Abstract ID: 039

ENHANCING THE PERFORMANCE OF GEL POLYMER ELECTROLYTE BY MIXED CATION EFFECT FOR Zn - METAL ION BATTERIES

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Abstract

Zinc-metal ion batteries (ZIBs) emerge as safer, cost-effective, and environmentally sustainable alternatives to lithium-ion batteries. However, their progress is limited by low ionic conductivity, dendrite formation, and poor electrolyte stability. Polyvinylpyrrolidone (PVP) has been widely employed in polymer electrolytes due to its excellent film-forming ability, strong coordination with metal ions, and high chemical stability. In this study, a high-performance PVP-based gel polymer electrolyte (GPE) was developed using a mixed-cation strategy involving Zn^{2+} and Cs^{+} ions. The GPE was fabricated by blending PVP with propylene carbonate and ethylene carbonate, followed by incorporation of $ZnCl_2$ and CsCl at varying ratios. Ionic conductivity was analyzed by the electrochemical impedance spectroscopy (EIS), and structural interactions were examined by FTIR spectroscopy. Results indicate that Zn^{2+} ions strongly coordinate with the carbonyl groups of PVP, enhancing ion transport, while the addition of Cs^{+} ions further promote segmental motion and mobility within the GPE matrix. The optimized Zn^{2+}:Cs^{+} ratio of 3:2 exhibits the highest ionic conductivity of 8.219×10^{-5} S cm^{-1} with a corresponding activation energy of 0.407×10^{-4} eV. These findings confirm that the synergistic effect of mixed cations significantly reduces ion migration barriers, enhances conductivity, and overcomes the limitations of single-cation systems. Hence, the PVP-based GPE incorporating Zn^{2+}/Cs^{+} offers a promising electrolyte design for next-generation zinc-ion batteries with improved safety and electrochemical stability.

Keywords*: Polyvinylpyrrolidone (PVP), Zinc-Metal Ion Batteries (ZIBs), Gel Polymer Electrolyte (GPE).*

Financial assistance from South Eastern University of Sri Lanka (Grant No.: SEU/ASA/RG/2021/11) is acknowledged.