

An Ion-Regulating Polymer Electrolyte With Zn Affinity for Stable Zinc Batteries

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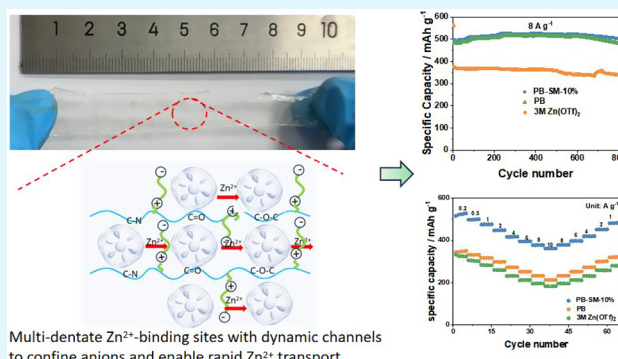
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Supporting Information

ABSTRACT: While polymer electrolytes offer a promising path to suppress dendrite growth and side reactions in aqueous zinc-ion batteries, their implementation often compromises ion transport kinetics and interfacial stability. Here, we report an ion-regulating copolymer electrolyte, poly(4-acryloylmorpholine)-co-poly(3-sulfopropyl-dimethyl-3-methacrylamidopropylammonium inner salt), engineered through a facile one-pot synthesis. This molecularly designed architecture combines multi-dentate zinc-binding sites with dynamic zwitterionic channels, enabling simultaneous anion confinement and rapid zinc-ion transport. The copolymer electrolyte promotes uniform ion flux and dense zinc deposition while maintaining intimate electrode contact, effectively eliminating dendrite formation and interfacial degradation. Symmetric Zn||Zn cells achieve excellent cycling stability over 1400 h with minimal polarization (~ 110 mV) at 0.5 mA cm^{-2} . When integrated with V_2O_5 cathodes, full cells exhibit outstanding reversibility, rate capability, and cycling durability. This work demonstrates a rational electrolyte design strategy that synchronizes bulk and interfacial ion regulation, providing a viable platform for high-performance, long-lived zinc batteries.

KEYWORDS: zwitterion-integrated copolymer electrolyte, zinc ion transport, aqueous zinc ion batteries, interface, dendrite suppression



INTRODUCTION

Compared with lithium-based batteries,¹ aqueous zinc-ion batteries (AZIBs) have garnered significant research interest as promising energy storage systems due to their cost-effectiveness, operational safety, environmental benignity, and high theoretical capacity.^{2–8} These attributes position them as viable solutions for renewable energy integration, grid electrification, and power supply for flexible wearable electronics.^{9–16} Nevertheless, their practical implementation faces substantial challenges, including hydrogen evolution reactions, corrosion issues, and dendritic zinc formation, which collectively impede their widespread adoption.^{17–19}

Enhancing the stability of aqueous zinc-ion batteries primarily involves strategies such as modifying the zinc anode microstructure,^{20,21} establishing protective coatings,^{22,23} optimizing electrolyte composition,^{24,25} or developing novel electrolyte systems.^{26,27} Among these approaches, the design of advanced electrolytes—particularly polymer-based ones—offers distinct benefits including straightforward fabrication processes, economic viability, customizable characteristics, and preservation of intrinsic capacity.^{28,29} To date, a diverse range of polymer electrolyte systems, including those derived from polyacrylamide,³⁰ poly(vinyl alcohol),³¹ poly(zwitterions),³² and polyacrylonitrile,³³ have been developed and extensively utilized in

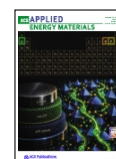
AZIBs. These materials exhibit inherent advantages such as improved interfacial compatibility with zinc anodes and readily tunable structures, enabling the combined benefits of chemical interactions and physical barriers that support synergistic mechanisms for dendrite suppression. Recent studies further indicate that incorporating zincophilic functional groups into polymer backbones can promote homogeneous zinc nucleation.³⁴ For example, polyanionic networks possess distinctive zincophilic properties that help uniformize zinc ion flux, thereby enhancing electrochemical performance.³⁵ Additionally, negatively charged carboxylated polymer electrolytes have been shown to reorganize the zinc ion solvation structure through chain–liquid synergistic effects, achieving high ionic conductivity (13.6 mS cm^{-1}) and a Zn^{2+} transference number of 0.77.³⁶ Despite these promising features, fine-tuning the interactions between polymer electrolytes and zinc species to substantially prolong the cycle

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life of AZIBs continues to present considerable difficulties. Moreover, the implementation of polymer electrolytes often introduces challenges related to sluggish ion kinetics and increased interfacial resistance within the cell.³⁷

In this work, we designed an ion-regulating polymer electrolyte featuring multiple zincophilic motifs, principally comprising poly(4-acryloylmorpholine) and polyzwitterionic chains (Figure S1). The poly(4-acryloylmorpholine) chain enables multi-dentate coordination to regulate zinc-ion diffusion, while the polyzwitterionic chain facilitates strong coordination between the cationic moieties of the zwitterionic units and zinc salt anions, thereby restricting anion migration. Simultaneously, the anionic groups in the zwitterions provide efficient transport pathways for zinc ions, collectively promoting rapid and uniform zinc deposition. This distinctive coordination mechanism establishes an optimal balance between ion confinement and mobility, significantly enhancing reaction kinetics. As a result, zinc anode corrosion and dendritic growth are effectively suppressed, enabling symmetric Zn||Zn cells to achieve stable cycling over 1400 h at 5 mA cm⁻² with capacity of 2.5 mAh cm⁻² without dendrite formation, along with superior rate capability. Furthermore, the corresponding Zn||V₂O₅ full cells exhibit remarkable reversibility, high-rate performance, and prolonged cycling stability.

