CARBON 57 (2013) 130–138

Available at www.sciencedirect.com

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One-pot synthesis of uniform Fe_3O_4 nanocrystals encapsulated in interconnected carbon nanospheres for superior lithium storage capability

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ARTICLE INFO

Article history:
Received 9 November 2012
Accepted 19 January 2013
Available online 29 January 2013

ABSTRACT

Uniform and small Fe_3O_4 nanocrystals (~9 nm) encapsulated in interconnected carbon nanospheres (~60 nm) for a high-rate Li-ion battery anode have been fabricated by a one-step hydrothermal process followed by annealing under Ar, which can be applied for the preparation of a number of metal oxide nanocrystals encapsulated in interconnected carbon nanospheres. The as-synthesized interconnected Fe_3O_4@C nanospheres displayed high performance as an anode material for Li-ion battery, such as high reversible lithium storage capacity (784 mA h/g at 1 C after 50 cycles), high Coulombic efficiency (~99%), excellent cycling stability, and superior rate capability (568 mA h/g at 5 C and 379 mA h/g at 10 C) by virtue of their unique structure: the nanosized Fe_3O_4 nanocrystals encapsulated in interconnected conductive carbon nanospheres not only endow large quantity of accessible active sites for lithium ion insertion as well as good conductivity and short diffusion length for lithium ion transport but also can effectively circumvent the volume expansion/contraction associated with lithium insertion/extraction.

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1. Introduction

Lithium ion batteries (LIBs) have been extensively used in portable electronic devices due to their high energy density and long cycle life. In recent years, the ever-increasing and urgent demand for the widespread application in hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs) has largely promoted the global research interests to develop LIBs with high reversible capacity, excellent rate capability and cycling stability [1–5]. However, graphite, the currently used anode material for commercial LIBs, has already approached its theoretical limit (372 mA h/g). Therefore, seeking alternative anode materials has become an urgent task nowadays. Among the feasible anode materials, Fe_3O_4 has been proven to be a possible candidate due to its high theoretical capacity (924 mA h/g), nontoxicity, high corrosion resistance, low cost, natural abundance and environmental friendliness. The capacity of lithium storage is mainly achieved through the reversible conversion reaction between lithium ion and Fe_3O_4, forming Fe nanocrystals dispersed in Li_2O matrix [5,6]. Despite of those intriguing features, Fe_3O_4 still suffers from rapid capacity fading and poor cyclability that is caused by the drastic volume expansion and contraction during lithium insertion/extraction. The low conductivity of Fe_3O_4 also induces additional performance degradation, especially when charging and discharging at high current densities.

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0008-6223/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.carbon.2013.01.056