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γ-MnOOH-graphene nanocomposite as promising anode material for Li-ion capacitors

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ABSTRACT

Developing environmentally benign electrode materials with faster Li-ion kinetics is an essential requirement for high-performance Li-based energy storage devices. Here we report the large-scale synthesis of γ-MnOOH-graphene (γ-MnOOH-rGO) nanocomposite, through a simple hydrothermal route, for their application as potential anode material in Li-ion batteries. As-synthesized nanocomposite with the γ-MnOOH nanorods uniformly anchored on the graphene sheets exhibits enhanced electrochemical performance and achieves a very high specific capacity of ~435 mAh g^{-1} at a current density of 1.0 A g^{-1}. Detailed electrochemical studies reveal faster Li-ion kinetics in γ-MnOOH-rGO nanocomposite electrode, dominated by non-diffusion controlled processes (~ 80% at 1.0 mV s^{-1}). Further, the full-cell Li-ion capacitor fabricated with γ-MnOOH-rGO nanocomposite as the anode and activated carbon as the cathode exhibits a maximum energy density of ~51 Wh kg^{-1} and a maximum power density of ~ 6.3 kW kg^{-1}, with excellent capacity retention of more than ~87% upon 8500 cycles. The present work thus demonstrates γ-MnOOH-graphene nanocomposite as promising anode material for advanced Li-ion batteries and high power Li-ion capacitors.

1. Introduction

Electrochemical energy storage systems such as batteries and supercapacitors are considered as most promising technologies that provide sustainable solutions to address the rising energy demands and environmental concerns [1]. Lithium-ion batteries (LIBs), prevalent in the electronic markets for the last three decades, continue to be the dominant power source for a wide range of applications, from portable electronic devices to large-scale hybrid electric vehicles and grid storage [2]. However, many research activities are focused on exploring alternative materials to replace the conventional graphite anode that is fundamentally limited by low specific capacity (~ 372 mAh g^{-1}), poor rate capability, and safety concerns [3,4]. In search of various anode materials for LIBs, manganese-based transition metal oxides attain much importance due to their low cost, high abundance, enhanced activity, multiple oxidation states, various possible crystal structures, and the environmentally benign nature [5–8]. Among the different manganese-based transition metal oxides, the tunnel structured γ-MnOOH shows promising potential as anode material for lithium-ion batteries owing to its high theoretical capacity of 914 mAh g^{-1} (three times greater than graphite) and better electronic conductivity $\sim10^{-4}$ - 10^{-5} S cm^{-1} in comparison with MnO_x ($\sim10^{-8}$ to 10^{-6} S cm^{-1}) [9,10]. However, like other manganese oxides, γ-MnOOH experience capacity fading upon cycling arising from severe volume changes resulting in low initial Coulombic efficiency and poor cycling stability [11–14]. Engineering of materials in the nano regime helps overcome these issues through the improved active surface area and reduced ion diffusion length, thus resulting in enhanced electrochemical performances. Hybridizing the materials with carbon matrices (such as graphene, carbon nanotubes, carbon nanofiber) further improves the electronic and ionic conductivities, thus suppressing the volume changes, resulting in long-term stability as well as high rate capability of the hybrid electrode [15–18].

Herein we employ γ-MnOOH-rGO nanocomposite, synthesized by a

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