RESULTS AND DISCUSSION

Poly(4-acryloylmorpholine)-co-poly(3-sulfopropyl-dimethyl-3-methacrylamidopropylammonium inner salt) (PA-SM) is achieved via free radical polymerization of 4-acryloylmorpholine and (3-sulfopropyl-dimethyl-3-methacrylamidopropylammonium inner salt). Specifically, a mixture of the two monomers in a specific ratio was polymerized into a film at 60 °C using APS as the initiator. The resulting film was subsequently immersed in a 3 M Zn(OTf)₂ solution for 1 min to obtain the electrolyte membrane. Based on the zwitterionic weight content (0%, 5, 10, and 15%), the samples were designated as PA, PA-SM-5%, PA-SM-10%, and PA-SM-15%, respectively. As will be detailed in the subsequent sections, the 10 wt % zwitterion content exhibits the highest ionic conductivity and endows the assembled batteries with the best electrochemical stability and cycling performance, thus serving as the primary composition for further study.

The FTIR spectrum of PA-SM-10% (Figure 1a) shows the disappearance of the characteristic peak at 3000–3100 cm⁻¹, which is associated with the double bond, indicating complete reaction of the double bonds in the monomers. As shown in Figure 1b, the optimal electrolyte membrane can be stretched from an initial length of 5 to 10 cm (100% elongation), demonstrating excellent stretchability and ductility. In Figure 1c, the first cyclic strain test between 0% and 200% reveals a hysteresis loop, attributed to energy dissipation within the polymer networks. The subsequent two consecutive cycles show no significant hysteresis, suggesting elastic behavior of the polymer electrolyte. Figure S2 presents the cyclic stress–strain curves of the electrolyte membrane under varying strains, where the hysteresis gradually increases, indicating substantial energy dissipation during cyclic deformation. Our previous study demonstrated that multiple zincophilic sites can effectively facilitate Zn²⁺ desolvation, while zwitterionic components further immobilize anions.³⁶ Figure 1d vividly illustrates the migration

mechanism of zinc ions in zwitterionic electrolytes featuring multiple zincophilic sites.

To determine the optimal composition of different polymer components in the electrolyte, the content of PSM (i.e., polyzwitterion) was systematically varied while keeping the PA content constant. Figure 2a presents the rate performance of symmetric zinc batteries assembled with electrolytes containing PSM contents of 15, 10, 5 and 1% relative to PA, tested at current densities ranging from 0.2 to 8 mA cm⁻². Note: The test was conducted under stepwise increasing current densities. All current densities were cycled 5 times, except at 0.2 mA cm⁻², where 10 cycles were applied. It can be observed that only PA-SM-10% enables uniform zinc plating/stripping across the entire current density range without short-circuiting, strongly demonstrating that the zwitterionic component at 10% achieves the optimal performance. Furthermore, Zn||Zn cells were constructed using PA-SM-10%, PA, and 3 M Zn(OTf)₂ electrolyte, respectively, to compare their long-term cycling stability. As shown in Figure 2b, the cell with PA-SM-10% exhibits stable operation for over 1400 h at 5 mA cm⁻² and 2.5 mAh without short-circuiting. In contrast, the PA-based symmetric cell shows noticeable micro-short circuits after only about 300 h of cycling. The cell with 3 M Zn(OTf)₂ electrolyte suffers from severe side reactions, significant potential fluctuations, and rapid micro-short circuit formation. When using thin Zn anode at DOD of 85%, the Zn||Zn cell using PA-SM-10% also exhibits much better cycle performance (Figure S3). These results clearly indicate that, under the synergistic effect of multiple zinc-affine sites (C–N, C=O, and C–O–C)³⁸ and zwitterionic functional groups, the electrolyte membrane facilitates efficient zinc-ion transport and induces uniform zinc deposition. More importantly, the zwitterionic component and multifunctional zincophilic sites collaboratively regulate the zinc-ion solvation structure, reducing the number of active water molecules in the solvation sheath. This can effectively suppress hydrogen evolution reaction and corrosion on the zinc surface.

