Flowable Zinc Slurry Battery for Long Duration Energy Storage Technology

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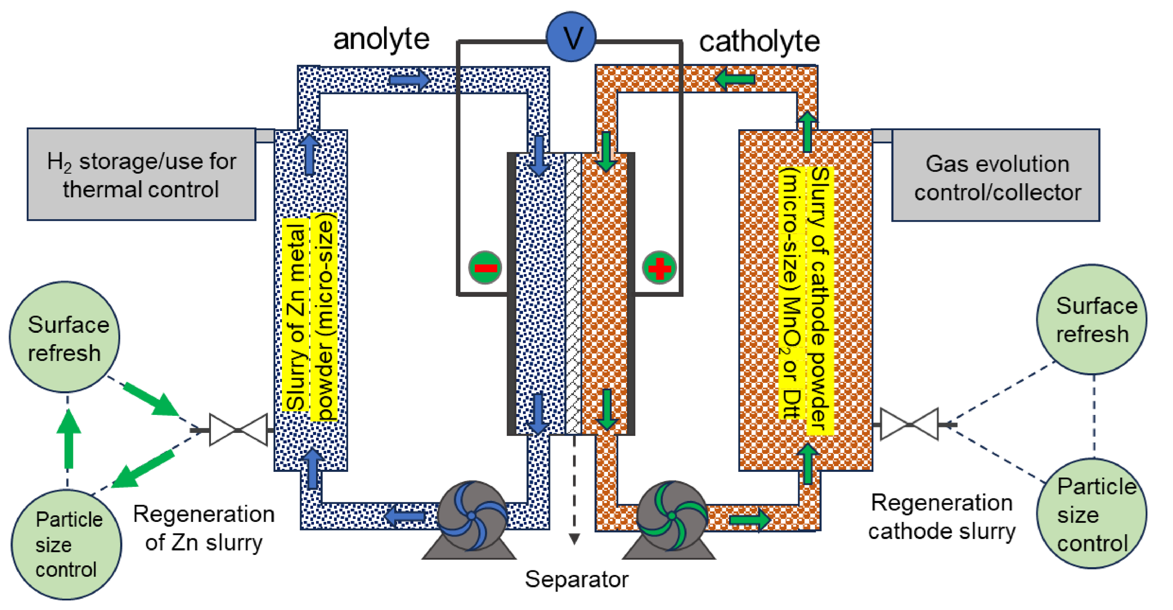
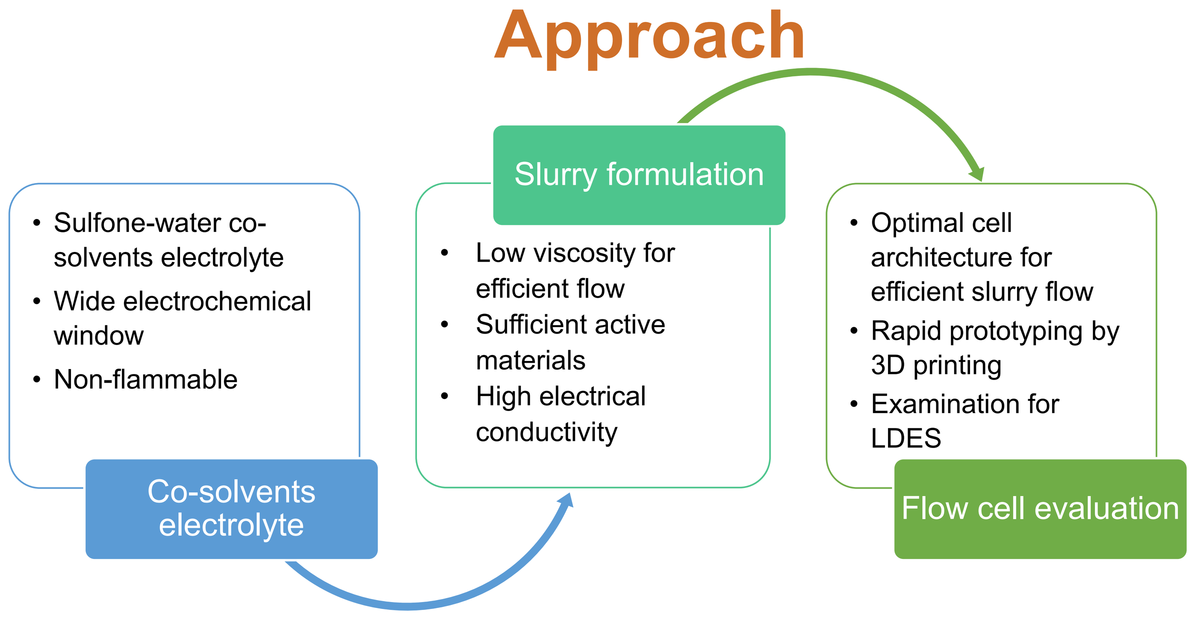
Introduction

Zinc-slurry-based batteries (ZSB) transform advanced aqueous rechargeable Zinc battery chemistry into a flow cell system with both anode (zinc metal powder) and cathode (e.g., MnO_2 or organic cathode) materials in the form of a slurry dispersed in the electrolyte. The flow system allows redox reactions to occur with minimal mass transport limitation and mitigates the dendrite formation issue at the Zn metal anode.

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

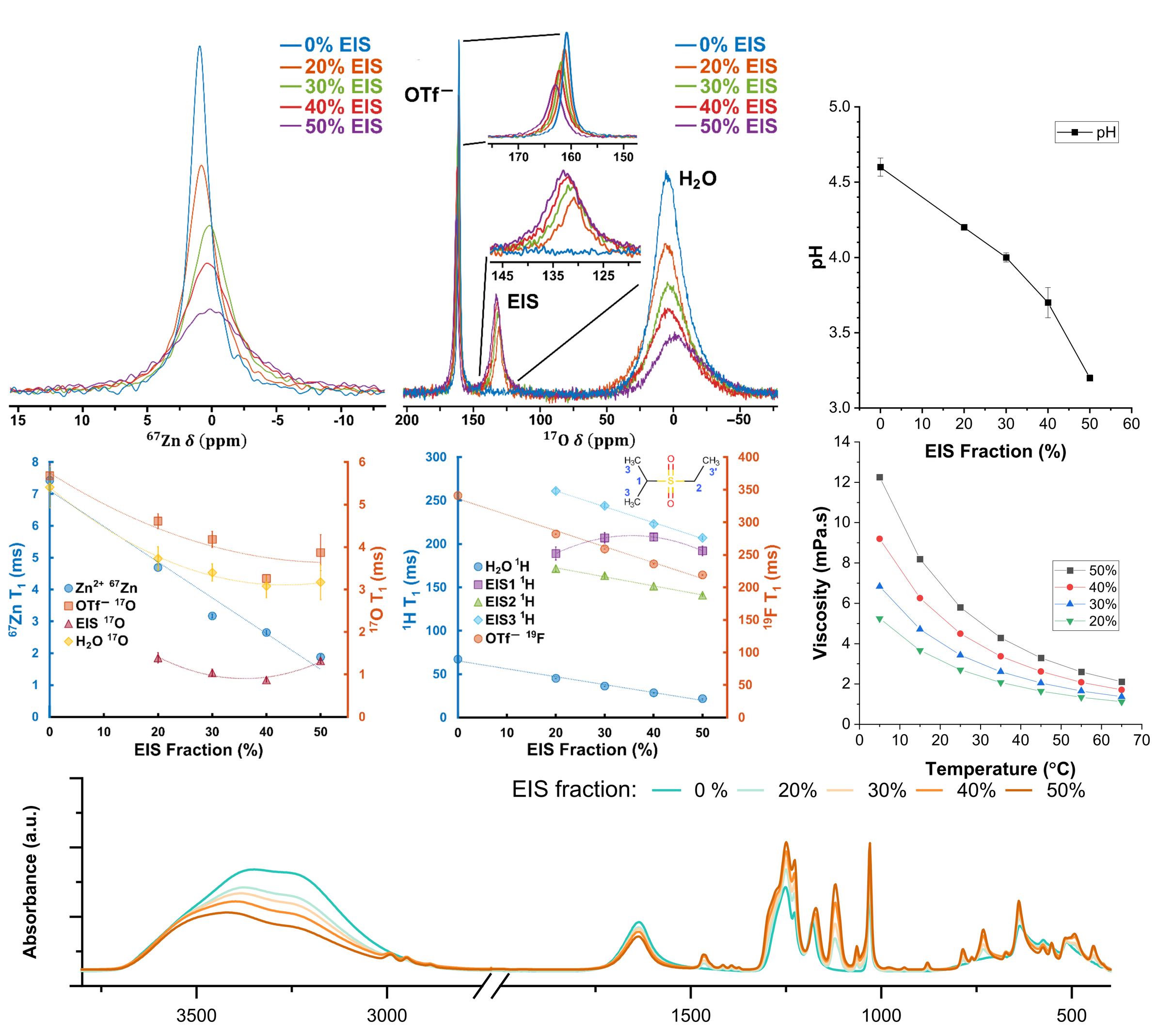


Approach



Co-solvent electrolyte design

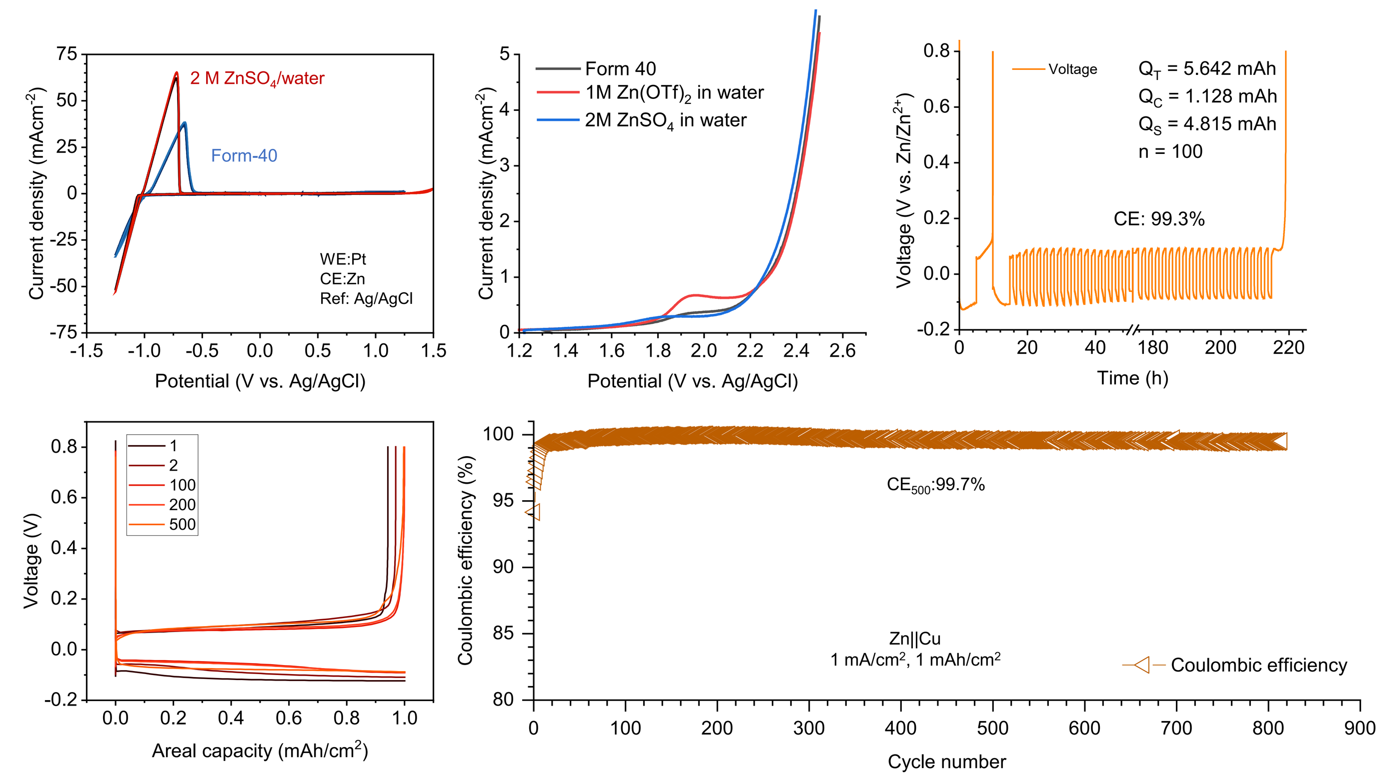
Regulating Zn^{2+} solvation with sulfone



