DEVELOPMENT OF ZINC POWDER ANODE FOR LIQUID ZINC-AIR BATTERIES USING POLYVINYL ALCOHOL AS A BINDER

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ABSTRACT

This research aims to enhance the mechanical stability and electrochemical performance of zinc powder anodes for liquid-electrolyte zinc-air batteries by employing polyvinyl alcohol (PVA) as a binder. The study initially involved physical characterization to determine the particle size of the zinc powder. Subsequently, anodes were fabricated using pure zinc powder and zinc-PVA composites at varying ratios (0, 0.025, 0.050, 0.075, and 0.100). The mixture was molded into 3 x 3 cm^2 electrodes using a hydraulic press at 800 psi. The mechanical integrity was evaluated via a three-point bending test, complemented by an analysis of the electrochemical properties to assess practical application feasibility. Morphological analysis using optical microscopy (OM) and scanning electron microscopy (SEM) revealed that increasing PVA content significantly improved zinc powder distribution and reduced inter-particle porosity. Samples PVA0.075 and PVA0.1 exhibited high surface continuity as the polymer film effectively coated and bonded the gaps between zinc particles. This modification directly influenced fracture behavior; while the binder-free sample (PVA0) demonstrated distinct brittle fracture and powder delamination, the PVA-enhanced samples inhibited crack propagation through a polymeric bridging mechanism. This mechanism effectively maintained the structural integrity of the anode. Electrochemical testing indicated that higher PVA ratios led to an increase in open circuit voltage (OCV) and improved efficiency in maintaining voltage and capacity during charge-discharge cycles, thereby extending battery lifespan. However, a decrease in power density was observed with higher binder content. All ratios yielded a consistent specific capacity of approximately 819 mAh/g. In conclusion, PVA serves as an effective binder that enhances both the mechanical robustness and electrochemical stability of zinc-air batteries, offering a promising pathway for high-performance battery development.

INTRODUCTION

Zinc - Air battery

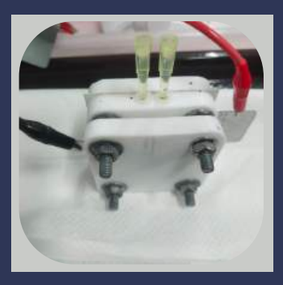


fig 1.1 Component of Zinc-Air battery

Zinc powders are a favorable anode in primary battery because of their

- high capacity
- high discharge efficiency
- low cost
- high safety feature associated with their manufacturing process

Zinc Powder Anode



fig 1.2 Zn powder Anode

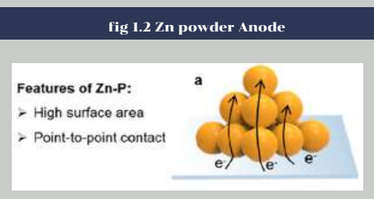


fig 1.3 Schematic of Zinc Powder Anode feature

OBJECTIVE

TO DEVELOP AND CHARACTERIZE ZINC POWDER ANODES USING POLYVINYL ALCOHOL (PVA) AS A BINDER TO ENHANCE THE ELECTROCHEMICAL PERFORMANCE AND STABILITY OF LIQUID ZINC-AIR BATTERIES

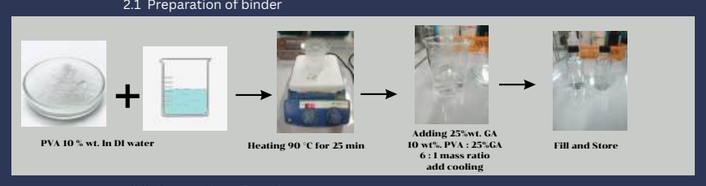
EXPERIMENT

1. Characterization of Zinc powder



2. preparing 0f Zinc powder anode with PVA

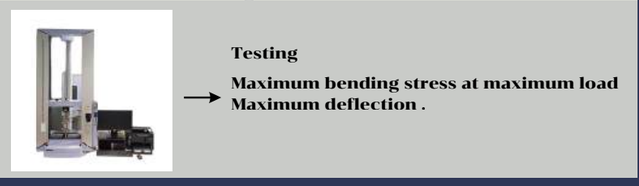
2.1 Preparation of binder



2.2 Preparation of anode



3.Mechanical Testing



4.Morphology of Zinc powder anode with PVA

The prepared zinc powder anode
zinc powder anode after battery performance testing



5.Zinc air battery performance test

Components	Materials
Plates	Polyvinyl chloride
Cathode	Oxygen
Cathode Current Collector Plate	Stainless steel
Gas diffusion layer	Carbon cloth
Catalyst	Manganese dioxide
Electrolyte	KOH 7 M
Anode	Zinc powder with PVA binder
Anode Current Collector Plate	aluminum



RESULTS AND DISCUSSION

1. MORPHOLOGY OF ZiNC POWDER

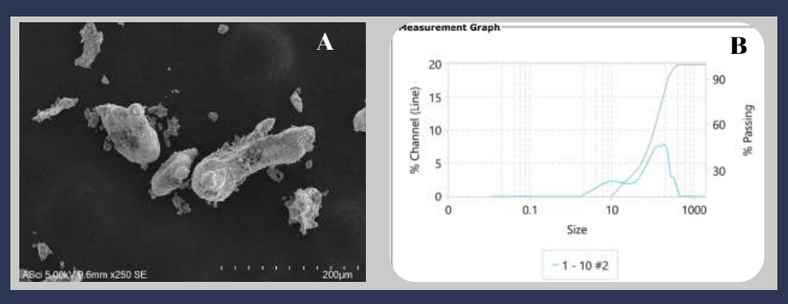


fig 3.1 (A)morphology Zinc powder,(B)particle size of Zinc powder

2.SURFACE MORPHOLOGY OF ZiNC ANODE



fig 3.2 SEM images of Zinc/Polyvinyl Alcohol composites at various weight ratios: (A) 1:0, (B) 1:0.025, (C) 1:0.05, (D) 1:0.075, and (E) 1:0.1

3. MECHANiCAL TESTiNG OF ZiNC ANODE

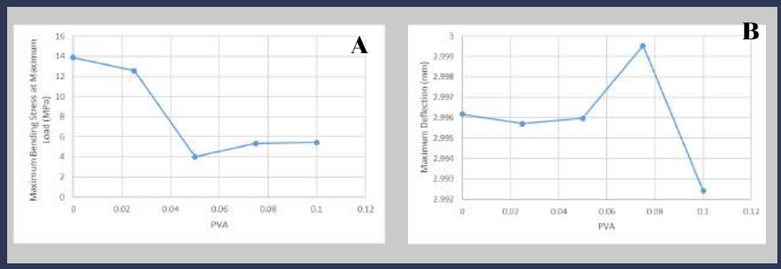


Fig. 3.3 Mechanical properties of the Zinc anode:
(A) Maximum bending stress at maximum load, and
(B) Maximum deflection .

