Electrochemical Evaluation of Lead Electrodes in Polyaniline-Doped Fumed Silica Gel Electrolytes

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The rapid advancement of technology increases energy demand, leading to natural resource depletion and environmental impact. Renewable energy offers an effective solution but suffers from intermittency issues, highlighting the need for energy storage systems. Valve-regulated lead-acid (VRLA) batteries are among the oldest, most cost-effective, maintenance-free, and recyclable storage options, widely used in emergency systems, telecommunications, and electric vehicles [1,2].

AGM (absorbed glass mat) and gel-type VRLA batteries use immobilized gel electrolytes, where a 3D network forms through the hydrolysis of fumed silica with sulfuric acid, creating a highly thixotropic gel with good capacity and high solution resistance [3].

Various additives have been developed to enhance gel resistance and charge transfer without compromising gel structure [4,5].

In this study, polyaniline (PANi) conductive polymer was incorporated as an additive in the preparation of gel electrolytes for VRLA batteries. PANi powder was synthesized through chemical oxidative polymerization in an aqueous solution, as illustrated in Fig. 1. Gel electrolyte were optimized using electrochemical analyses methode for charge-discharge test.

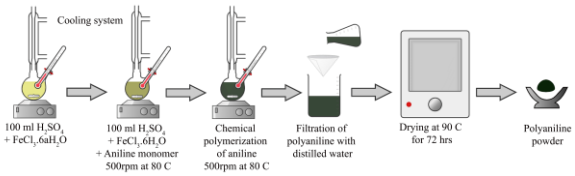

Fig.1. Synthesis of PANi conductive polymer

The produced polyaniline was characterized using BET, SEM, FTIR, and electrical conductivity measurements to assess its surface area, morphology, chemical structure, and conductive properties. All electrochemical analyses were carried out using a Gamry potentiostat (INTERFACE1010B) and a NEWARE 4000 multichannel device.

Electrochemical measurements, including cyclic voltammetry (CV), electrochemical impedance spectroscopy (EIS), and Tafel extrapolation, were conducted to evaluate the performance of lead electrodes in fumed silica-based gel electrolytes, both with and without polyaniline (PANi) incorporation. The observed redox peaks were attributed to the reversible electrochemical reactions involving the formation of lead sulfate from metallic lead and its subsequent reduction back to elemental lead. The results demonstrated that the inclusion of the conductive polymer polyaniline significantly enhanced the electrochemical activity and stability of the lead electrodes. Specifically, PANi contributed to improved charge transfer kinetics and reduced interfacial resistance, indicating its potential as an effective additive for improving the performance of gelled electrolytes in lead-based electrochemical systems.

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References

[1] S. Sarmah, Lakhanlal, B.K. Kakati, D. Deka, Recent advancement in rechargeable battery technologies, Wiley Interdiscip. Rev. Energy Environ. 12 (2023). https://doi.org/10.1002/wene.461.

[2] J. Mitali, S. Dhinakaran, A.A. Mohamad, Energy storage systems: a review, Energy Storage Sav. 1 (2022) 166–216. https://doi.org/10.1016/j.enss.2022.07.002.

[3] P.T. Moseley, D.A.J. Rand, J. Garche, Lead–acid batteries for future automobiles, in: Lead-Acid Batter. Futur. Automob., Elsevier, 2017: pp. 601–618. https://doi.org/10.1016/B978-0-444-63700-0.00021-0.

[4] S. Yasa, O. Kumbasi, M.B. Arvas, M. Gencten, M. Sahin, Y. Sahin, S-Doped Graphene Oxide/N-Doped Graphene Oxide/PANI: A Triple Composite for High-Performance Supercapacitor Applications, ECS J. Solid State Sci. Technol. 12 (2023) 051002. https://doi.org/10.1149/2162-8777/acd3af.

[5] A. Mansuroglu, M. Gencten, M.B. Arvas, M. Sahin, Y. Sahin, Investigation the effects of chlorine doped graphene oxide as an electrolyte additive for gel type valve regulated lead acid batteries, J. Energy Storage 64 (2023) 107224. https://doi.org/10.1016/j.est.2023.107224.

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