The zinc surface morphology of cycled symmetric batteries in Figure 2b was further characterized by SEM. As shown in Figure 2c, the Zn||Zn cell using 3 M Zn(OTf)₂ electrolyte exhibits a zinc surface covered with abundant flake-like zinc dendrites. When PA is employed, numerous dendrites remain visible on the zinc surface (Figure 2d). In contrast, the cell with PA-SM-10% displays a smooth and uniform zinc surface without obvious dendrites after cycling (Figure 2e). The pristine zinc surface (Figure S4) exhibits an SEM morphology similar to that of the zinc surface cycled with PA-SM-10%, further evidencing the dendrite-suppression capability of PA-SM-10%. These results further confirm the synergistic effect between multiple zincophilic sites in the PA segments and the zwitterionic functional groups in suppressing zinc dendrite formation.

According to the impedances in Figure S5, the room-temperature ionic conductivity of PA, PA-SM-10% and PA-SM-15% are 0.12, 3.04 and 1.72 mS cm⁻¹, respectively. It is found that with the right polyzwitterion content (PA-SM-10%), the RT ionic conductivity of the electrolyte is comparable to or even higher than that reported in the current articles.^{28,39,40} Synthesizing the good mechanical properties of PA-SM-10%, this polymer electrolyte is the focus of subsequent research.

To investigate the radius and density of Zn nuclei, cyclic voltammetry measurements were conducted using Zn||Cu asymmetric cells to determine the nucleation overpotential (NOP).

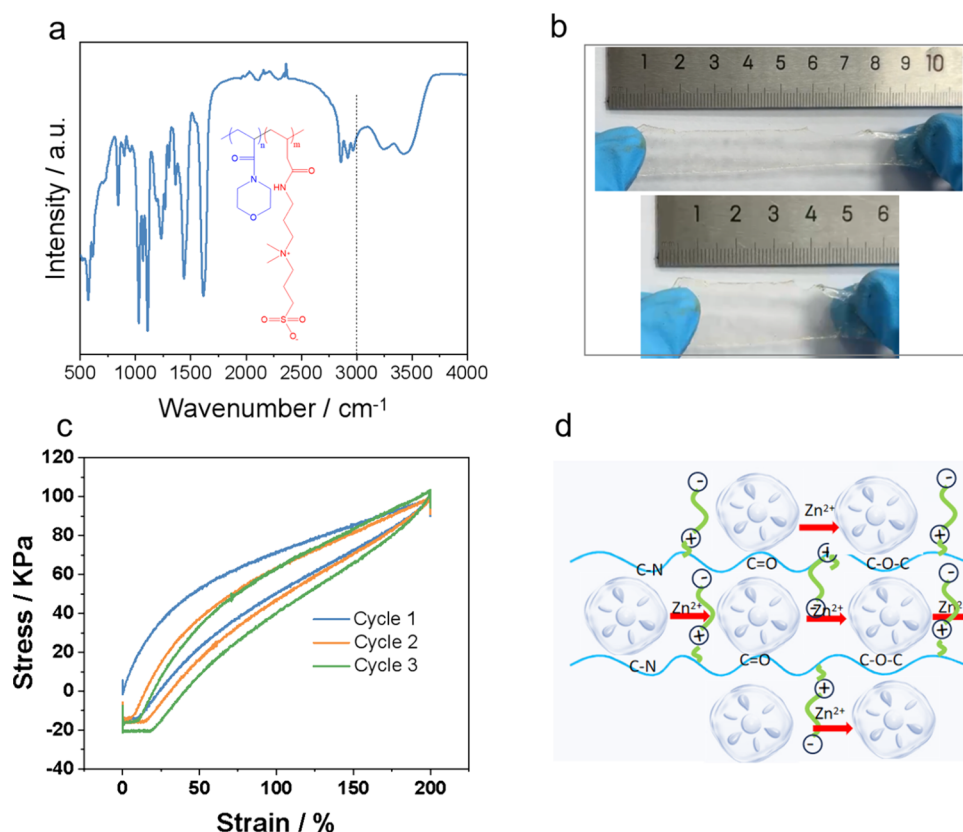


Figure 1. (a) IR spectrum of PA-SM-10% (it also shows the structural formula of the polymer). (b) Images of PA-SM-10% under original and stretched states. (c) Cyclic stress–strain curves of the electrolyte membrane. (d) Schematic diagram of zinc ion migration.

As displayed in Figure 3a, the more negative nucleation overpotential observed for PA-SM-10% indicates a higher nucleation driving force, which promotes the formation of a larger number of smaller Zn nuclei and thus a more uniform deposition morphology. Further evidence is provided by the voltage–time curves, which show a larger nucleation overpotential in PA-SM-10%. This increase is due to the occupation of some electrochemically active sites on the Zn anode by polymer segments, which hinders the charge transfer of zinc ions (Figure 3b).

The linear sweep voltammetry (LSV) curves in Figure 3c clearly show that the PA-SM-10% electrolyte shifts the hydrogen evolution reaction (HER) onset potential to more negative values compared to the pristine PA electrolyte. This negative shift indicates that a higher overpotential is required to initiate HER, meaning the driving force for water reduction is substantially lowered by the addition of the zwitterionic polymer. For the oxygen evolution reaction (OER), the PA-SM-10% electrolyte shows a delayed onset and a much slower increase in anodic current compared to the PA electrolyte (Figure 3d). This indicates that the zwitterionic polymer also moderates the oxidation of water, likely through similar interfacial confinement and hydrogen-bonding interactions that stabilize water molecules against decomposition.