4. ZiNC AiR BATTERY PERFORMANCE TESTiNG

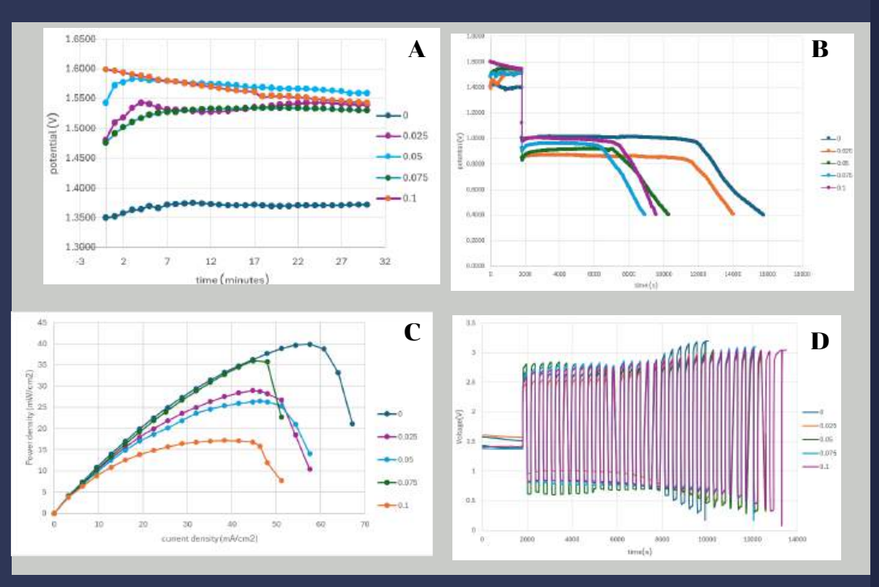


Fig. 3.4 Electrochemical performance of the Zinc-air battery: (A) Open Circuit Voltage (OCV) , (B) Discharge curve, (C) Power density curve, and (D) Battery cycling performance.

5. MORPHOLOGY OF ZiNC POWDER ANODE AFTER BATTERY TESTiNG

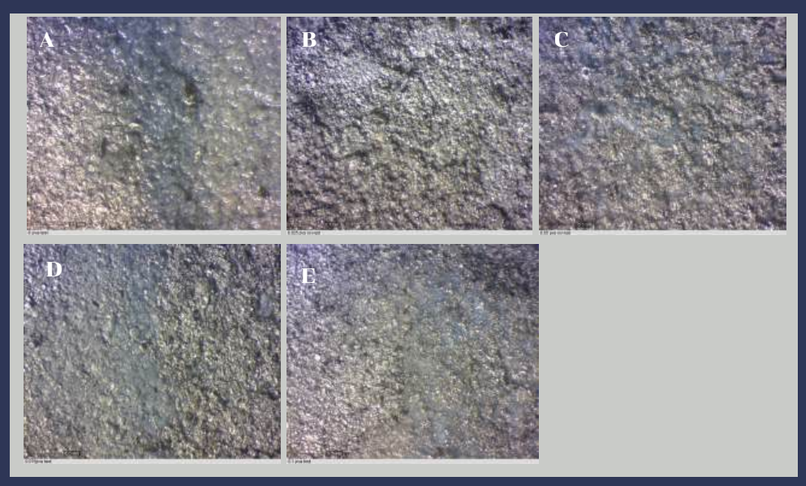


fig 3.5 OM images of Zinc/Polyvinyl Alcohol (Zn/PVA) composites at various weight ratios: (A) 1:0, (B) 1:0.025, (C) 1:0.05, (D) 1:0.075, and (E) 1:0.1

CONCLUSION

The use of PVA as a binder significantly enhances zinc anode performance as follows:

- Structural Integrity: PVA forms a polymeric bridging network, improving particle adhesion and inhibiting crack propagation compared to binder-free anodes.
- Discharge Performance: PVA 0.075 and 0.1 ratios provide superior voltage stability while maintaining a consistent specific capacity of 819 mAh/g.
- Durability: By reducing material delamination, the 0.075 and 0.1 ratios achieve the highest capacity retention and significantly extend the battery's cycle life.

REFERENCE

[1] G. Cihanoğlu and Ö. Ebil, "Binder Effect on Electrochemical Performance of Zinc Electrodes For Nickel-Zinc Batteries," JOTCSA, vol. 5, no. sp.is. 1, pp. 65-84, 2018.

[1] X. Chen et al., "Polyvinyl Alcohol Coating Induced Preferred Crystallographic Orientation in Aqueous Zinc Battery Anodes," SSRN Electronic Journal, 2022, doi: 10.2139/ssrn.4013282.