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SnO_2 quantum dots/graphene aerogel composite as high-performance anode material for sodium ion batteries

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ABSTRACT

A three-dimensional SnO_2 quantum dots/graphene aerogel (SnO_2 QDs/GA) composite was prepared using a facile and scalable strategy without adding any surfactant and reducing agent .This as-prepared nanocomposite, with zero-dimensional SnO_2 QDs (2–5 nm) anchoring and dispersing on the surface of three-dimensional graphene aerogel, exhibits better properties as anode material for sodium ion batteries than bare SnO_2 for its higher reversible capacity (319 mAh g^{-1} at 50 mA g^{-1} after 50 cycles) and stability (rate capacity still remains 150 mAh g^{-1} at 800 mA g^{-1}). Such three-dimensional graphene aerogel could not only act as an electronic conductive matrix for the fast transportation of sodium ion and electrons, but also provide double protection against the aggregation and volume changes of SnO_2 QDs during cycling.

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1. Introduction

Sodium ion batteries (SIBs) are regarded as an attractive alternative to lithium ion batteries (LIBs) with similar energy storage process and lower cost [1]. SnO_2 is a promising candidate as anode material for SIBs for its large Na storage capacity [2]. However SnO_2 suffers from severe volume change upon discharge/charge process which will cause pulverization of electrode. Therefore, embedding ultrafine SnO_2 nanoparticles onto conductive carbon-based substrate is an effective strategy to tackle the abovementioned problems. Among the reported carbon-based materials, graphene is a good substrate due to its superior conductivity, good mechanical strength and large surface area. Recently, Chen's group [3] used ice-templated method to prepare SnO_2 nanoparticles/3D graphene composite (SnO_2@3DG). SnO_2@3DG showed a reversible capacity of 432 mAh g^{-1} after 200 cycles at 100 mA g^{-1} Bai et al. [4] reported a facile microwave-assisted polyol reduction method to obtain SnO_2/graphene nanocomposites. The as-prepared SnO_2/graphene nanocomposites showed a high reversible capacity of 220 mAh g^{-1} at 0.1 A g^{-1}. Importantly, Patra and coworkers [5] synthesized 1-nm SnO_2 particles/graphene composite using supercritical CO_2 fluid. Their results confirm the sluggish Sn-Na alloying/dealloying reaction is responsible for the lower measured capacity.

However, to the best of our knowledge, there are few reports on the preparation of SnO_2/graphene without adding extra surfactant and reducing agent for the application of SIBs. Especially, a hydrothermal method is generalizing and systematizing controllable syntheses of nano-morphologies in a sealed heated solution [6]. Therefore, we reported the preparation of SnO_2 quantum dots/graphene aerogel (SnO_2 QDs/GA) using a facile hydrothermal strategy and subsequently heat-treatment process. Benefitting from the SnO_2 quantum size and conductive network GA with specifically large surface area, the as-prepared SnO_2 QDs/GA exhibited good electrochemical performance on rate capability and cyclic stability for SIBs.

2. Experimental

Graphene oxide was prepared using a modified Hummers' method [7]. 0.35 g $SnCl_4{\cdot}5H_2O$ was dissolved into the GO dispersion (2 mg mL^{-1}) to form a transparent solution. Then the mixed solution was sealed into a 100 ml Teflon-lined stainless steel autoclave and heated at 180 °C for 12 h. After that, the reaction mixture was cooled down to room temperature. The obtained cylindrical was washed repeatedly with distilled water, freeze-dried and calcined at 500 °C for 4 h at 5 °C min^{-1} in N_2 atmosphere to obtain SnO_2 QDs/GA. Bare SnO_2 was synthesized by similar method without adding GO. The morphology was obtained by scanning electron microscopy (FESEM, JSM-7001F) and high-resolution transmission

