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Facile synthesis of branched MoS_2 nanowires

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ABSTRACT

In this work, the branched MoS_2 nanowires are synthesized by a facile and feasible reflux method. It is clearly that the MoS_2 nanowires interconnect with each other, forming regular branched network. In this fabrication, the polyvinyl pyrrolidone (PVP) is used as surfactant which is critical for the formation of branched MoS_2 wires. Without the PVP, only MoS_2 nanoparticles can be obtained.

1. Introduction

Molybdenum disulfide (MoS_2) has been widely studied ascribed to its unique physical and chemical properties which can be applied in energy storage [1], catalysis [2] and solid lubricants [3]. Particularly, the MoS_2 possesses S-Mo-S layered structure while the individual layers are connected by van der Waals interactions [4]. In order to optimize the characters of MoS_2 for practical applications, various nanostructures including nanorods, nanowires, nanotubes, nanosheets and hierarchical nanostructures have been prepared [5–7]. Among them, the one-dimensional (1D) architectures such as nanowires have attracted extensive attentions devoted to their space-confined transport phenomena as well as excellent electrical conductivity [8]. For example, Morris and co-workers [9] fabricated MoS_2 nanowire arrays by sulfurizing the as-prepared MoO_3 wires in a horizontal quartz tube furnace. Chen et al. [10] prepared MoS_2 nanowires through a reflux reaction using Na_2MoO_4, CH_4N_2S and concentrated hydrochloric acid as precursors. Ye and co-authors [11] synthesized MoS_2 nanowires by a chemical vapor deposition (CVD) method. These studies provided valid strategies to construct MoS_2 nanowires while the hard reaction conditions or complex operating procedures limit their wide applications. Therefore, it is necessary to find out a simple and low-cost way to prepare MoS_2 nanowires.

Herein, the MoS_2 nanowires were facile fabricated by a reflux reaction using the PVP as surfactant for the first time. The uniform MoS_2 nanowires with diameters of 50 nm and length of a few hundred nanometers interconnect with each other to form branchlike structures. Furthermore, the comparative experiment without adding PVP was conducted in order to explore the function of PVP in forming MoS_2 nanowires. Based on the corresponding TEM images of products and atomic construction analysis of MoS_2, the growth mechanism of MoS_2 nanowires was proposed.

2. Experimental section and characterizations

The chemical reagents utilized in this work are all of analytical grade and were directly used without further purification. The MoS_2 nanowires were prepared by a simple reflux treatment. Firstly, 0.3 mmol $MoCl_5$ and 0.3 g PVP (polyvinyl pyrrolidone, Mw = 58000) were dissolved in 100 mL ethylene glycol (EG) under magnetic stirring for about 2 h. And then add 0.4 mL hydrazine hydrate into this solution which was refluxed in an oil bath at 168 °C under stirring (marked as solution A). At the same time, 4 mmol thiourea was dissolved in EG (40 mL) with magnetic stirring (denoted as solution B). After two hours, the solution B was dropwise added into the solution A and this mixed solution was kept at 168 °C for another 3 h. Subsequently, the mixture was cooled down and the product was collected by washing with deionized water and ethanol for three times. The ionic strength of the filtrate is measured to be less than 10 μs cm^{-1}, indicating that there is no residue on the as-synthesized MoS_2 nanowires. At last, the obtained samples were dried at 60 °C for overnight.

The structure and morphology of samples were characterized by field emission scanning electron microscope (FE-SEM, JSM-6701F) and transmission electron microscope (TEM, FEI Tecnai TF20) instruments. The X-ray diffraction (Rigaku RINT-2000) instrument was used to reveal the crystal phase of products using Cu Kα radiation with 40 kV. An

