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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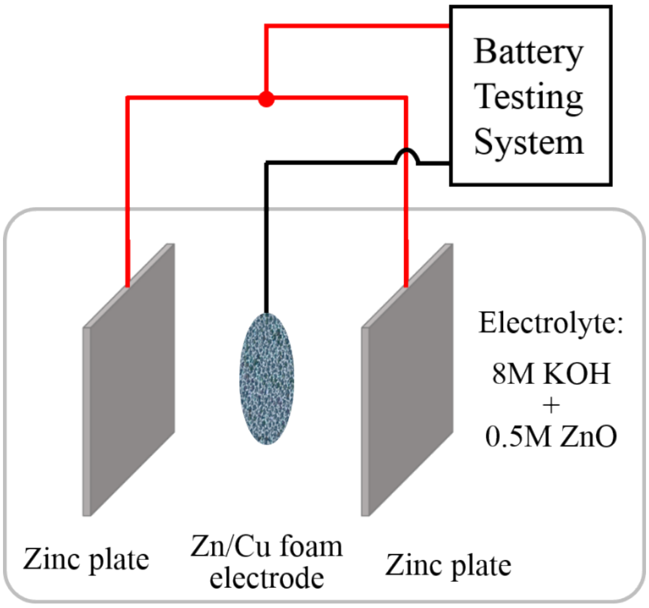

Fig. S1. Schematic diagram for zinc/zinc quasi-symmetric cell.

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 $mA \cdot cm^{-2}$ was adopted to evaluate the cycling stability of zinc electrode. Thus, the actual current of zinc electrode can be calculated as follows:

I = current density × area = 250 $mA \cdot cm^{-2} \times 2.54\ cm^2 \times 2 = 1270$ mA

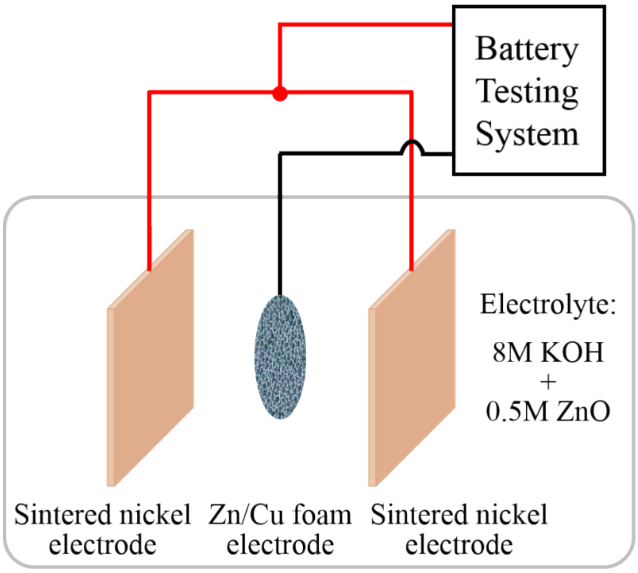

Fig. S2. Schematic diagram for prototype Zn/Ni battery.

