Suppressing Hydrogen Evolution in Iron Anodes for Alkaline Rechargeable Batteries

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Iron as anode in Fe-Air or Fe-Ni batteries are gainig considerable attention due to their safety, affordability, nontoxicity, and high energy density. Iron is cheap, highly abundant and environmentally friendly, making it an attractive alternative to other battery chemistries. Additionally, iron does not form dendrites during cycling, enhancing both the safety and long-term stability of the battery. With a high theoretical capacity of 960 $mAhg^{-1}$, iron-based batteries hold significant potential for large-scale energy storage systems, offering a sustainable and cost-effective solution.[1] However, challenges such as passivation and hydrogen evolution reaction hinder their electrochemical performance. This study aims to develop solutions to overcome these challenges.

Passivation occurs when a non-conductive iron hydroxide layer forms on the surface of the iron anode, disrupting the contact between the anode and the electrolyte. We have used carbon coating as a way of providing solution for this passivation.

Hydrogen gas evolution is a parasitic reaction that occurs during charging when iron oxide converts back to iron, negatively impacting the battery's efficiency. We have used additives such as sulfur and bismuth additives (Bi_2S_3, FeS, and Bi_2O_3) so as to control hydrogen evolution for the sake of improved effciency.

Electrochemical tests were conducted in a Swagelok cell. The anode was prepared with 80 wt% active material as iron, 10 wt% carbon black, and 10 wt% PTFE. PTFE and 4 ml of ethanol/water mixture were stirred for 10-15 minutes, followed by the addition of carbon black and iron powder for 1 hour to form a slurry.Then, the slurry was applied onto Ni foam, dried at 60 °C overnight, and pressed at 20 MPa. Commercial $Ni(OH)_2$ electrodes used as cathodes, and 6 M KOH was used as the electrolyte with a PP cloth separator.

For carbon coating, glucose is dissolved in ethanol, and 1 g of active material is added. After mixing for 1 hour and drying overnight at 60°C, the mixture is pyrolyzed in a tube furnace under nitrogen flow.

Further improvement, many concentrations and combinations of Bi_2S_3, FeS, and Bi_2O_3 were used as additive to suppress hydrogen evolution. Preliminary results indicate that 10 wt% FeS and 5 wt% Bi_2S_3 yield the best performance.

Recent studies have shown that with carbon coating and the addition of FeS and Bi_2S_3, the iron anode exhibits high capacity and improved stability.

The effect of these sulfide additives will be evaluated through a series of experiments, where they will be added to the anode and electrolyte both separately and together to see their effects on suppressing hydrogen evolution, and the carbon coating procedure will be optimized for improved performance.

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References

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