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Advanced lithium sulfur batteries with a ternary sulfur/polyaniline/carbon composite as cathode material

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There has been a challenge to develop and design lithium batteries with high specific energy for the requirement of an increasingly diverse range of applications from microchips to cars and electric energy storage systems. Lithium sulfur (Li-S) batteries have received great attention due to their high theoretical capacity, easy availability, low cost and non-toxicity. The combination of lithium metal with theoretical specific capacity of 3830 mAh g^{-1} as anode and elemental sulfur (S_8) with theoretical specific capacity of 1675 mAh g^{-1} as cathode in a battery can generate theoretical specific energy as high as 2600 Wh kg^{-1}, more than 5 times higher than the theoretical energy of commercial lithium ion batteries.

However, Li-S batteries are still under realization as many problems remain unsettled. The insulating nature of both sulfur and its reduction product, lithium sulfide, leads to low active material utilization. Moreover, the soluble lithium polysulfides (Li_2S_x, $4 \leq x \leq 8$) generated during the discharge process can easily escape from the electrode to the liquid electrolyte (termed as "shuttle" phenomenon), resulting in a loss of active material and an increase of resistance in cells.

Many efforts have been made to overcome these drawbacks. Fabrication of sulfur/carbon composites is proved to be promising in which conductive carbon matrices with some featured structures have been constructed to disperse sulfur and hold the soluble polysulfides. Besides, conducting polymers such as polypyrole (PPy), polythiophene (PTh), Poly(3,4-ethylenedioxythiophene)-poly(styrene sulfonate) (PEDOT:PSS) and polyaniline (PANi) have been successfully used in sulfur composites either as a coating layer or a conductive matrix to improve the cycle performance and rate capability of Li-S batteries. Especially, PANi is widely used owing to its relatively facile processability, electrical conductivity and environmental stability.

Herein, we reported a polyaniline-carbon black (PANi-C) composite for encapsulating sulfur (Fig. 1). PANi-C is a highly conductive polymer-carbon composite with PANi impregnated in porous carbon. The sulfur/PANi-C (SPC) composite was prepared by mixing and heating sulfur and PANi-C at 155 °C and 280 °C continuously. It is proved that PANi plays a bridge role between sulfur and carbon in SPC composites, resulting in minimization of active material loss and improvement of electrochemical performance in lithium sulfur batteries. The cell with SPC composite showed a good reversibility in accommodating the charge-discharge reactions, resulting in enhanced cyclablity and good rate capability. The cell with SPC composite as cathode showed enhanced cyclablity and good rate capability, retaining a discharge capacity of 732 mAh g^{-1} at 0.2 C after 100 cycles as shown in Fig.2.

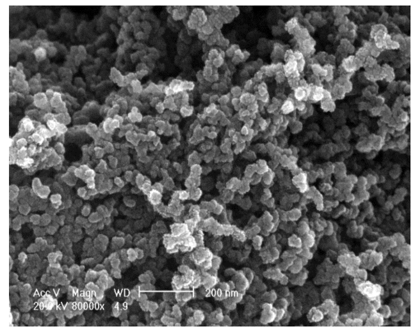

Fig. 1. Morphology of PANi-C observed by FE-SEM

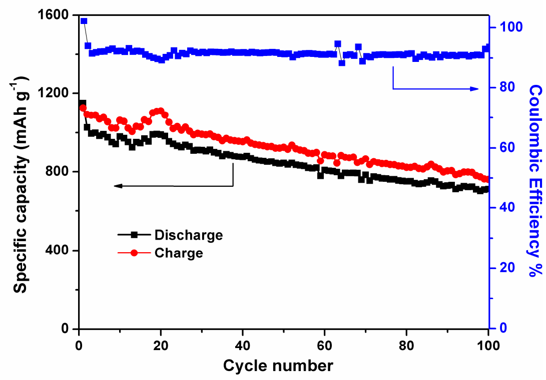

Fig. 2. Cycle performance and coulombic efficiency of the cell with SPC composite at 0.2 C.