Morphology Effect of Carbon Matrix on Improving the Cycle Stability of Lithium-Sulfur Batteries

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Sulfur becomes a promising cathode material of lithium-ion batteries due to its high theoretical capacity (1672 mA h g$^{-1}$) and low cost$[1]$. However, sulfur suffers from low utilization and severe capacity fading, which respectively originates from its poor conductivity and high solubility of the polysulfide intermediates. To solve these problems, carbon is added to the sulfur cathode as the matrix to increase its conductivity and alleviate the escape of polysulfides$^{[2-3]}$. Previously, plentiful works had focused on the enhancement of electrochemical performance of sulfur/carbon composites cathode with improved conductivity and confinement effect. Nevertheless, it is rather scarce to find papers which study the correlation between morphologies of carbon matrix and electrochemical behavior of sulfur active particles.

To investigate the morphology effect of carbon matrix on the electrochemical performance of lithium-sulfur batteries, herein, we prepared three carbon samples with similar porous structures and different morphologies (nanospheres, nanorods and nanofibers) based on the same polymer precursor. Sulfur was encapsulated into the pore channels of three carbon matrixes with similar content via melt-diffusion method. Electrochemical results exhibit that the length/width ratio of carbon matrix has great influence on the performance of lithium-sulfur batteries. The sulfur/carbon composites show a higher reversible capacity and more stable cycle performance as the length/width ratio of carbon increase. It presents that the sulfur-carbon nanofibers display highest initial capacity of 1312.5 mA h g$^{-1}$ and the lowest decay rate of 0.56% per cycle within the initial 100 cycles at 0.2 C. The improved electrochemical properties may be ascribed to that: (1) the larger length/width ratio means shorter pathways for lithium ion transport and larger electrode/electrolyte contact interfaces to promote sulfur utilization and rapid charge-transfer reactions. (2) The fibrous carbon particles bridge each other to enhance the contact area for fast electron transfer, further increase the utilization of sulfur cathode.

Fig. 1. SEM images of: (a) carbon nanospheres, (b) carbon nanorods, (c) carbon nanofibers. (d) The comparison of cycling performance of sulfur-carbon nanospheres, sulfur-carbon nanorods and sulfur-carbon nanofibers at 0.2C.

References