Dendrite-Free Zinc Deposition in Alkaline Zinc–Iron Flow Batteries Enabled by Organic Additive

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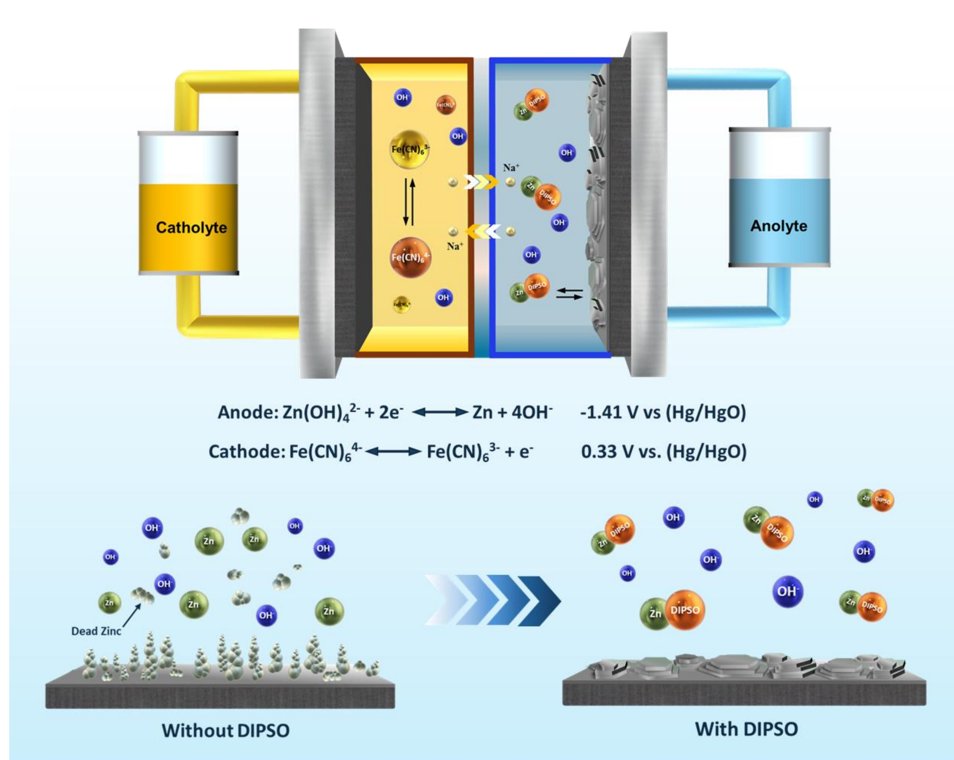
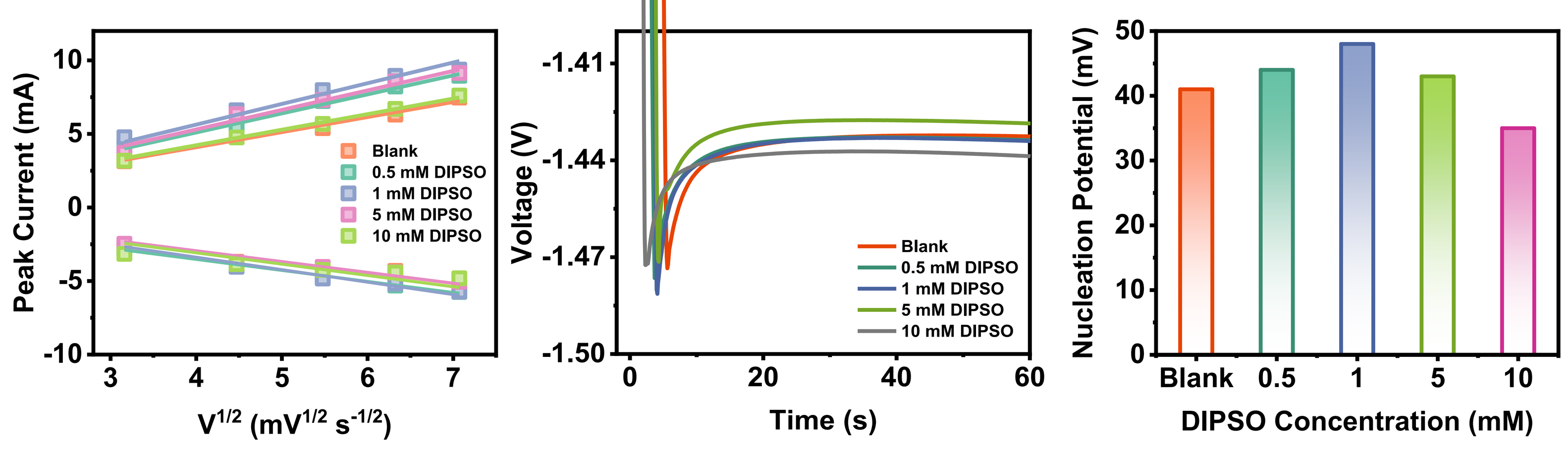
01 Introduction

Alkaline zinc–iron flow batteries are promising energy storage systems owing to their high cell voltage, low cost, and aqueous-based safety. However, non-uniform zinc deposition causes dendrite growth, dead zinc formation, and side reactions, leading to capacity fading and poor cycling stability. In this study, DIPSO, an alkanolamine-based organic additive, was introduced into the alkaline zinc electrolyte. DIPSO forms a stable Zn-DIPSO complex under alkaline conditions, increases the zinc nucleation overpotential, and promotes the formation of small and dense zinc nuclei. As a result, dendrite-free and uniform zinc deposition is achieved, enabling stable cycling performance of AZIFBs.

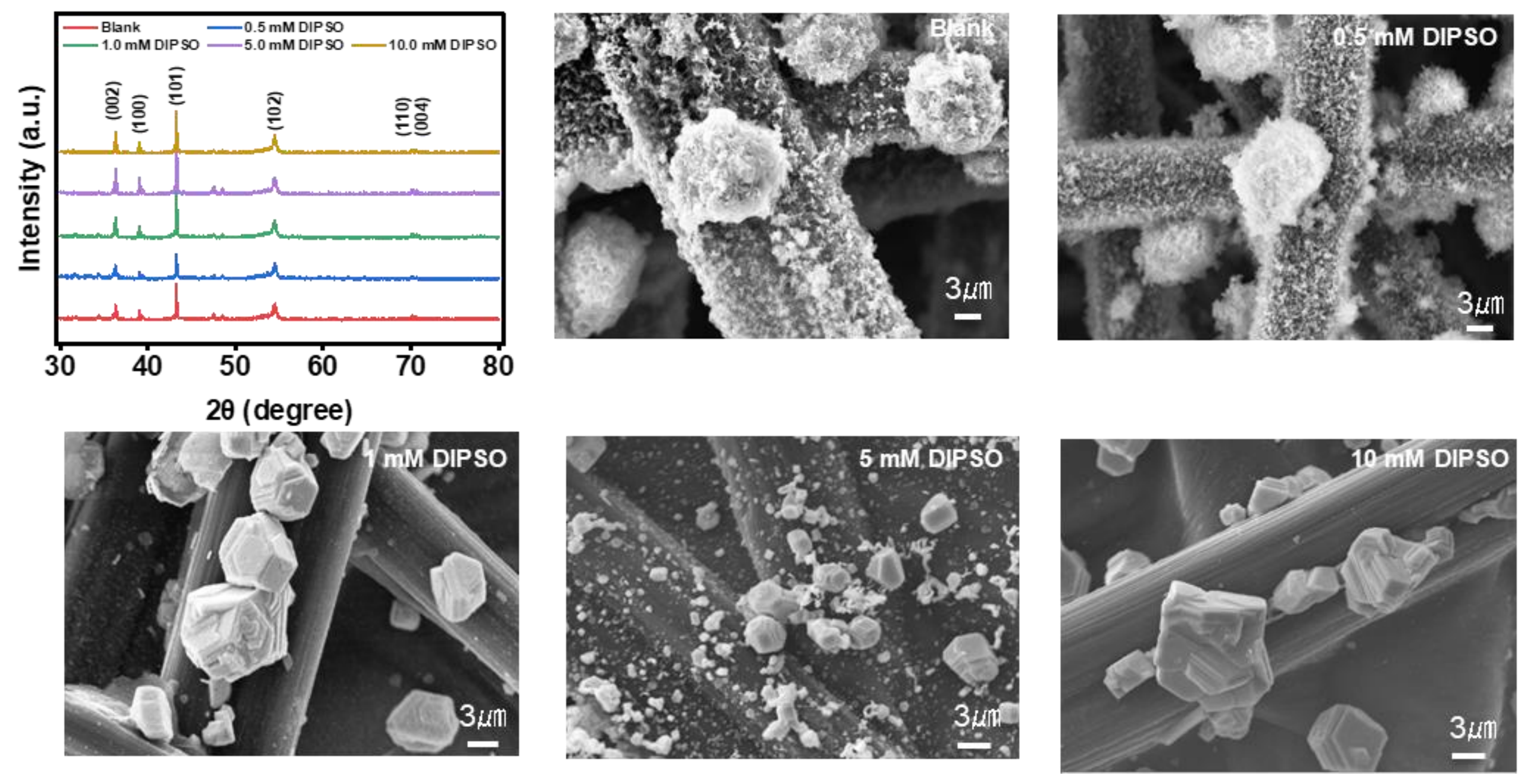


02 Electrochemical Analysis



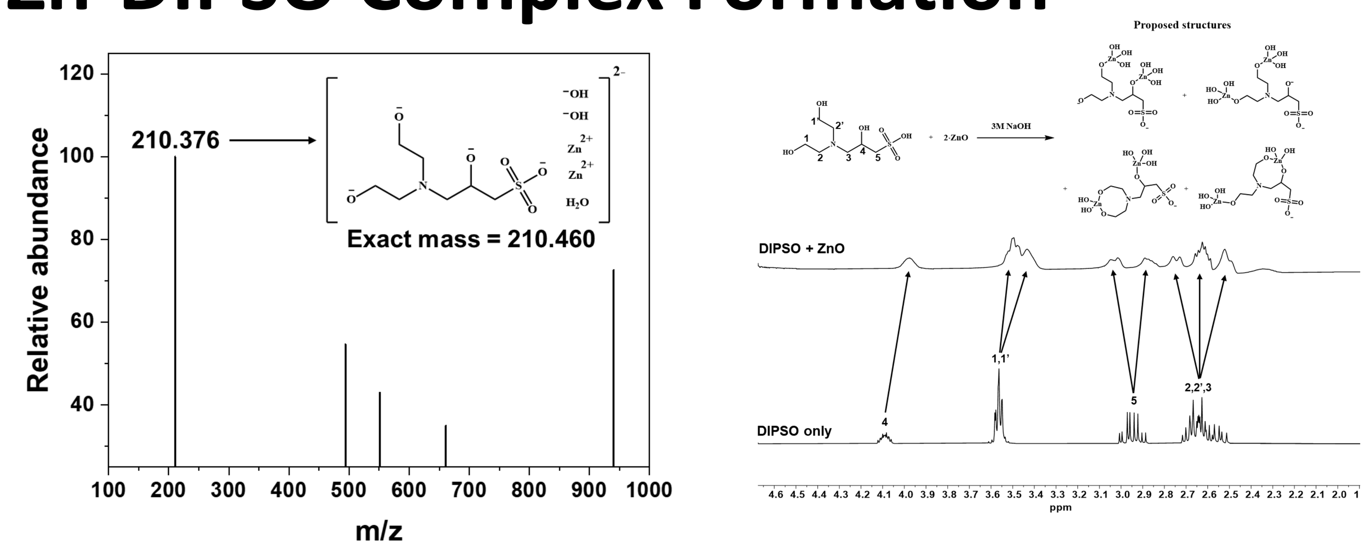
- After DIPSO addition, the Zn oxidation/reduction peak currents increased linearly with scan rate, indicating stable Zn redox behavior.
- Chronopotentiometry showed the highest nucleation overpotential at 1 mM DIPSO, favoring the formation of small and dense Zn nuclei.

