Supplementary Information

Superior cycling stability and high rate capability of three-dimensional Zn/Cu foam electrodes for zinc-based alkaline batteries

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Table of Contents

Fig. S1. Schematic diagram of zinc/zinc quasi-symmetric cell.

Fig. S2. Schematic diagram of prototype Zn/Ni battery.

Fig. S3. Photographs and I-V curves of Zn/Cu foam electrodes prepared by different electrodeposition methods.

Fig. S4. Coulombic efficiency of Zn/Cu foam electrodes prepared by different electro-deposition current densities.

Fig. S5. Photographs of Copper foam and Zn/Cu foam electrode.

Fig. S6. X-ray Diffraction patterns of Zn/Cu foam electrodes.

Fig. S7. Electrochemical impedance spectroscopies of Zn/Ni battery after different cycles.

Table. S1. Comparison of the cycling stability of zinc electrodes in zinc/zinc (quasi-)symmetric cells.

Table. S2. Comparison of the cycling stability of zinc electrodes in Zn/Ni secondary batteries.
Fig. S1. Schematic diagram for zinc/zinc quasi-symmetric cell.

Current density of Zn/Cu foam electrode is calculated according to both areas of the electrodes. In zinc/zinc quasi-symmetric cell, current density of 250 mA·cm\(^{-2}\) was adopted to evaluate the cycling stability of zinc electrode. Thus, the actual current of zinc electrode can be calculated as follows:

\[
I = \text{current density} \times \text{area} = 250 \text{ mA} \cdot \text{cm}^2 \times 2.54 \text{ cm}^2 \times 2 = 1270 \text{ mA}
\]
Fig. S2. Schematic diagram for prototype Zn/Ni battery.
Different electro-deposition methods were adopted to prepare Zn/Cu foam electrodes. Fig. S3 shows the photographs and I-V curves of these Zn/Cu foam electrodes. Obviously, the electrodes prepared by pulse electro-deposition exhibit the most uniform zinc distribution. Though the peak power density of Zn/Cu foam electrode with constant voltage method is the highest among these methods mainly due to the thick zinc layer on the electrode reduce the distance between zinc electrode and air cathode, pulse electro-deposition is chosen in the following experiments.
Different current densities in pulse electro-deposition method were conducted to screen the best condition. Three electrodes were prepared at each current density to ensure the repeatability. To evaluate the coulombic efficiency, Zn/Cu foam electrodes were weighted after washed in abundant water and dried in N\textsubscript{2}. Fig. S4 shows that the electrodes prepared at current density of 125, 500 and 1000 mA\textperiodcentered cm\textsuperscript{2} show the highest coulombic efficiency and the best repeatability. Thus, considering the deposition time, 1000 mA\textperiodcentered cm\textsuperscript{2} was chosen in the following experiments.
Fig. S5. Photographs of Copper foam (a) and Zn/Cu foam electrode (b).
Fig. S6. X-ray diffraction patterns of Zn/Cu foam electrodes.

X-ray diffraction (XRD) patterns of the as-prepared Zn/Cu foam electrodes with zinc loading of 20 mAh (Zn/Cu foam-20mAh) and 200 mAh (Zn/Cu foam-200mAh) were conducted on X’pert Pro (PANalytical) diffractometer (60 kV, 55 mA) using Cu Kα radiation at a scanning rate of 2θ = 5° min⁻¹.
Fig. S7. Electrochemical impedance spectroscopies of Zn/Ni battery after different cycles.
Table. S1. Comparison of the cycling stability of zinc electrodes in zinc/zinc (quasi-)symmetric cells.

<table>
<thead>
<tr>
<th>Current density/mA·cm$^{-2}$</th>
<th>Depth of discharge</th>
<th>Cycle number</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>100%</td>
<td>10,000</td>
<td>This work</td>
</tr>
<tr>
<td>24</td>
<td>23%</td>
<td>45</td>
<td>1</td>
</tr>
</tbody>
</table>

Table. S2. Comparison of the cycling stability of zinc electrodes in Zn/Ni secondary batteries.

<table>
<thead>
<tr>
<th>Current</th>
<th>Discharge capacity retention at maximum cycle number†</th>
<th>Ref.</th>
</tr>
</thead>
</table>
| 25.4C (100 mA·cm$^{-2}$) | 97.8%@100th  
89.2%@800th  
82.2%@9000th | This work |
| 0.3C    | 35%@160th                                           | 2    |
| 0.3C    | 52.9%@300th                                         | 3    |
| 0.2C    | 95.4%@50th                                          | 4    |
| 1C      | 98.2%@800th                                         | 5    |
| 1C      | 90.9%@100th                                         | 6    |
| 0.5C    | 87%@320th                                           | 7    |

†Discharge capacity retention are calculated based on the maximum discharge capacity instead of the initial discharge capacity.

Supplementary References