As shown in Figure 3e, the Zn anode in PA-based electrolytes exhibits a more positive corrosion potential (approximately -15 mV vs. Zn/Zn^{2+}) compared to that in 3 M Zn salt electrolyte (-38 mV vs. Zn/Zn^{2+}). PA-based electrolytes also display lower corrosion current density than that of $3\text{ M Zn}(\text{OTf})_2$, indicating a slower corrosion rate of the metal electrode.

According to the Arrhenius equation, $1/R_{\text{ct}} = A_{\text{exp}}(-E_a/RT)$, where A is the pre-exponential factor, E_a is the activation energy representing the desolvation barrier, R is the gas constant, and T is the absolute temperature,²⁰ the calculated E_a for the symmetric cell with PA-SM-10% is lower than that with the plain polymer electrolyte (PA, without zwitterionic segments; Figure 3f). This result confirms that the incorporation of zincophilic sites and zwitterionic segments in the polymer electrolyte can more effectively reduce the desolvation energy barrier.²³ We performed electrochemical impedance spectroscopy (EIS) on symmetric cells with different electrolyte systems to first analyze the influence of temperature on interfacial behavior. Figure 4a shows the temperature-dependent interfacial resistance of symmetric cells using the $3\text{ M Zn}(\text{OTf})_2$ liquid electrolyte. The interfacial resistance gradually decreases with increasing temperature, with an initial value of approximately $425\ \Omega$ at room temperature. In contrast, for the polymer electrolyte without zwitterionic segments, the initial interfacial resistance exceeds $1000\ \Omega$, and the resistance decline upon heating is much more moderate. At all measured temperatures, this system exhibits significantly higher overall impedance levels (Figure 4b). Remarkably, the PA-SM-10% system incorporating zwitterionic moieties performs excellently: not only does it substantially reduce the interfacial resistance already at room temperature, but its impedance also drops more rapidly as the temperature rises, demonstrating superior temperature responsiveness and ion transport capability.

Subsequently, we conducted galvanostatic discharge of symmetric cells at a current density of 1 mA cm^{-2} while periodically