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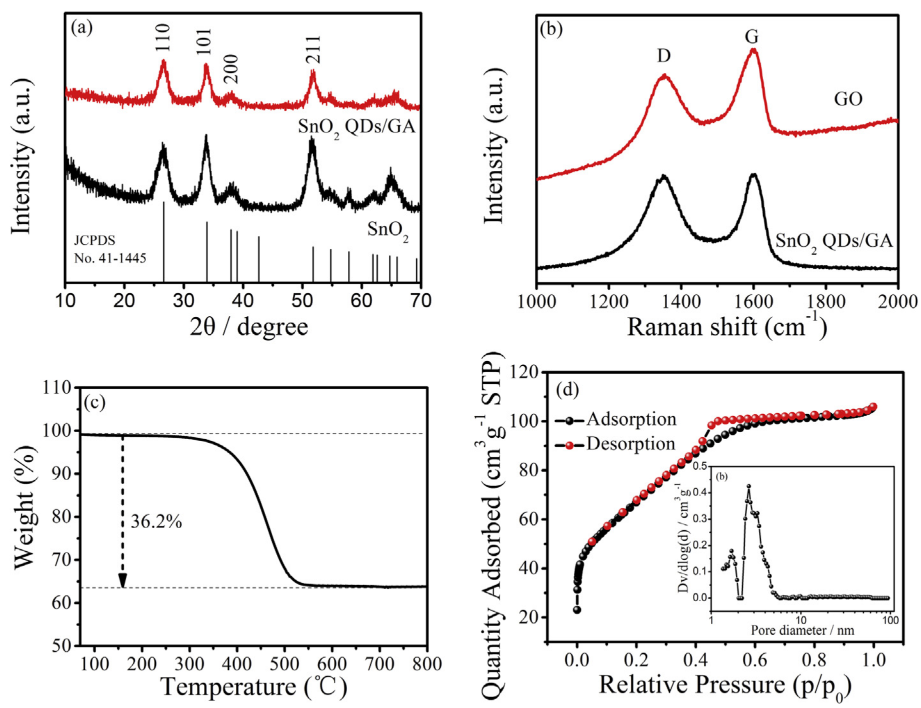

Fig. 1. (a) XRD patterns of SnO_2 and SnO_2 QDs/GA, (b) Raman spectra of GO and SnO_2 QDs/GA, (c) TGA curve of SnO_2 QDs/GA and (d) BET measurement of SnO_2 QDs/GA. The inset shows pore-size distribution.

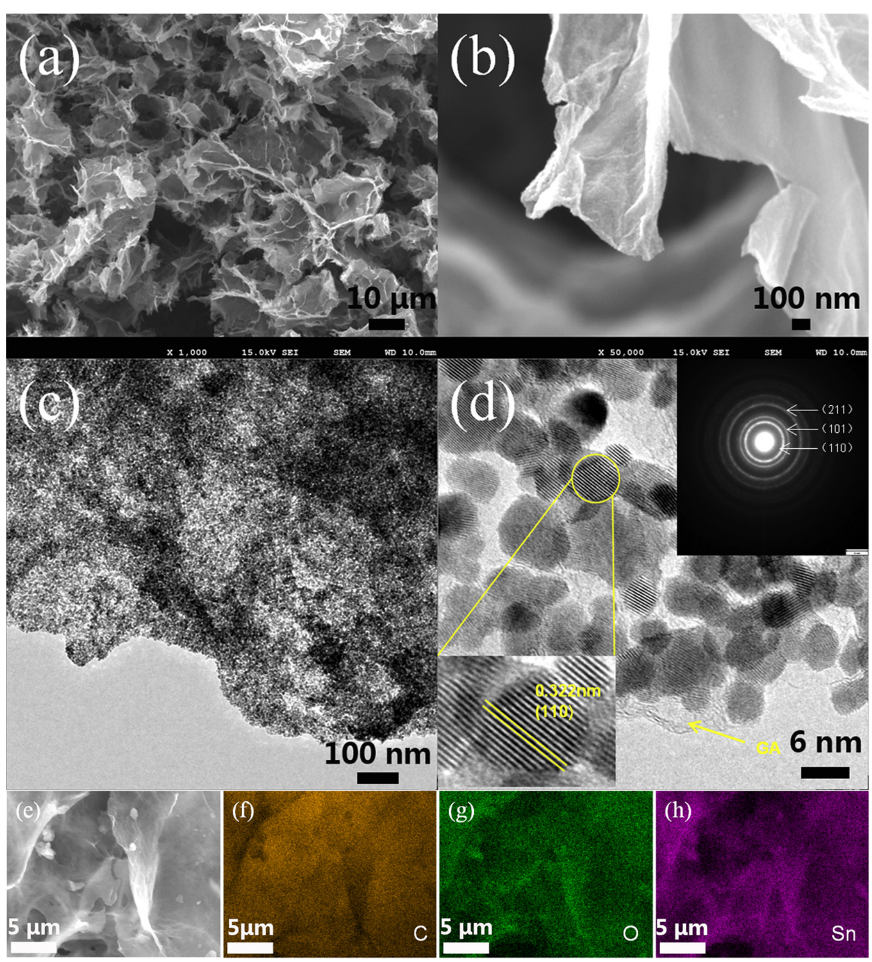

Fig. 2. (a-b) SEM images of SnO_2 QDs/GA. (c-d) HRTEM images of SnO_2 QDs/GA. (e) SEM images of SnO_2 QDs/GA and the corresponding elemental mapping images of (f) C, (g) O, (h) Sn.

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