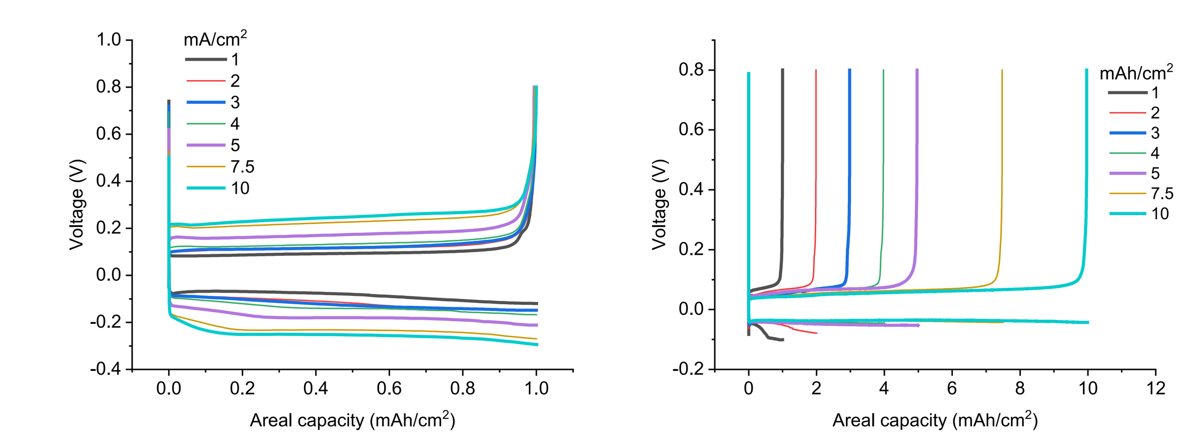
As ethyl isopropyl sulfone (EIS) fraction is increased, the anions are better excluded from participation in the Zn^{2+} solvation shell, at the cost of slower overall tumbling dynamics. 40% EIS fraction the optimal realization of a unique dynamical state that the cooperative solvation of the Zn^{2+} by the EIS and H_2O achieves.

Enhanced Zn anode performance

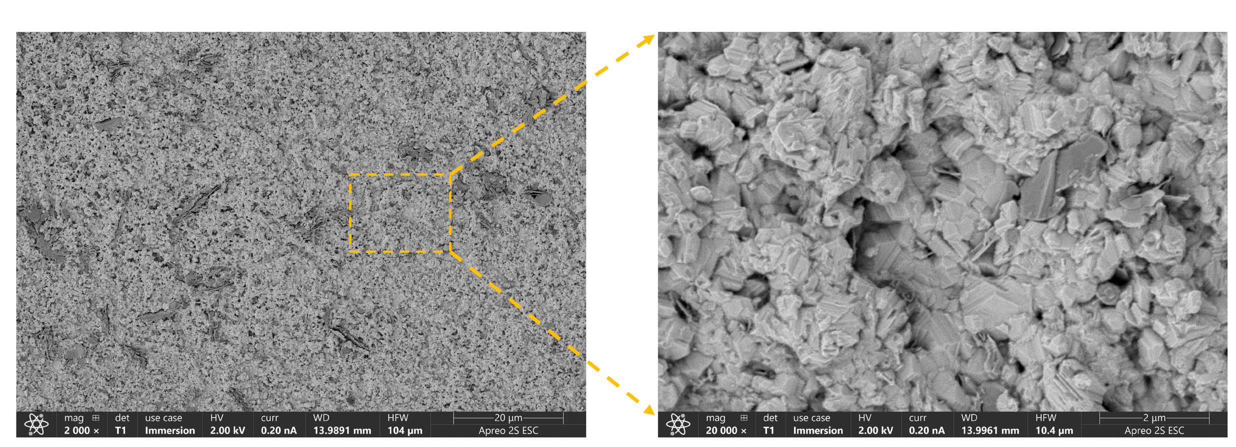
High energy efficiency, extended cycle life



The 1 M $Zn(OTf)_2$ in a water-sulfone mixture (40 % EIS, Form-40) demonstrates excellent Zn plating/stripping efficiency over 800 cycles, with an accumulated capacity of up to 0.8 Ah/cm².