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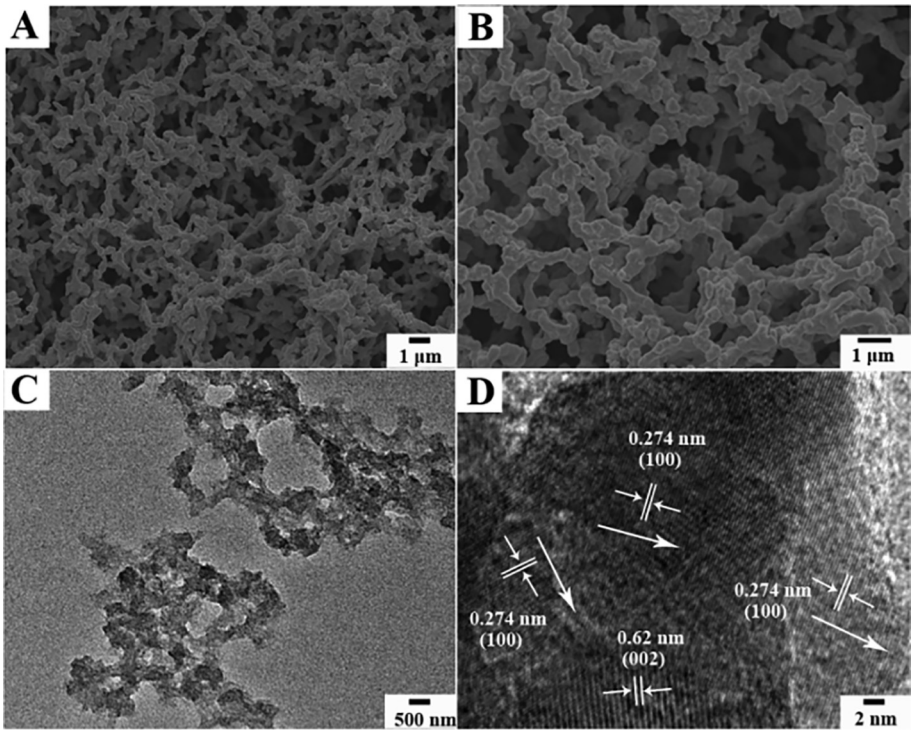

Fig. 1. (A and B) SEM images (C) TEM image and (D) high-resolution TEM (HRTEM) image of branched MoS_2 nanowires.

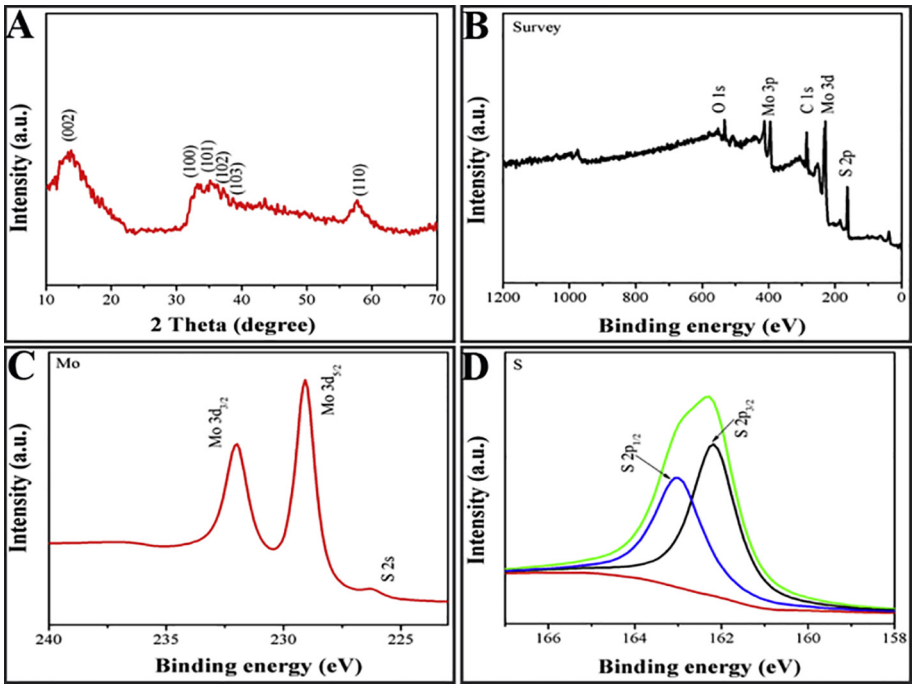

Fig. 2. XRD pattern (A) of branched MoS_2 nanowires and XPS patterns of (B) survey (C) Mo 3d (D) S 2p of the branched MoS_2 nanowires.

ESCALAB 250 X-ray photoelectron spectrometer (XPS) was utilized to unclose the corresponding valence states of elements.

3. Results and discussion

The structure and morphology of as-prepared samples were revealed by scanning electron microscope (SEM) and transmission electron microscope (TEM) images. As shown in Fig. 1A and B, the nanowires with a length about several hundred nanometers interconnect with each other, leading to branched networks. Furthermore, the nanowires exhibit smooth surface and uniform diameter of approximately 50 nm. The TEM image of products also validates the branched nanowire structure (Fig. 1C). The corresponding HRTEM image of nanowires displays lattice spacing of 0.274 nm and 0.62 nm, which can be ascribed to the (1 0 0) and (0 0 2) crystal planes of MoS_2 [12,13]. Particularly, the (1 0 0) facets along the growth direction can be established as the crystal growth planes, suggesting the oriented growth of MoS_2 crystals. Moreover, the (0 0 2) crystal planes demonstrate the characteristic layer feature of MoS_2.

In order to investigate the crystalline structure of as-obtained