Chia Seeds-Based Gel Electrolyte for Sustainable and Stable Zinc Ion Batteries

Gulsah Yaman Uzunoglu[1]

[1] Department of Chemical Engineering, Istanbul Health and Technology University (ISTUN), Istanbul 34445, Türkiye

Aqueous zinc batteries represent a promising option for energy storage and conversion technologies in the "post-lithium" era, owing to their elevated energy density, enhanced safety, and affordability. Rechargeable aqueous zinc ion batteries (RZBs) are recognized as promising alternatives to lithium-ion batteries due to their cost-effectiveness, safe-and-sustainable-by-design, and scalability. Nonetheless, their performance is hindered by inadequate cyclability, which is attributed to dendrite formation and the hydrogen evolution reaction (HER) occurring at the zinc anode [1]. Such limitations demand the formulation of advanced electrolyte solutions to boost ZIB performance, concurrently prioritizing sustainability. The electrolyte is crucial in ZIBs, as it facilitates the ionic conductivity and ion transfer of the positive and negative electrodes. Natural materials and their derivatives, sourced from renewable and sustainable resources, may offer promising strategies to reduce both HER activity and dendrite formation [2]. Natural organic compounds, including proteins, amino acids, saccharides, and organic acids, have recently been demonstrated to influence the solvation structure of the electrolyte and to improve the electrode/electrolyte interface in ZIBs. These natural materials offer non-toxicity, excellent compatibility, biodegradability, and are abundant, aligning with the demand for safe-by-design, high-performance ZIBs. Chia seeds (CS) are a type of crop rich in protein, fatty acids, and carbohydrates. When these seeds are immersed in water, they generate a clear, adhesive gel that adheres to the seed coat [3].

In this work, a sustainable gel electrolyte derived from chia seeds containing 2M $ZnSO_4$ has been developed to improve the electrochemical stability of ZIBs. This electrolyte formulation aims to reduce the presence of free water molecules and alleviate the hydrogen evolution reaction (HER) as well as the formation of zinc dendrites. The results obtained indicate that the CS-based electrolyte significantly enhances the electrochemical stability and performance of ZIBs. The formulation of the CS-based electrolyte in symmetrical Zn‖Zn cells demonstrates an impressive cycle life of 800 hours at a current density of 1.0 mA cm^{-2} (1.0 mAh cm^{-2}), which significantly exceeds the longevity of traditional aqueous electrolytes used in ZIBs. Furthermore, the CS-based electrolyte, enriched with organic moiety, achieves a specific capacity of 250 mAh g^{-1} at 1.0 A g^{-1} for the V_2O_5 cathode in a fully assembled Zn‖V_2O_5 cell.

References

[1] X. Zhang, Y. Liu, S. Wang, J. Wang, F. Cheng, Y. Tong, L. Wei, Z. Fang, J. Mao, Energy Storage Materials 2024, 70, 103471; bZ. Zhang, Z. He, N. Wang, F. Wang, C. Du, J. Ruan, Q. Li, D. Sun, F. Fang, F. Wang, Advanced Functional Materials 2023, 33, 2214648.

[2] G. Yaman Uzunoglu, R. Yuksel, Small 2025, 21, 2411478.

[3] B. Kulczyński, J. Kobus-Cisowska, M. Taczanowski, D. Kmiecik, A. Gramza-Michałowska, Nutrients 2019, 11.

Gulsah Yaman Uzunoglu received her B.S. and M.S. degrees in Chemistry from Middle East Technical University, Ankara, Türkiye, in 2000 and 2002, respectively. She received her Ph.D. degree in Chemistry from the Ohio State University in 2008. She worked as a chief senior researcher for TUBİTAK National Metrology Institute (2008-2012) and TUBITAK Marmara Research Center Energy Institute (2016-2020). She is currently a faculty member in the Department of Chemical Engineering at Istanbul Health and Technology University. Her research interests are solid-state batteries, electrochemical energy storage, functional nanomaterials and sustainable materials.

Gulsah Yaman Uzunoglu, e-mail: gulsah.uzunoglu@istun.edu.tr tel: +90-530-760-0660