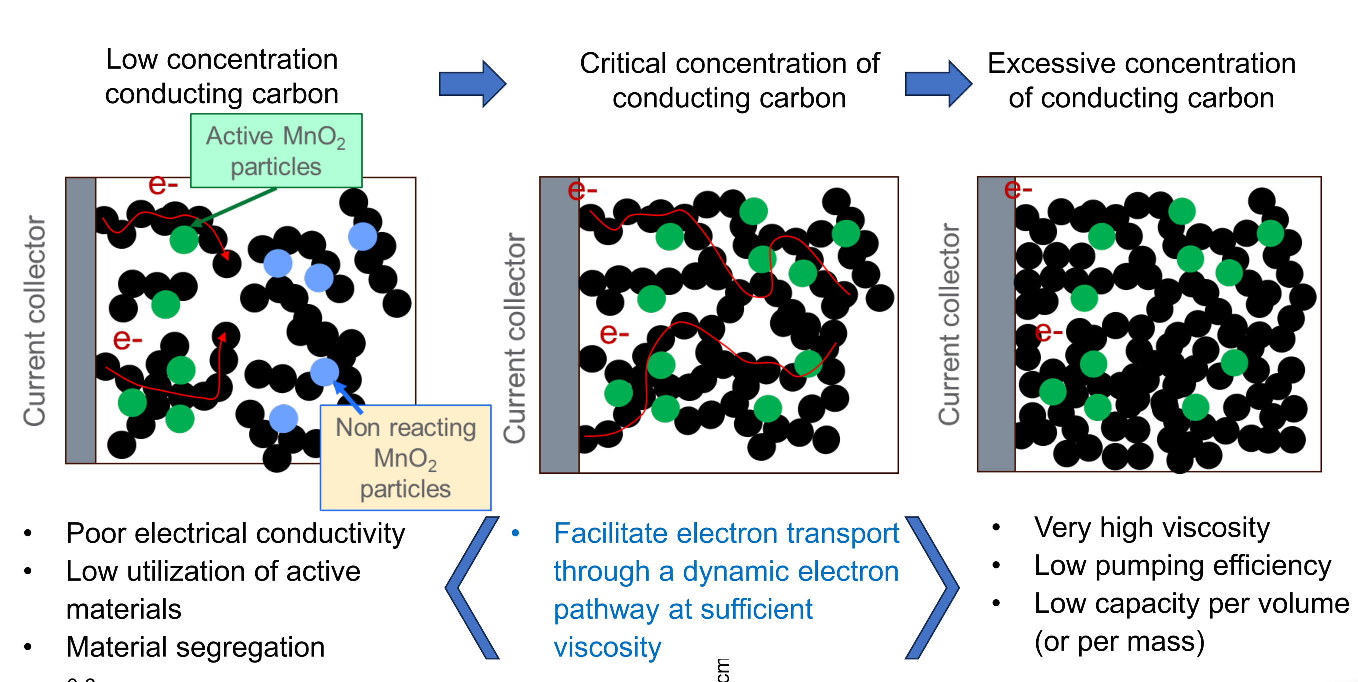
For high-energy applications, the benchmark performance of the Zn anode was examined at current densities of up to 10 mA/cm² and an areal capacity of 10 mAh/cm².

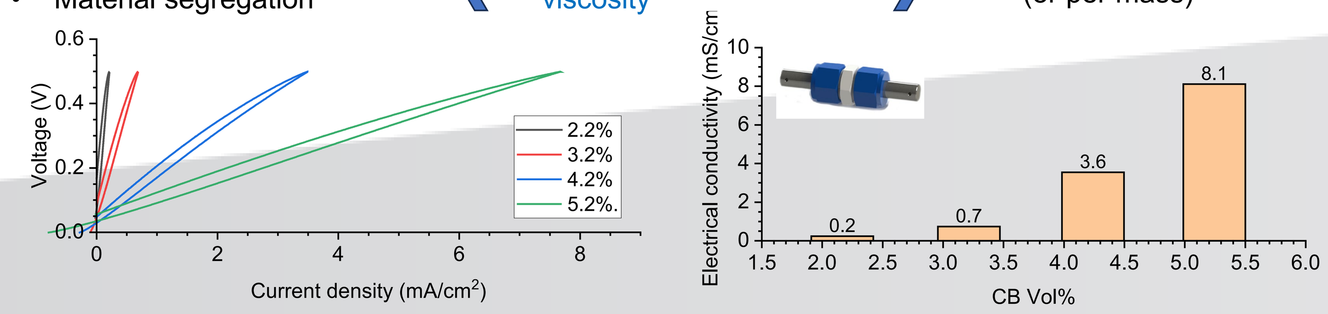


Form-40 electrolyte facilitates uniform Zn deposition without dendrite formation, suggesting a strong potential of co-solvent electrolytes in rechargeable zinc batteries.

