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Featured Letter

Facile preparation of fullerene nanorods for high-performance lithium-sulfur batteries

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A B S T R A C T

Lithium-sulfur batteries have been considered as one of the most promising electrochemical power sources due to its extremely high energy density and high theoretical specific capacity. However, poor cycling life due to the dissolution of lithium polysulfides hinders its practical application. In this paper, C_{60} nanorods are prepared by a facile, scalable and repeatable antisolvent induced precipitation method at an ambient temperature and used as a novel interlayer material for lithium-sulfur batteries. It was proved that C_{60} nanorods could efficiently inhibit the diffusion of lithium polysulfides via both physical adsorption and strong chemical bonding. Lithium-sulfur batteries with C_{60} interlayer delivered a capacity of 725 mAh g^{-1} and a capacity retention of 154.5% after 500 cycles at 4800 mAg^{-1} with a coulombic efficiency around 100%.

1. Introduction

Owning to the high theoretical energy density (2500 Wh/kg or 2800 Wh/L) and low cost of sulfur element, lithium-sulfur batteries have been considered as the most promising power sources for portable and Electric Vehicles (EV) [1]. However, the performance of lithium-sulfur batteries is limited by several key issues, such as the low electronic and ionic conductivity of solid sulfur-related active materials, the huge volume changes during charge-discharge process and the side reactions caused by the dissolution of intermediate polysulfides in the electrolyte [2,3] (see Scheme 1).

In order to address these issues, a lot of work have been done, such as confining sulfur in the porous conductive network, developing low polysulfides solubility electrolytes, modifying the separator, protecting the anode and introducing polysulfides reservoirs et al. [4–9]. Recently, introducing interlayer between the sulfur cathode and the separator has been proved to be an efficient solution by Manthiram et al. [10]. The interlayer could act as an upper current collector which not only reduces the charge transfer resistance of sulfur cathodes significantly, but also localizes and retains the lithium polysulfides during cycling process. Moreover, the novel cell configuration does not require the formation of complex sulphur-conductive matrix composites, leading to facile and low-cost manufacturing [10]. Many materials with high electronic conductivity have been explored, such as carbon nanotubes, graphene, carbon paper, conductive polymers, oxides, nitrides et al. [10–17]. However, exploring new effective still remains a challenge for the practical application of the interlayers. C_{60}, an important allotrope of the carbon, has attracted attention due to its unique properties, such as excellent optoelectronic, redox, electrochemical and catalytic properties [18]. Moreover, it has been proved that C_{60} molecules could react with polysulfides, which may provide a more stable chemical bonding adsorption [19]. Additionally, the insulating character of C_{60} and high melting point (>700 °C) enable it to be a candidate of separator coating layer to prohibit the short-cut hazard caused by separator melting when subscribed to high temperature. Herein, we report a facile, scalable and repeatable ambient synthesis approach to produce C_{60} nanorods. It is demonstrated that the C_{60} nanorods could effectively hindered the side reactions of polysulfides to enhance the cycling performance.

2. Results and discussion

X–ray diffraction (XRD) patterns of the C_{60} nanorods are shown in Fig. 1a. All the diffraction peaks can be indexed to a pure ace-centered cubic (fcc) C_{60} phase (JCPDS: 44-0558). The sharp XRD patterns indicate the well crystallization character of C_{60} nanorods. Fig. 1b presents the XPS spectra of C 1s for the C_{60} nanorods. The C 1s binding energy of the as prepared C_{60} are determined

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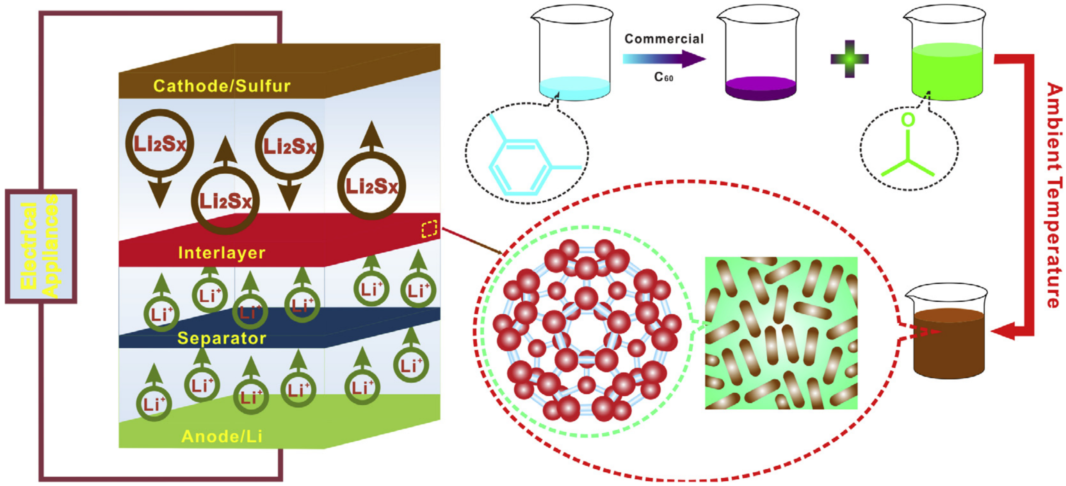

Scheme 1. Schematic of the synthesis of C_{60} nanorods and charge-discharge process of the lithium-sulfur battery with C_{60} nanorods as the interlayer.

