage technology that is more cost-effective, safe, and durable, which is crucial to meeting the Administration's goal of providing reliable, affordable, secure, and resilient energy.

Acknowledgement

This material is based upon work supported by the U.S. Department of Energy, Office of Electricity (OE), Energy Storage Division.

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Dr. Xin Zhang (Pacific Northwest National Laboratory)
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