Formulation of cathode slurry

Critical concentration of carbon matrix

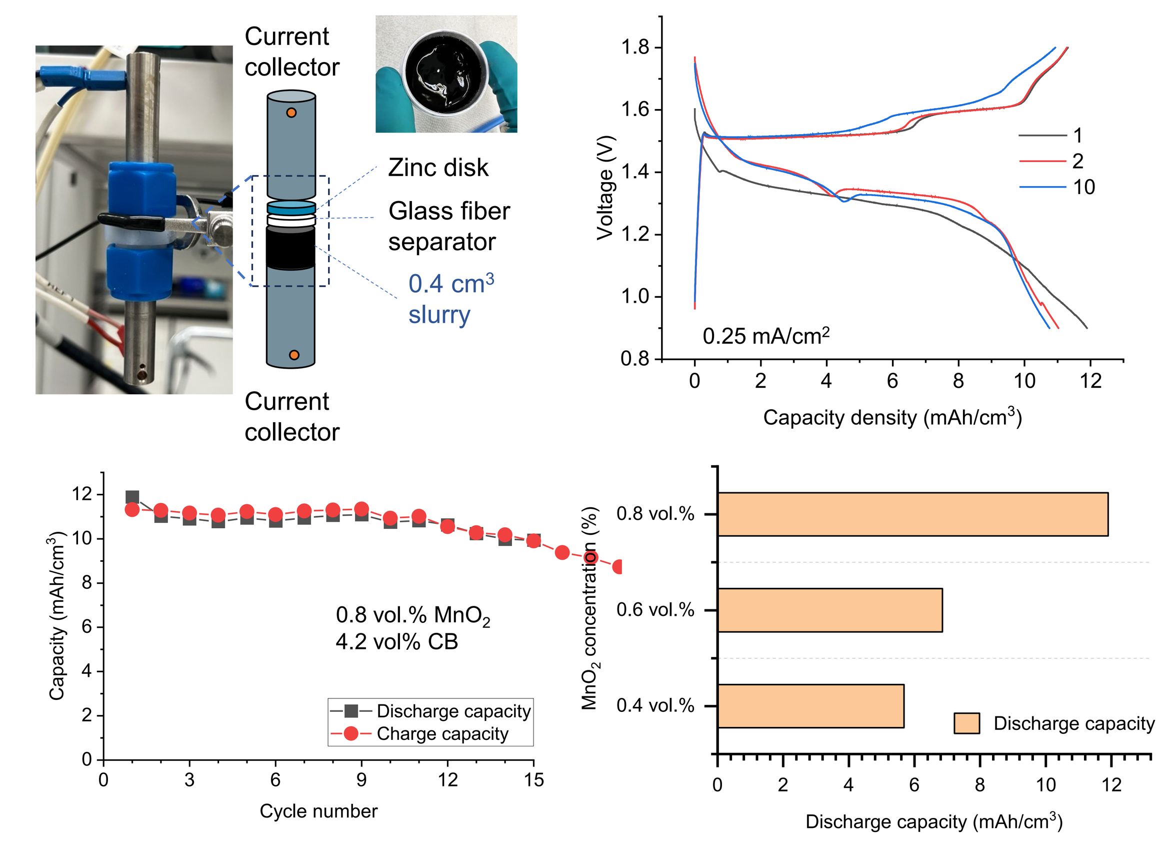




The carbon concentration was optimized to provide sufficient electrical conductivity while maintaining low viscosity.