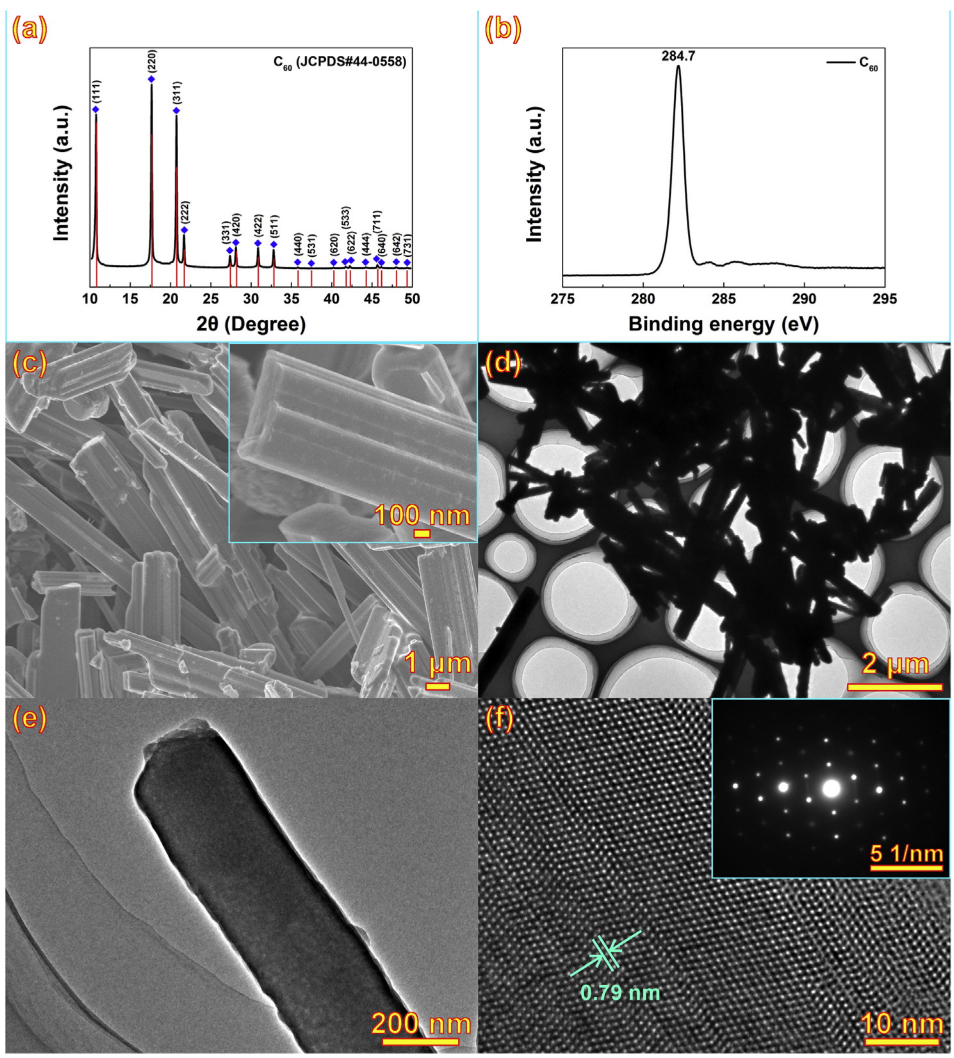

Fig. 1. XRD patterns (a), C1s XPS spectra (b), SEM (c) and HRTEM (d, e, f) images of the C_{60} nanorods.

to be 284.7 eV, which correlates to the typical Vasquez's value of fullerene C_{60} [18,20]. The SEM image of the C_{60} nanorods is shown in Fig. 1c. A rod like C_{60} structure is obtained. The diameter of the nanorod is about 100–300 nm and their length are about 3–5 μm.

We further observed the C_{60} nanorods by TEM and HRTEM to obtain the inner structure information. The TEM images in Fig. 1d and e confirm that the C_{60} is solid rod shape. The HRTEM image in Fig. 1e shows the continuous and parallel lattice fringes