



Fabrication, characterization and application of nitrogen-containing carbon nanospheres obtained by pyrolysis of lignosulfonate/poly(2-ethylaniline)

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HIGHLIGHTS

- ▶ Novel LS–PEA composite was used to fabricate nitrogen-containing carbon nanospheres.
- ▶ The C-700 carbon nanospheres exhibited excellent electrochemical performance.
- ▶ We report an effective route to the preparation of low-cost carbon nanospheres.

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ABSTRACT

Lignosulfonate/poly(2-ethylaniline) (LS–PEA) composite nanospheres were prepared via *in situ* polymerization of 2-ethylaniline (EA) with lignosulfonate (LS) as a dispersant. LS–PEA nanospheres with an average diameter of 155 nm were obtained at an optimal LS concentration of 20 wt.%. Subsequently, nitrogen-containing carbon nanospheres were fabricated via direct pyrolysis of the LS–PEA composite nanospheres at 600–800 °C. The carbon nanospheres prepared by pyrolysis were used as anodes of lithium-ion batteries. The first charge and discharge capacity of carbon nanospheres prepared at 700 °C at current densities of 60 and 100 mA g^{−1} were 980 and 432 mAh g^{−1}, and 764 and 342 mAh g^{−1}, respectively. The batteries still owned a high capacity of 353 and 296 mAh g^{−1} after 20 cycles. The results indicated that these nitrogen-containing carbon nanospheres could be used as a promising candidate for electrode materials of lithium-ion batteries.

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1. Introduction

Lignin is usually considered a waste component of biomass and is mostly consumed as fuel, and only a small amount is employed in specialty products (Kijima et al., 2011; Wu et al., 2008). Lignin has been applied in applications, such as biofuel (Chen and Dixon, 2007), carbon material (Kijima et al., 2011; Mussatto et al., 2010; Suhas et al., 2007), and adsorbent production (Lü et al., 2012; Wu et al., 2008). Carbon materials prepared from lignin are cheap and easy to prepare, but they have not been used as anode materials for lithium-ion batteries.

Lithium-ion batteries are being used for many applications, but demands for low-cost and long-life still limit their practical application for high energy densities applications (Luo et al., 2010). One approach to reduce their cost would be finding cheaper anode materials and improving charge/discharge cyclic performance. Carbon materials are promising materials for the anodes of lithium-ion batteries because these materials are easy to prepare, environmentally friendly and low-cost. In particular, the introduction of nitrogen-containing functional groups to the surface of carbon

materials will effectively enhance their electrochemical performance (Hulicova-Jurcakova et al., 2009; Xiang et al., 2011a).

Polyaniline (PANI) can be used to prepare various types of nanostructured materials; for example, nanofibers, nanorods, nanotubes, and nanospheres (Anilkumar and Jayakannan, 2008). Particularly, PANI is a promising candidate as precursor of nitrogen-containing nanostructured carbon materials because it contains about 15.4 wt.% nitrogen (Lü et al., 2010). Nitrogen-containing carbon nanospheres with large surface areas are suitable for the anode of lithium-ion batteries.

Lignosulfonate (LS), a highly water-soluble polyanion with sulfonic group, is a major derivative of lignin from the pulp processing industries. LS has been used to control the size, stability, and electroconductivity of the polyaniline–lignosulfonate composites (Lü et al., 2010); however, the effect of LS on the morphology and properties of PANI derivatives needs further investigation.

In the present study, lignosulfonate/poly(2-ethylaniline) (LS–PEA) nanospheres were prepared via *in situ* polymerization of 2-ethylaniline in the presence of LS. The introduction of ethyl groups on the poly(2-ethylaniline) chains was expected to enhance the controllability of the formation of LS–PEA nanospheres because the electron-withdrawing groups lower the reactivity of the 2-eth-

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