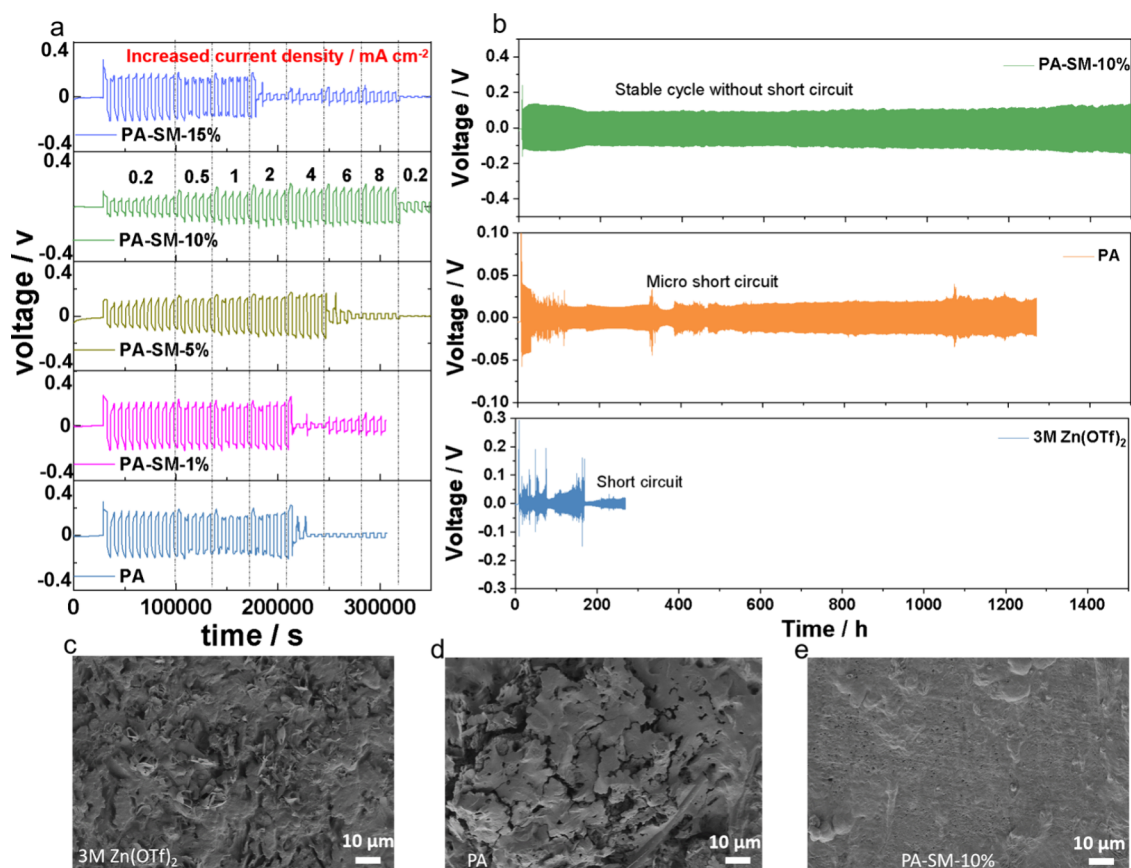


Figure 2. (a) Rate performance of Zn||Zn cell using various electrolytes. (b) Cycle performance of Zn||Zn cells using various electrolyte. (c–e) SEM images of cycled Zn surface using 3 M Zn(OTf)₂, PA, and PA-SM-10%.

performing in-situ EIS to evaluate long-term cycling stability. The results reveal that the interfacial resistance of the zwitterionic electrolyte system remains highly stable throughout continuous discharge for up to 21 h, consistently staying below 420 Ω. In comparison, the 3 M Zn(OTf)₂ liquid electrolyte system exhibits an initial interfacial resistance as high as 700 Ω. Although its resistance decreases slightly in the early stage of cycling, it subsequently shows a pronounced rebound, indicating severe parasitic reactions at the electrode/electrolyte interface and progressive deterioration of interfacial stability.

Taken together, these results unequivocally demonstrate that the introduction of zwitterionic moieties not only effectively lowers the interfacial resistance over a wide temperature range but also significantly enhances interfacial stability during long-term cycling, thereby playing a pivotal role in improving the overall battery performance.

The full cell performance is further evaluated in Figure 5. As shown in Figure 5a, the charge–discharge curves of the PA-SM-10%-based cell at the 1st and 800th cycles exhibit characteristic features typical of a V₂O₅ cathode. Figure 5b displays the cycling performance of Zn||V₂O₅ cells using 3 M Zn(OTf)₂, PA, and PA-SM-10% at a current density of 8 A g⁻¹. Over 800 cycles, the cell with 3 M Zn(OTf)₂ delivers an average capacity of only 360 mAh g⁻¹, whereas the PA-based cell achieves 507 mAh g⁻¹, confirming that the polymer electrolyte with multiple zincophilic sites enhances zinc-ion transport kinetics. Notably, the introduction of the zwitterionic segment further increases the average capacity to

518 mAh g⁻¹ for the PA-SM-10%-based cell. This improvement underscores the crucial role of the zwitterionic component in stabilizing the electrode/electrolyte interface and promoting uniform zinc deposition, which collectively enhance both cycling stability and capacity retention—consistent with the findings discussed above.

Even more pronounced differences are observed in the rate capability tests (Figure 5c). The PA-SM-10%-based full cell outperforms both the PA-based and the liquid-electrolyte cells across the entire current density range from 0.2 to 10 A g⁻¹. Remarkably, at a high current density of 10 A g⁻¹, the PA-SM-10% cell delivers a capacity of 420–430 mAh g⁻¹, while the PA cell achieves less than 300 mAh g⁻¹. This substantial difference further highlights the advantage of the zwitterionic moieties in facilitating fast Zn²⁺ transport kinetics, especially under demanding rate conditions.

It is worth noting that a comparison between Figures 5b and c reveals an apparent discrepancy: at the same current density of 8 A g⁻¹, the long-term cycling test (Figure 5b) gives a capacity of approximately 500 mAh g⁻¹ for PA-SM-10%, whereas the rate capability test (Figure 5c) shows 420–430 mAh g⁻¹. This difference is not contradictory but rather arises from the different testing protocols. In the rate capability measurement, the cell is subjected to rapidly successive current steps without prior stabilization, which imposes greater stress on the electrodes and leads to some capacity loss. In contrast, the long-term cycling test includes a low-current activation step before the 8 A g⁻¹ cycling, which significantly improves the interfacial stability

