Improving Zinc Anode Stability and Efficiency in Alkaline Rechargeable Batteries

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Zn-Ni and Zn-air rechargeable batteries are seen as promising candidates for next-generation energy storage, providing benefits including safety, abundant resources, environmental friendliness, low-cost, and sufficient energy density. Nevertheless, their practical application remains limited due to the instability of Zn anodes, where dendrite formation and hydrogen evolution reaction (HER) dramatically compromise cyclic stability and performance of battery. [1]

Zinc is highly susceptible to corrosion in alkaline electrolytes, leading to uneven surface morphology and the formation of insulating by-products such as ZnO and $Zn(OH)_2$. These passivation layers block active sites, lower Coulombic efficiency, and promote further surface degradation. Corrosion also drives inhomogeneous Zn dissolution and redeposition, which contributes to the shape change problem.

Non-uniform deposition during repeated Zn plating and stripping causes the creation of needle-like dendritic structures. These dendrites continue to grow and finally reach the cathode, resulting in internal short circuits, dead zinc formation, and sudden capacity drop.

The hydrogen evolution reaction takes place as an undesirable outcome of cycling, consuming electrolyte and generating gas bubbles. These bubbles block active sites, create internal pressure, and may cause swelling or bulging of cells. Local current density fluctuations resulting from gas evolution lead to non-uniform Zn deposition, accelerating dendritic growth and anode degradation.

Electrochemical tests were conducted in a Swagelok cell. The anode was prepared using 80 wt% arc-sprayed Zn/ZnO powder (Zn core with a thin ZnO shell) produced in the lab, 10 wt% carbon black, and 10 wt% PTFE. PTFE was first dispersed in 4 mL of an ethanol/water mixture and stirred for 10–15 min, followed by the addition of carbon black and Zn/ZnO powder, and mixed for 1 h to form a slurry. The slurry was applied onto Cu foam, dried at 60 °C overnight, and pressed at 20 MPa. Commercial $Ni(OH)_2$ electrodes were used as cathodes. The electrolyte was 6 M KOH saturated with 0.35 M ZnO, and a polypropylene (PP) cloth was used as the separator.

Bare Zn/ZnO anode showed poor performance with rapid capacity fading and high HER. To suppress HER, Bi_2O_3 was introduced as an additive. Adding 3 wt% Bi_2O_3 increased the capacity from 15 to 300 mAh/g and partly suppressed HER. Furthermore, adding 0.5 M LiOH into the electrolyte improved cycle life and stability, while providing better HER control.

For further improvement, carbon coating was applied. Glucose was dissolved in DI water and 1 g of active material was added. The mixture was stirred for 1 h, dried overnight at 60 °C, and then pyrolyzed in a tube furnace under nitrogen at 400 °C for 2 h with a heating rate of 3.33 °C/min. The obtained powder was cooled and used for electrode preparation.

Recent studies showed that carbon-coated Zn/ZnO anodes combined with these additives provide longer cycle life and higher capacity. As a result, HER was effectively suppressed and no significant capacity fading was observed up to the 50th cycle.

The ongoing study aims to achieve further improvements in both capacity and stability.

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References

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