Performance of MnO_2 cathode slurry

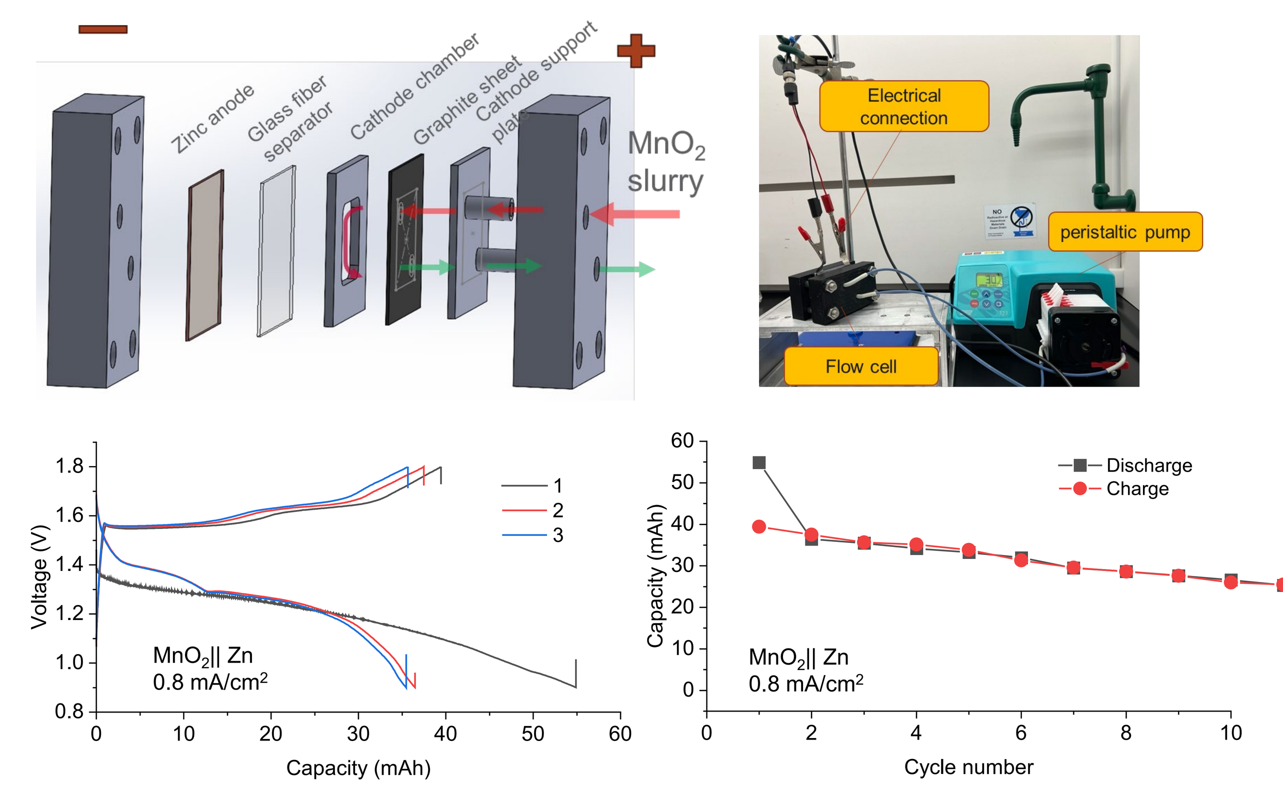
Examine the performance in a static cell



The MnO_2 slurry cathode demonstrates stable cycling with low overpotential. A carbon content of 4.2% helps stabilize the electrical network within the slurry, thereby facilitating the charge/discharge process of MnO_2 active materials.

Initial cycling on a flow system

Partial flow cell testing of the cathode slurry



Initial cycling of the partial flow cell confirms the feasibility of the slurry cathode for zinc batteries. The higher overpotential observed in charge/discharge curves is attributed to increased cell impedance and the non-uniform flow rate of the peristaltic pump.

Conclusions and Future Work

- Regulating the solvation of Zn^{2+} cation by co-solvents (water-sulfone) effectively enhances the performance of the Zn metal anode.
- The critical carbon concentration of conducting carbon was determined to be optimal for facilitating current conduction as well as improving the flowability of the slurry.
- Future work will focus on: Integrating Form-40 electrolyte and polymer to enhance the performance and stability of the slurry in the flow cell; Customizing cell architecture to improve pump efficiency and examine the full cell using both anolyte and catholyte slurry; Examining the cycling performance for long-duration energy storage (LDES) applications (i.e., >10-hour discharge).

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