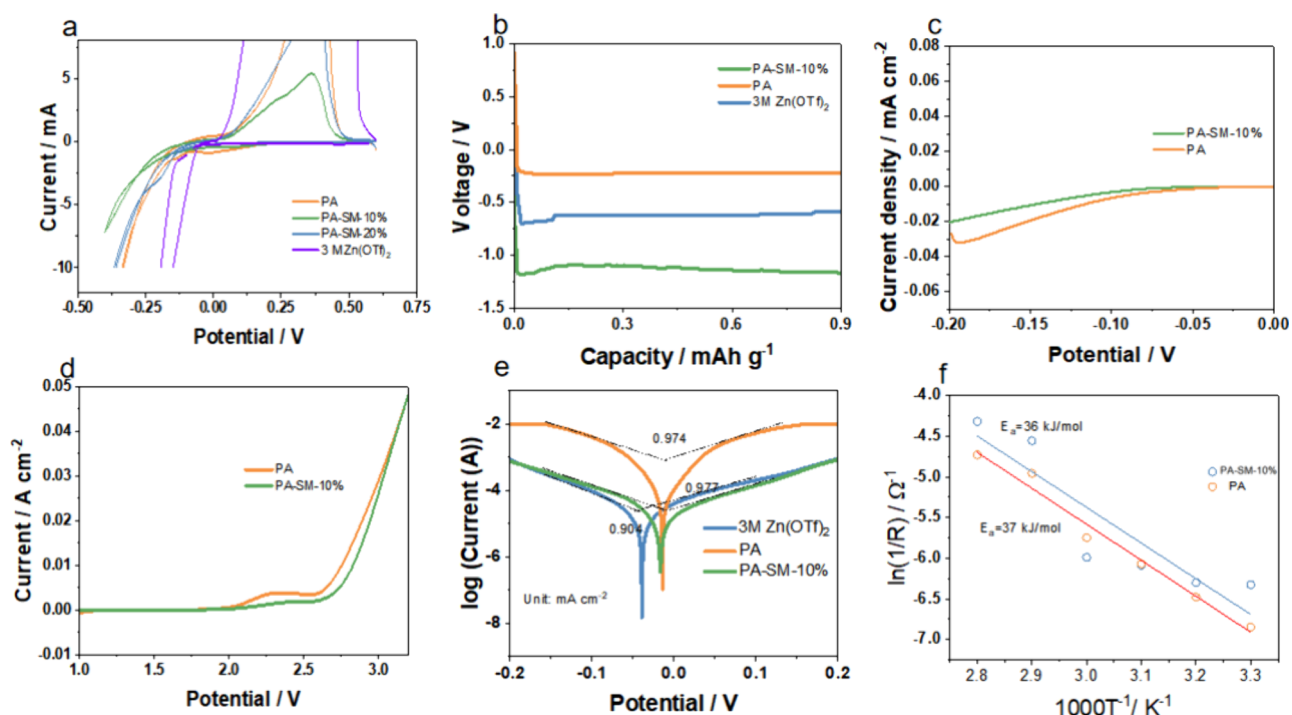


Figure 3. (a) Cyclic voltammograms of Zn||Cu cells of various electrolytes at 5 mV/s. (b) Voltage–capacity curves of various electrolytes under 1 mA cm⁻². (c, d) LSV curves of PA and PA-SM-10%. (e) Tafel curves of various electrolytes. (f) Relationship of R_{ct} vs temperature of PA and PA-SM-10%.

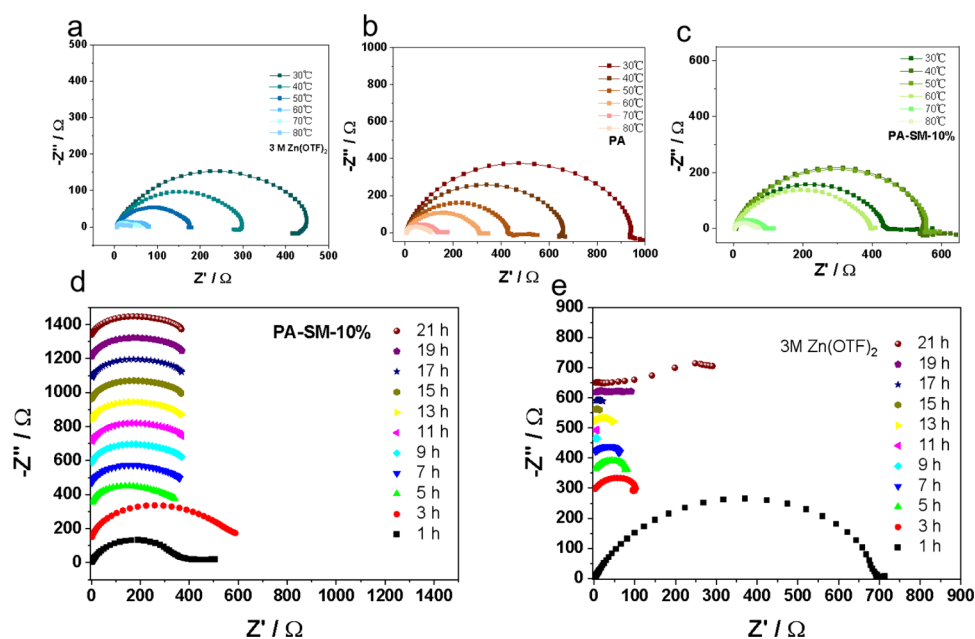


Figure 4. (a–c) EIS based on bare symmetrical zinc battery at various temperature. In-situ EIS of symmetrical zinc batteries using (d) PA-SM-10% and (e) 3 M Zn(OTf)₂, respectively.

and thus results in higher measured capacities. Therefore, the two sets of data complement each other, collectively demonstrating the superior performance of the PA-SM-10% electrolyte.

