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Facile synthesis of sulfur doped Sb_2Se_3 nanosheets with enhanced electrochemical performance

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ABSTRACT

In this work, ultrathin Sb_2Se_3 nanowires as well as the sulfur doped nanosheets are synthesized by a facile solvothermal method through changing the volume of thioglycollic acid. The growth process of the nanoarchitectures and the effects of reaction parameters are investigated systematically by X-ray powder diffraction (XRD), field emission scanning electron microscopy (FESEM) and transmission electron microscope (TEM). Based on the experimental results, the formation mechanism of the Sb_2Se_3 nanosheets is proposed as a thioglycollic acid directed anisotropic growth process combined with an Ostwald ripening mechanism. Moreover, the electrochemical properties of the products are measured, the sulfur doped Sb_2Se_3 nanosheets show the superior performance and better stability than those of ultrathin Sb_2Se_3 nanowires.

1. Introduction

Inorganic nanocrystals with different morphologies and desired compositions have attracted immense attention due to their morphology- and composition-dependent properties and their potential application in many fields including photocatalysis [1,2], lithium ion batteries [3,4], as well as the electronic and magnetic devices, etc. [5]. Therefore, different morphological materials such as zero dimensional (0D) quantum dots [6,7], 1D nanowires, [8,9] nanorods and nanotubes [10–12], 2D nanosheets and nanoplates [13,14], and, of course, 3D crystalline objects are fabricated [15–17].

Among these morphologies, dimensionality two has drawn much interest because of the new discoveries on their unique optical, electronic, catalytic and mechanical properties. And various methods have been developed for the fabrication of 2D nanocrystals. For example, TiS_2 and SnS with well-defined layered 2D shapes have been prepared through hot injection method [18,19]. SnS and Sb_2Te_3 nanoplates have been fabricated by one-pot heating-up method [20,21]. Bi_2Te_3 and PbTe nanoplates by using hydrothermal method have been well-reported [22,23].

Antimony triselenide, a kind of direct bandgap semiconductor, has been attracted a great deal of attention due to its application in solar selective and decorative coating [24], thermoelectric cooling devices [25], and electrochemical hydrogen storage and lithium ion battery devices [26,27]. In the past decades, inspired by its excellent characteristics, considerable efforts have been devoted to the fabrication of Sb_2Se_3 micro and nanostructures. For instance, 1D Sb_2Se_3 nanowires [27,28], nanorods [29] and nanobelts/nanoribbons [30–32] have been prepared via hydrothermal/solvothermal method and a template directed solution process. Sb_2Se_3 microcrystals with sheaf-like, [33] polygonal tubular, [34] tetragonal tubular, [35] spherical-like, [35] submicron rods like, [36] morphologies have been fabricated through a solvent-relief-self-seeding (SRSS) process, a microwave-assisted procedure and a hydrothermal method with the assistance of poly(vinyl pyrrolidone) (PVP). 3D hierarchical urchin-like [30] and carpenterworm-like Sb_2Se_3 [16] have been synthesized by a solvothermal route with the assistance of citric acid and glucose. However, to the best of our knowledge, less work has focused on a one-pot synthesis of Sb_2Se_3 2D nanostructures. To develop a facile route to controllable synthesis of Sb_2Se_3 2D nanostructures and investigate their formation mechanism still remains a great challenge.

Herein, we report a facile solvothermal method for the fabrication of 2D Sb_2Se_3 nanosheets. The morphology of Sb_2Se_3 can be tuned by varying the amount of thioglycollic acid and reaction time. Meanwhile, thioglycollic acid can be used as sulfur source in the reaction system, leading to the formation of sulfur doped Sb_2Se_3 nanosheets. Based on the electron microscopy observations, the morphology evolution and the growth mechanism are investigated systematically. Furthermore, the electrochemical hydrogen storage and the electrochemical Li intercalation performance are tested. The sulfur doped Sb_2Se_3 nanosheets demonstrate comparatively high capacity and excellent cycle performance than those of ultrathin Sb_2Se_3 nanowires.