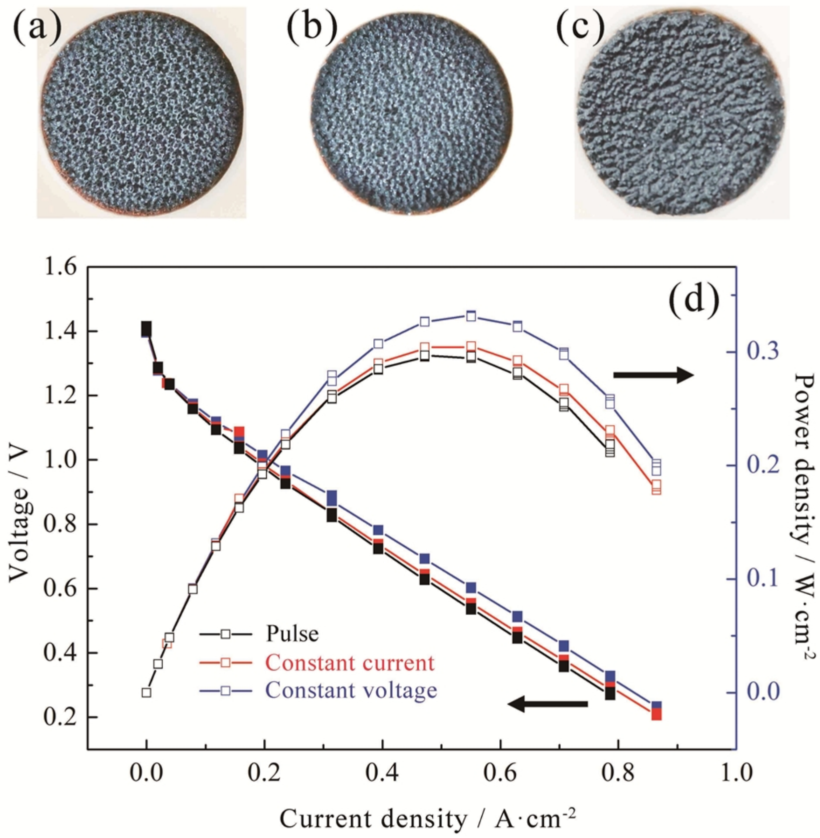

Fig. S3. Photographs and I-V curves of Zn/Cu foam electrodes prepared by different electro-deposition methods. (a) Pulse electro-deposition (current density: 1 A·cm^{-2}, frequency: 250 Hz, duty ratio: 0.25, zinc loading: 200 mAh); (b) Constant current electro-deposition (current density: 1 A·cm^{-2}, zinc loading: 200 mAh); (c) Constant voltage electro-deposition (voltage: 1.7V, zinc loading: 200 mAh); (d) I-V curves of zinc/oxygen batteries with Zn/Cu foam electrodes (Electrolyte: 7 mol·L^{-1} KOH, cathode: commercial air electrode, O_2 flow rate: 50 sccm).

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.

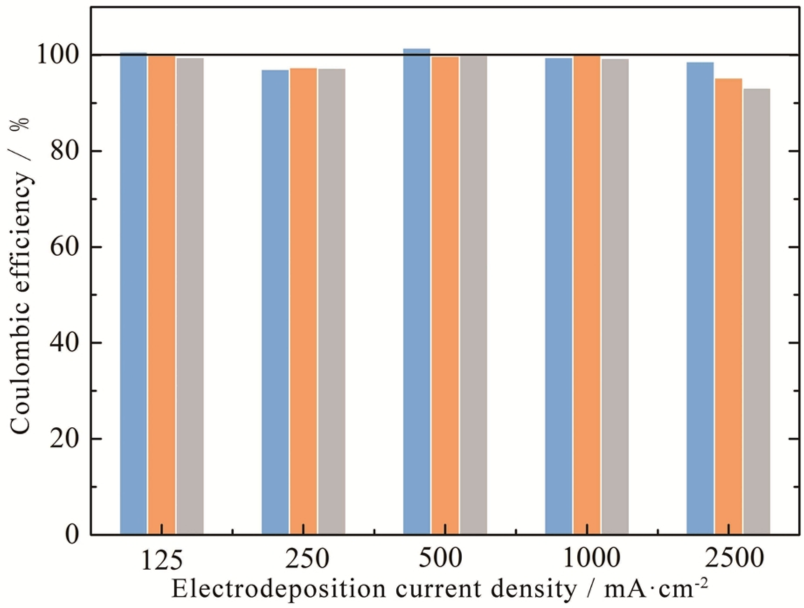

Fig. S4. Coulombic efficiency of Zn/Cu foam electrodes prepared by different electro-deposition current densities (frequency: 250 Hz, duty ratio: 0.25).

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_2. Fig. S4 shows that the electrodes prepared at current density of 125, 500 and 1000 $mA \cdot cm^{-2}$ show the highest coulombic efficiency and the best repeatability. Thus, considering the deposition time, 1000 $mA \cdot cm^{-2}$ was chosen in the following experiments.