According to the above discussion, PA-SM-10% exhibits the best performance, the optimal performance of PA-SM-10% stems

from a well-balanced incorporation of zwitterionic moieties. At 5% content, the functional groups are insufficient to regulate ion transport and suppress dendrites effectively, whereas at 15%, excessive zwitterions reduce ionic conductivity and increase mechanical hysteresis, compromising interfacial stability. The 10% composition achieves an optimal trade-off, enabling efficient

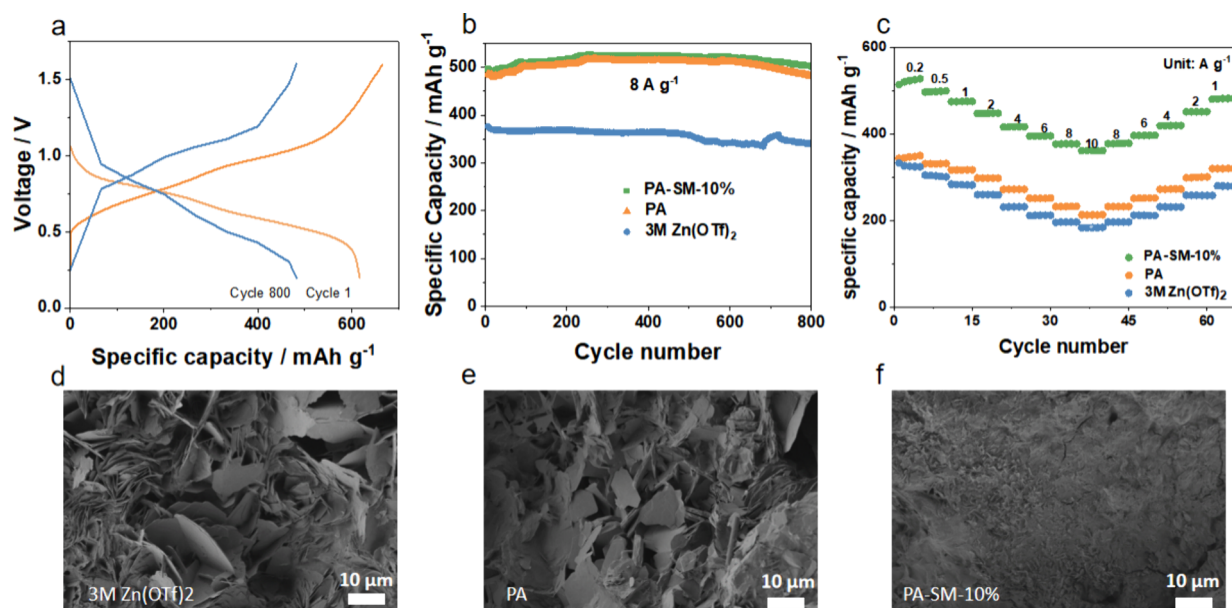


Figure 5. (a) Charging/discharging curves of Zn||V₂O₅ cells using PA-SM-10%. (b) Cycle performance of Zn||V₂O₅ cells using various electrolytes. (c) Rate properties of Zn||V₂O₅ cells using various electrolytes. (d) SEM images of cycled Zn anode based on Zn||V₂O₅ cells using 3 M Zn(OTf)₂, (e) PA, and (f) PA-SM-10%.

Zn²⁺ conduction, robust mechanical flexibility, and a stable electrode-electrolyte interface, thus ensuring long-term cycling stability.

Notable differences are also observed in the morphology of the cycled zinc anodes. The liquid electrolyte-based cell shows large, irregular flake-like zinc dendrites after cycling (Figure 5d). With PA, the zinc anode still exhibits considerable dendritic growth (Figure 5e). In contrast, the zinc anode cycled with PA-SM-10% displays a smooth surface without obvious dendrites (Figure 5f). This is mainly due to the synergistic combination of multiple zincophilic sites from PA and the zwitterionic segments in PA-SM-10%, which collectively regulate the zinc-ion solvation structure and guide uniform zinc deposition at the interface. In summary, while the liquid electrolyte shows baseline cyclability, the PA-SM-10% delivers higher performance metrics and substantially improved interfacial stability, addressing key bottlenecks toward practical AZIBs. The comprehensive performance including electrolyte conductivity and battery performance in Table S1 is also superior to that of the recent reported works.

CONCLUSIONS

In summary, we have successfully designed an ion-regulating electrolyte system, poly(4-acryloylmorpholine)-co-poly(3-sulfopropyl dimethyl-3-methacrylamidopropylammonium inner salt), which effectively addresses the critical challenge of limited ion transport kinetics in both bulk electrolyte and interfacial regions of AZIBs. The strategically incorporated C=O, C-N, and C-O-C groups within the poly(4-acryloylmorpholine) segments significantly promote the desolvation process of hydrated zinc ions, while the zwitterionic moieties enable simultaneous anion confinement and creation of fast zinc-ion transport pathways. This molecular-level engineering yields an exceptional room-temperature ionic conductivity over 3 mS cm⁻¹, coupled with efficient ion regulation capability. The synergistic combination of multi-zincophilic sites and zwitterionic functional groups

ensures strong interfacial adhesion to the zinc anode and guides uniform zinc deposition, effectively suppressing dendrite formation. This optimal balance between coordinated ion capture and rapid transport enables remarkable electrochemical performance: symmetric Zn||Zn cells achieve extended cycling stability over 1400 h at 5 and 2.5 mAh cm⁻², while solid-state Zn||V₂O₅ full batteries maintain a high specific capacity of ~518 mAh g⁻¹ over 800 cycles at 8 A g⁻¹ with 98% average Coulombic efficiency, alongside outstanding rate capability. This work establishes a novel electrolyte design paradigm that could propel the development of high-performance, safe AZIBs and may extend to other metal battery systems.

