Carbon-based Interlayer System for Li-S Batteries

By

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Abstract

For the past few decades, lithium ion (Li-ion) battery is one of the most popular energy storage systems. As the electric vehicles are gaining momentum, however, the low energy density of Li-ion batteries compromises their merits, and exploration of new electrochemistry that could meet the high standards of energy, safety and environment for electric vehicles is imperative. The lithium-sulfur chemistry for high energy-density batteries are confirmed feasible and is highly promising to be commercialized and used in electric vehicles. Besides the design of electrodes in Li-S batteries, the modification of the separator is also proven effective in containing polysulfides and elevating cycling stability of Li-S cells. In this thesis, several carbon-based interlayers are proposed and delivered improvements in localizing polysulfides andreactivating the trapped active material, leading to much elevated cycling performance. The first work employed ultrathin Tortech paper with a thickness of around 5 μm as an interlayer inserted between the sulfur cathode and the commercial separator. Following this approach, this Tortech paper was also adopted to fabricate a hybrid freestanding and high areal-sulfur loading cathode by simple folding. This facile design of the electrode paired with the tight-knit Tortech paper interlayer achieved an areal sulfur loading up to 15.3 mg cm\(^{-2}\) and suggests impressive cycling stability. Further, to fully exploit the potential of carbon and S-immobilizing materials, a novel CNF-based composite with interspersed TiO\(_2\) nanoparticles within the nitrogen-doped shell of carbonized polydopamine was fabricated as a flexible interlayer. With the protection of this unique interlayer, the lithium sulfur cells delivered a high reversible capacity and a long cycling stability with a decay rate of 0.06% per cycle (500 cycles at 2C). In addition, carbon nanofibers (CNFs) were used to form a carbon-based framework which was interposed by CoS sheets and embedded by KB nanoparticles. The obtained CNF/CoS/KB interlayer had a high conductivity granted by the conductive carbon matrix and effective polysulfide-immobilizing ability endowed by the interaction of CoS and Li\(_2\)S\(_4\). As a result, a significantly enhanced cycling performance of the cell cycled at 1C was obtained with a capacity decay rate of 0.076% per cycle for 760 cycles, suggesting the superiority of this CNF/KB/CoS coating layer. At last, a net-structured filter composed of Co(OH)\(_2\)-anchored CNFs and KB nanoparticles was prepared as an effective inhibitor of polysulfide intermediate diffusion with physical flexibility and robustness on the commercial separator. This unique integration (Co(OH)\(_2\)/CNF/KB) could successfully block soluble polysulfides to the cathode-side separator and reutilize the sequestered active material. These rational designs based on carbon and S-immobilizing materials offer new opportunities for practical applications of Li-S batteries.

- ALL ARE WELCOME -