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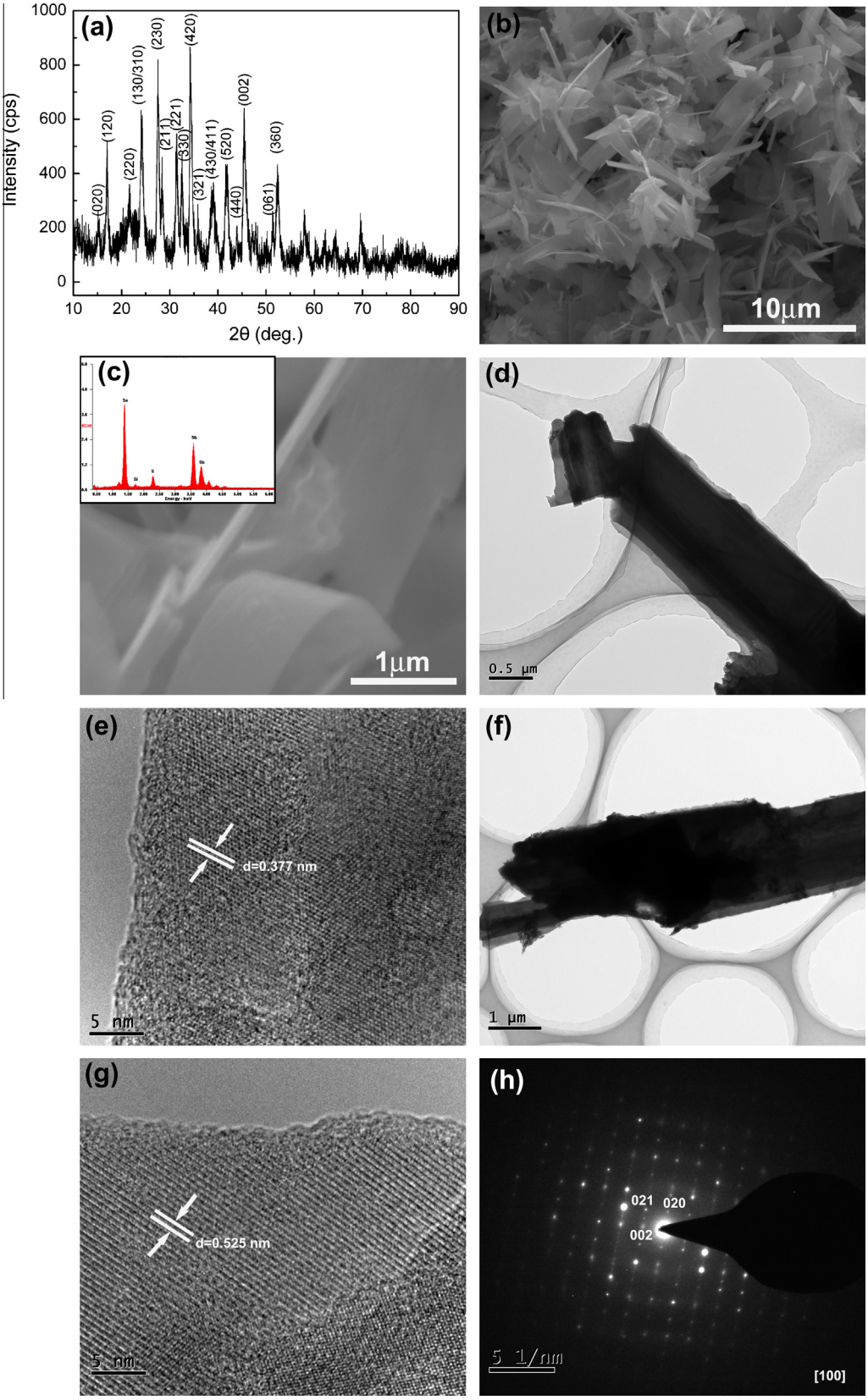

Fig. 1. Characterization of Sb_2Se_3 nanosheets obtained at 120 °C for 9 h in the presence of 1 mL thioglycollic acid: (a) typical XRD pattern, (b) low magnification FESEM image, (c) high magnification FESEM image, inset: EDS pattern, (d) TEM image, (e) HRTEM image, (f) TEM image, (g) HRTEM image, (h) corresponding SAED pattern of a single Sb_2Se_3 nanosheet.