EXPERIMENTAL SECTION

Materials

Zinc trifluoromethanesulfonate (Zn(OTf)₂, 98%, Aladdin), vanadium pentoxide (V₂O₅, 99.5%, Macklin), 4-acryloylmorpholine (Aladdin, ≥98%), 3-sulfopropyl dimethyl-3-methacrylamidopropylammonium inner salt (Aladdin, ≥98%), and Zinc Foil (99.9%, Sigma-Aldrich) were used directly without other treatment. All reagents are directly applicable unless otherwise stated.

Preparation of Electrolytes

First, the polymer sample was prepared by thermally polymerizing a mixture of 0.5 g (3.55 mmol) of 4-acryloylmorpholine and 0.01 g (0.035 mmol) of ammonium persulfate (APS) in 0.5 mL of deionized water, with varying amounts of [3-(methacryloylamino)propyl]dimethyl(3-sulfopropyl)ammonium (0.005 g (0.017 mmol), 0.025 g (0.086 mmol), 0.05 g (0.17 mmol), 0.075 g (0.26 mmol)) hydroxide added. The mixture was thoroughly stirred, transferred into a mold fabricated using two glass slides separated by 200-μm-thick silicone rubber spacers, and subjected to thermal polymerization at 60 °C for 10 h. The resulting product was then immersed in a 3 M Zn(OTf)₂ solution for 1 min to obtain the final electrolyte material (the calculated content of liquid electrolyte was about 35 wt %).

Modification of Electrode Active Material (V₂O₅) and Preparation of Electrode

V₂O₅ was ball-milled prior to use. Typically, 2.0 g of V₂O₅ was added to a ball-mill jar and milled (100 rpm) vigorously at room temperature for 48 h. For the electrode slurry, 80 mg of the ball-milled V₂O₅, 10 mg of conductive carbon black and 10 mg of PVDF were ground together in an agate mortar for 15 min until homogeneous. Then, 0.5 mL of NMP was added, followed by another 15 min of grinding and stirring. The resulting slurry was doctor-bladed onto a Ti current collector with a controlled wet thickness of 30 μm. The coated electrode was dried at 60 °C in an air-oven for 1 h, followed by further drying in a vacuum oven at 100 °C for 12 h. Finally, the electrode was cut into appropriate dimensions for use with areal mass of 3.0 mg cm⁻².

Characterization

FTIR spectroscopy (L1600400 Spectrum TWO DTGS) was applied to record the structural information of electrolyte. SEM images were performed using a Field Emission Scanning Electron Microscope (FESEM, Hitachi SU8010). The stress-strain curves of the samples were obtained by Instron 3300 electronic universal material testing system at a test rate of 10 mm/min.

Electrochemical Measurements

The basic electrochemical properties (e.g., LSV, CV) of the electrolytes were measured using a Zennium Electrochemical workstation (ZahnerEnnium).¹ Electrochemical impedance spectroscopy (EIS) for ionic conductivity calculation was performed on stainless steel–stainless steel cells using a DH7000D electrochemical workstation (Jiangsu Donghua Analytical Instrument Co., Ltd.). Galvanostatic cycling tests of symmetric Zn||Zn cells and full cells were conducted on a Neware battery test system. Zn||Zn symmetric cells with 30 μm thick Zn foils were employed for testing at different depths of discharge (DOD). The DOD was calculated by the following equation:

$$\text{DOD} = \frac{y}{C_{\text{zn, volume}} \times 10^{-4}} \times 100\% = y/0.585x \times 100\%$$

where x (μm) is the thickness of the Zn foil and y (mAh cm⁻²) represents the Zn areal capacity used in electrochemical testing.

The cell is assembled in ambient air. A V₂O₅ cathode and a zinc foil anode are used. The polymer electrolyte membrane is placed between the two electrodes. The stack is sandwiched between the positive and negative casings of a CR2025 coin cell, and then mechanically crimped to seal the cell. The N/P ratio of the cell is 20. All galvanostatic charge–discharge, rate capability, and long-term cycling tests are performed using a Neware battery testing system (e.g., BTS series) at room temperature.

■ ASSOCIATED CONTENT

SI Supporting Information

The Supporting Information is available free of charge at <https://pubs.acs.org/doi/10.1021/acsaem.6c01937>.

Synthesis route of polymer (Figure S1), cyclic stress–strain curves (Figure S2), cycle performance of Zn||Zn cells (Figure S3), SEM image of Zn (Figure S4), EIS spectra (Figure S5), and performance comparison (Table S1) (DOCX)

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Notes

The authors declare no competing financial interest.

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