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Freeze-drying growth of Co_3O_4/N-doped reduced graphene oxide nanocomposite as excellent anode material for lithium-ion batteries

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Abstract

A Co_3O_4/N-doped reduced graphene oxide (N-doped GN) nanocomposite was successfully synthesized by a facile freeze-drying method and heat-treated subsequently. When used as an anode material for lithium ion batteries (LIBs), the composite showed superb cycling stability and rate performance. More remarkably, the Co_3O_4/N-doped GN composite achieved an ultrahigh reversible capacity of 950 mA h g^{-1} exceeds the theoretical capacity (890 mA h g^{-1}) of Co_3O_4 after 100 cycles at a current density of 0.2 A g^{-1}, which made it a promising anode material for LIBs. Therefore, the nanocomposite can be deemed to be potential candidates as anode materials for further investigation.

Keywords: Co_3O_4/N-doped GN; Nanocomposite; Anode; Lithium ion battery

1. Introduction

Currently lithium ion batteries (LIBs) represent a key class of battery architecture that has emerged as a prime candidate for energy storage devices due to their high energy density, long cycle lifetime, no memory effect and environmental benignity [1–3]. As one of the key components of LIBs, the anode material dominates the electrochemical properties and performance of the device. It is well known that the vast majority of commercial anode materials used for LIBs are graphite. However, the most commonly used commercial graphite anode material is limited to a low theoretical capacity of 372 mA h g^{-1}. With the increasing demand for higher energy densities LIBs, it is essential to find anodes with high theoretical specific capacity, excellent cycling performance, and good rate capability [4]. For the last ten years or more, transition-metal oxides have been known to display desirable properties, such as high theoretical capacity (ca. 500–1000 mA h g^{-1}) and spatial confinement, as prospective anode materials for superior performance LIBs [5]. Among the various transition metal oxides, Co_3O_4 has attracted considerable interest owing to its higher theoretical specific capacity (about 890 mA h g^{-1}) and natural abundance. However, the poor cycling stability owing to the large volume changes during the repeated Li^+ intercalation–deintercalation processes hinders its practical application [6,7]. GN, an atomic single layer of honeycomb carbon lattice, has been considered as an ideal supporting material to functionalize the Co_3O_4 nanoparticles (NPs) due to its outstanding electrical conductivity, excellent mechanical flexibility, large specific surface area, and high thermal and chemical stabilities [8]. The GN serves not only as a conductive agent, but also as an inactive confining buffer to accommodate the volume change during charge/discharge cycling. Therefore, we believe that a high performance Co_3O_4 anode could be achieved by rational designing of a Co_3O_4/N-doped GN composite.

Herein, we successfully fabricated Co_3O_4/N-doped GN composite by a facile freeze drying treatment and a subsequent heat treatment method, which has never been reported. The freeze drying treatment could maintain the original structure of GN with large surface area and relieve the expansion without

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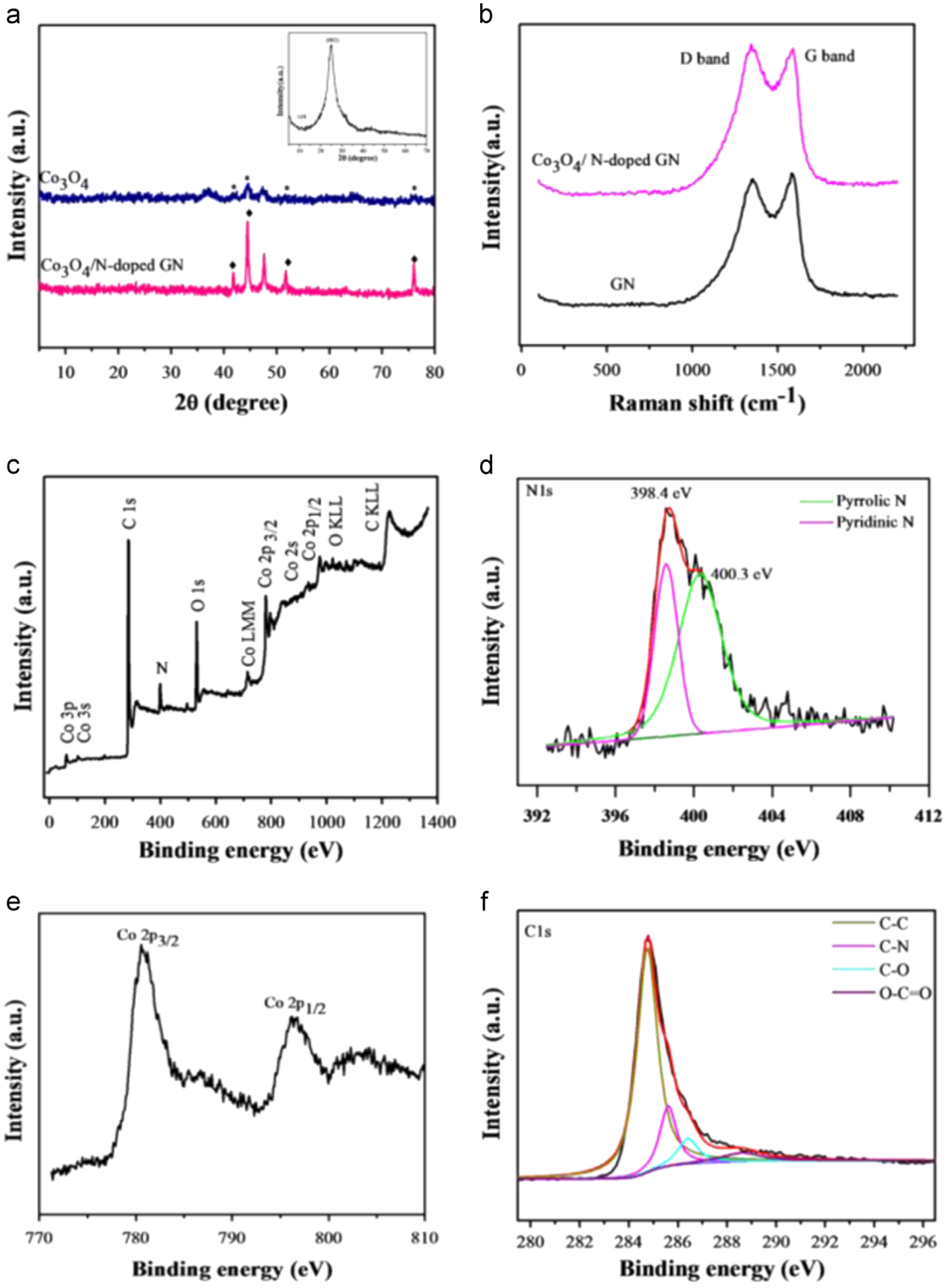

Fig. 1. (a) XRD patterns of the samples; (b) Raman spectra of the GN and Co_3O_4/N-doped GN composite; The inset of (a) is the XRD pattern of GN; XPS spectra of the Co_3O_4/N-doped GN composite for (c) survey, (d) N 1s, (e) Co 2p, (f) C 1s.