Cu_9S_5-nanowires-pinned-WS_2 Sheets on Hollow Cubic Carbon for synergistic promotion in K-ion Battery Performance

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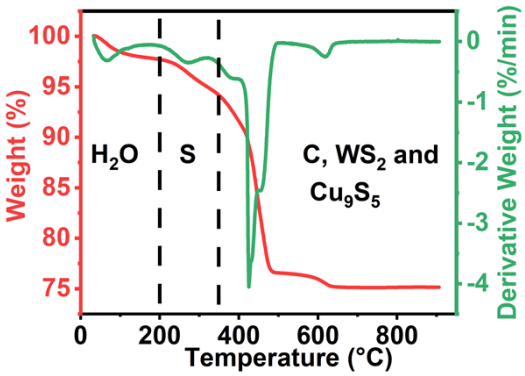

Figure S1 TG/DTG curves of Cu_9S_5/C/WS_2

To analyze the content of each component in the Cu_9S_5/C/WS_2 sample, thermogravimetric tests were performed. Figure S1 shows the TG and DTG curves of the Cu_9S_5/C/WS_2 sample. The loss of mass before 200 °C is due to the evaporation of adsorbed water, the mass change from 200 to 350 °C is attributed to the residual sulfur source on the surface, and the loss of mass from 350 to 900 °C is mainly attributed to the combustion of carbon, the transformation of WS_2 to WO3, and the transformation of Cu_9S_5 to CuO[1, 2].

To determine the exact content of Cu_9S_5, the samples were etched with a nitric acid solution, and since WS_2 and C do not react with nitric acid at room temperature, the weight loss due to the volatilization of NO gas during the reaction can be used to

calculate the content of Cu_9S_5. The chemical reaction that occurs is shown in equation (1):

$$Cu_9S_5 + 24HNO_3 \rightarrow 9Cu(NO_3) + 6NO\uparrow + 5S\downarrow + 12H_2O \quad (1)$$

By calculation, the content of Cu_9S_5 was obtained as 17.17%. The contents of WS_2 and C can be further determined based on the weight loss of Cu_9S_5 of 2.18%, the weight loss of WS_2 of 6.45%, and the mass loss in the thermogravimetric curve from 350-900 °C (18.98%). The content of C was calculated to be 14.19% and the content of WS_2 to be 68.64% in the sample. Finally, the Cu_9S_5/C/WS_2 sample can be obtained as 17.17% of Cu_9S_5, 14.19% of C, and 68.64% of WS_2.

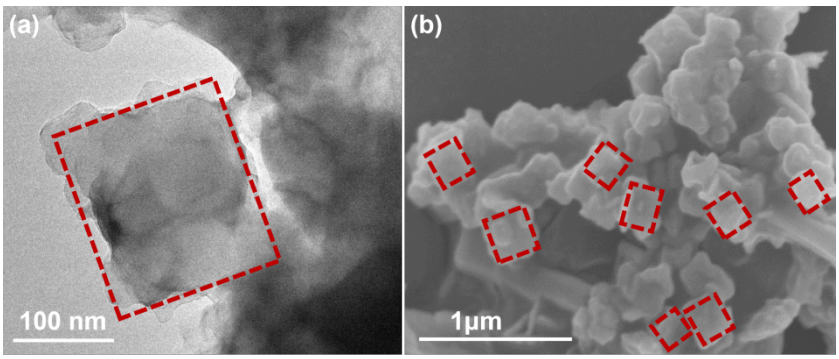

Figure S2 TEM and SEM images of $Cu_9S_5/C/WS_2$ electrode after 150 cycles

Figure S2 shows that the structural stability is good of $Cu_9S_5/C/WS_2$ and it still maintains the cubic shape after 150 cycles.

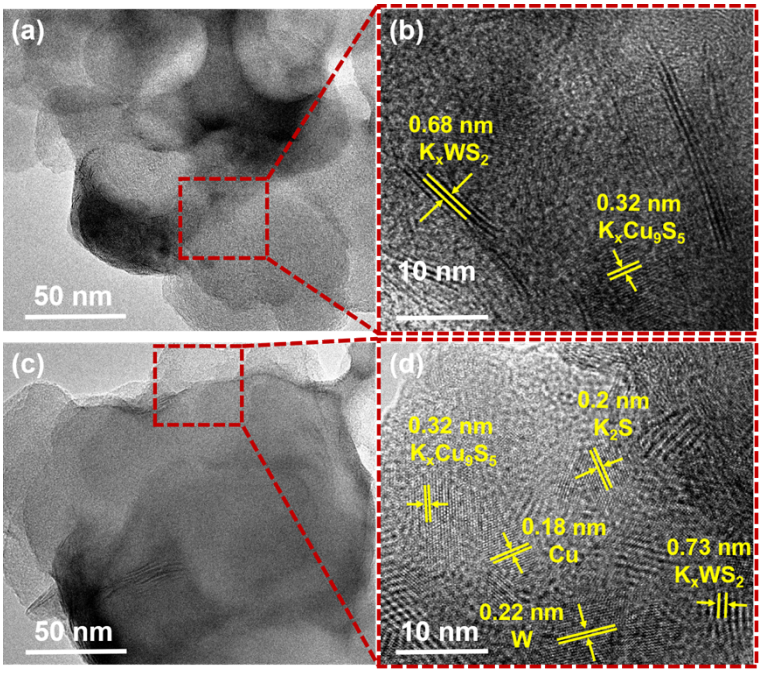

Figure S3 TEM images at different reaction stages of Cu_9S_5/C/WS_2 electrode in the discharge process：(a-b) 2.1 V, (c-d) 0.3 V

Figure S2 (a) and (b) show the TEM patterns when the electrodes were discharged to 2.1 V. From the figures. It shows that the lattice spacing of WS_2 is 0.68 nm and the lattice surface of Cu_9S_5 is 0.32 nm. The lattice spacing significantly increased of WS_2 and Cu_9S_5 when compared with before discharging and charging process (WS_2: 0.65 nm, Cu_9S_5: 0.225 nm). It could be caused by the insertion of potassium during the discharge process. Figure (d) shows that K_2S, Cu, and W monomers appear in the structure of the electrode when discharged to 0.3 V, which confirms the occurrence of the conversion reaction of WS_2 and Cu_9S_5 during the discharge process.

References

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