03 Surface Characterization



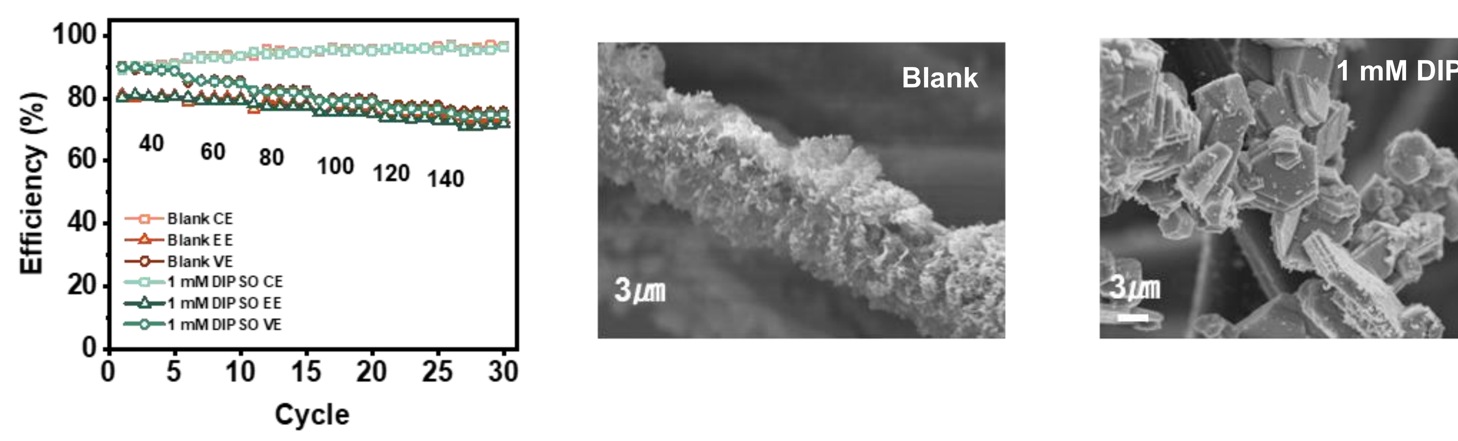
- XRD analysis of the Zn-deposited carbon paper showed that the fraction of the Zn (002) plane increased with increasing DIPSO concentration, indicating that DIPSO affects the preferred growth direction of Zn.
- SEM images revealed rough and non-uniform Zn deposits in the blank and 0.5 mM DIPSO electrolytes, whereas relatively uniform and compact Zn particles were formed with DIPSO concentrations of 1 mM or higher.

04 Zn-DIPSO Complex Formation

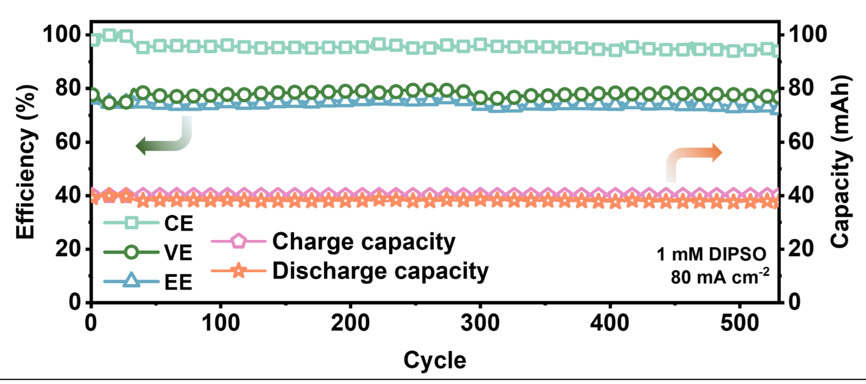


- The m/z = 210.376 peak observed in ESI-MS corresponds to the [DIPSO + $2Zn^{2+}$ + $2OH^-$ + H_2O] complex, confirming a 1:2 complexation ratio between DIPSO and Zn ions.
- In ^{1}H NMR, the upfield shifts of H1, H1', and H4 protons and peak splitting indicate that the hydroxyl groups of DIPSO coordinate with Zn ions to form various DIPSO-Zn complex structures.

05 Full-Cell Performance of AZIFB



- The AZIFB with 1 mM DIPSO showed efficiencies comparable to the blank cell at various current densities, indicating that DIPSO does not significantly interfere with the Zn redox reaction.
- After cycling, SEM images showed rough and dendritic Zn deposits in the blank electrolyte, whereas the DIPSO-containing electrolyte induced denser and more uniform Zn deposition.



- The AZIFB with 1 mM DIPSO maintained stable performance for over 500 cycles at 80 mA cm^{-2}.

06 Conclusion

DIPSO effectively regulates Zn nucleation and promotes uniform Zn deposition through Zn-DIPSO complex formation. As a result, the AZIFB with 1 mM DIPSO achieved dendrite-suppressed and long-term stable operation.

Acknowledgment

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