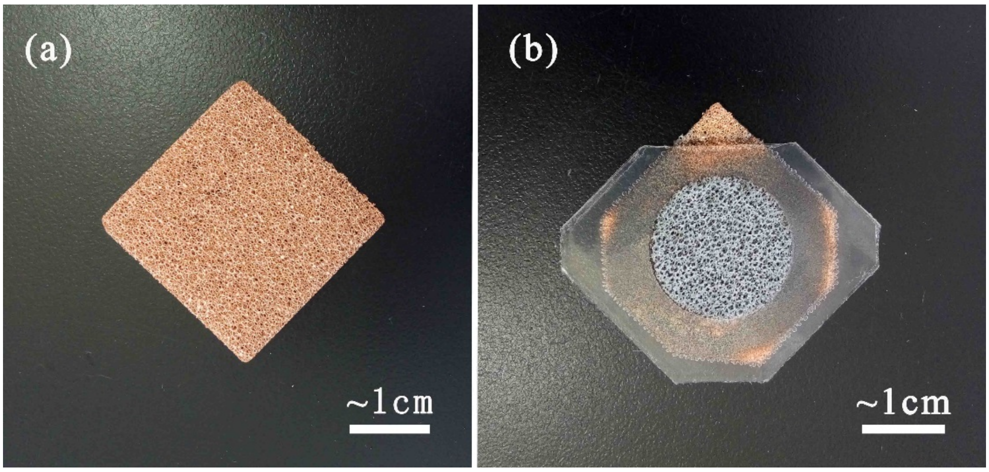

Fig. S5. Photographs of Copper foam (a) and Zn/Cu foam electrode (b).

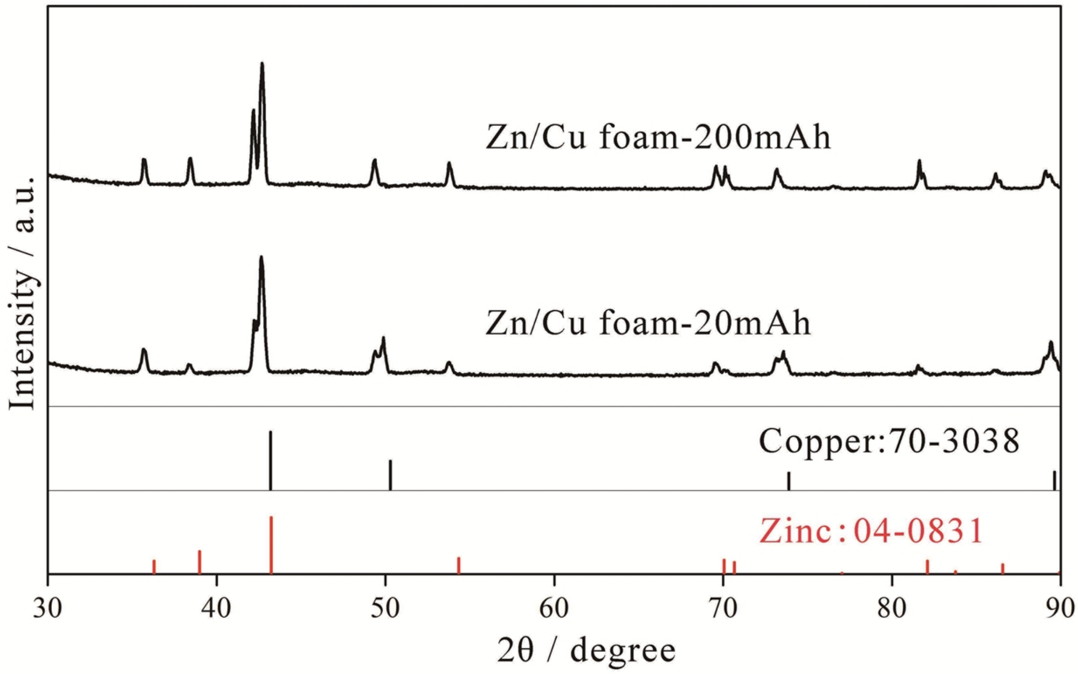

Fig. S6. X-ray diffraction patterns of Zn/Cu foam electrodes.

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 $2\theta = 5^{\circ}\ min^{-1}$.

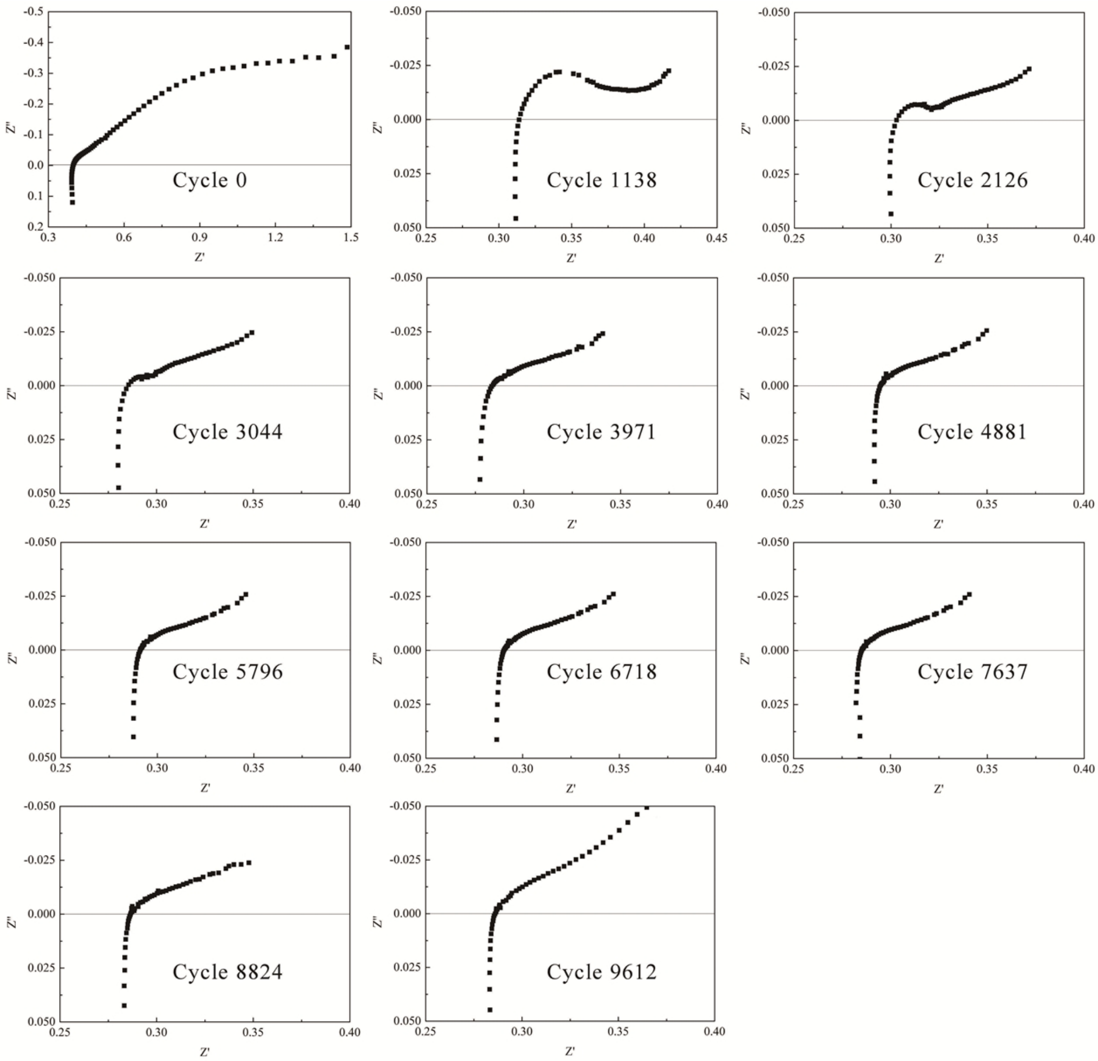

Fig. S7. Electrochemical impedance spectroscopies of Zn/Ni battery after different cycles.

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

Current density/mA·cm^{-2}	Depth of discharge	Cycle number	Ref.
250	**100%**	**10,000**	**This work**
24	23%	45	1

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

Current	Discharge capacity retention at maximum cycle number†	Ref.
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

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