Boosting Aluminum-Air Battery Performance Through Nano-Based Additives

Al Logmani, Jamal (School: King Fahd University of Petroleum and Minerals (KFUPM) Boys High School)

The need for sustainable energy storage drives the search for alternatives to lithium-ion batteries, which face limitations in energy density, cost, environmental impact, and material scarcity. Aluminum-air batteries (AABs) offer a promising solution, leveraging aluminum's abundance and eco-friendliness. However, parasitic reactions hinder performance. This project investigates novel nano-based additives to mitigate these reactions and enhance AAB performance in a 4M sodium hydroxide electrolyte. Magnesium oxide (MgO) nanoparticles and a polyacrylic acid (PAA)/ceric ammonium nitrate (CAN) combination were developed and tested as additives, comparing their effectiveness to conventional zinc oxide (ZnO). Hydrogen evolution and electrochemical techniques assessed corrosion inhibition; galvanostatic discharge evaluated performance; and characterization techniques identified inhibition mechanisms. Hydrogen evolution, potentiodynamic polarization, and linear polarization resistance tests revealed that both the MgO and PAA/CAN combinations, at a concentration of 1000 ppm, significantly outperformed ZnO in corrosion inhibition. MgO achieved 97% inhibition efficiency, PAA/CAN 91%, and ZnO 56%. Galvanostatic discharge tests demonstrated enhanced anode utilization and increased battery capacity. The MgO additive showed a discharge capacity of 864 mAh/g, the PAA/CAN combination 1064 mAh/g, and ZnO 739 mAh/g. Surface analysis using SEM, EDX, FTIR, and 3D optical profilometry confirmed the formation of protective layers on the aluminum anode through adsorption (MgO) and co-adsorption (PAA/CAN). This research advances the development of efficient and sustainable energy storage systems, potentially expanding AAB applications while capitalizing on abundant aluminum resources.

Awards Won: