

Facile synthesis of SnS tubules

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Abstract : Tin sulfide tubules have been synthesized by a hydrogen-assisted thermal decomposition method using tin disulfide nanopowders as the source material. The as-synthesized SnS tubules are in a typical outer diameter of 200 to 600 nm and a wall thickness of 80

nm. This method yields high-purity orthorhombic phase SnS tubules. © Global Scientific Inc.

Keywords : Tin sulfide; Tubules; Thermal decomposition.

INTRODUCTION

Quasi-one-dimensional nanomaterials provide novel research target as ideal building blocks for next generation of nanodevices, and they have attracted intensive interest both scientifically and technologically^[1]. Nanotubes are an interesting family of nanostructures and have been proved to show superior performance to nanofibrils and nanoparticles in many application fields^[2]. Since the report of carbon nanotube in 1991 by Iijima^[3], nanotubes of many different materials have been reported^[4-17].

SnS is a semiconductor with an indirect and a direct bandgap (1.09 and 1.3 eV, respectively), and could be used as an efficient solar absorber^[18-20]. SnS nanotubes with a pure phase have rarely been reported^[21].

In this work, we report on the facile synthesis of SnS tubules by hydrogen-assisted thermal decomposition of SnS₂ nanopowders.

EXPERIMENTAL

Briefly, 5 g SnS₂ nanopowders (c.a. 40 nm in di-

ameter) were put at the middle of a ceramic tube in a furnace, and then the furnace was flushed with high-purity argon gas for 1 h. The furnace was heated to 850 °C in 7 min and kept at this temperature for 2 h with an Ar (90 vol %) / H₂ (10 vol %) flow rate of 40 sccm (standard cubic centimeter per minute), and the Ar gas was run until the furnace cooled down to room temperature in the ambient condition.

The collected products were characterized by x-ray diffraction (XRD, PW1710 instrument with Cu K α radiation), scanning electron microscopy (SEM, JEOL JSM 6300), and transmission electron microscopy (TEM, Hitachi 800).

RESULTS AND DISCUSSION

The dark gray wool like product was collected and examined with X-ray diffraction (XRD). The XRD pattern in Figure 1 clearly demonstrate the phase purity of the product and all the diffraction peaks can be indexed to orthorhombic phase SnS (JCPDS 33-1375).

The morphologies of the product were obtained by scanning electron microscopy (SEM). Figure 2a displays large scale of SnS one-dimensional materials, and

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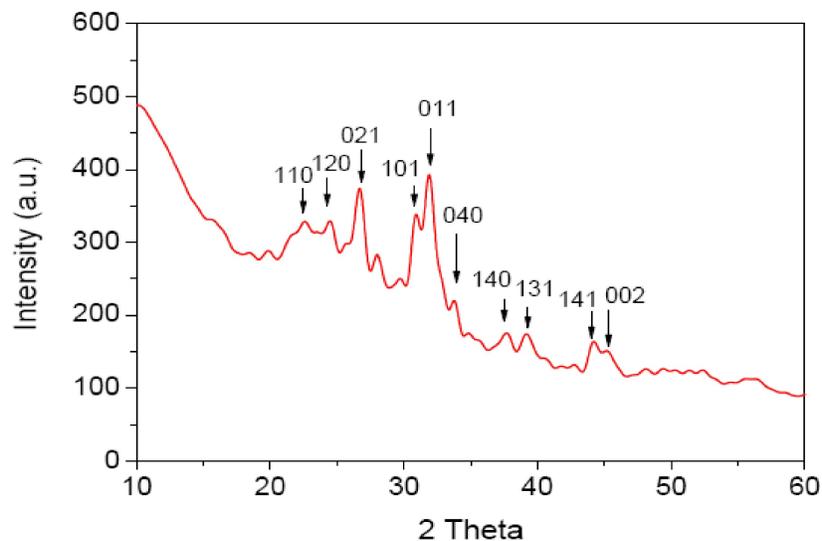


Figure 1: XRD pattern of SnS tubules. All the diffraction peaks could be indexed to orthorhombic phase SnS.

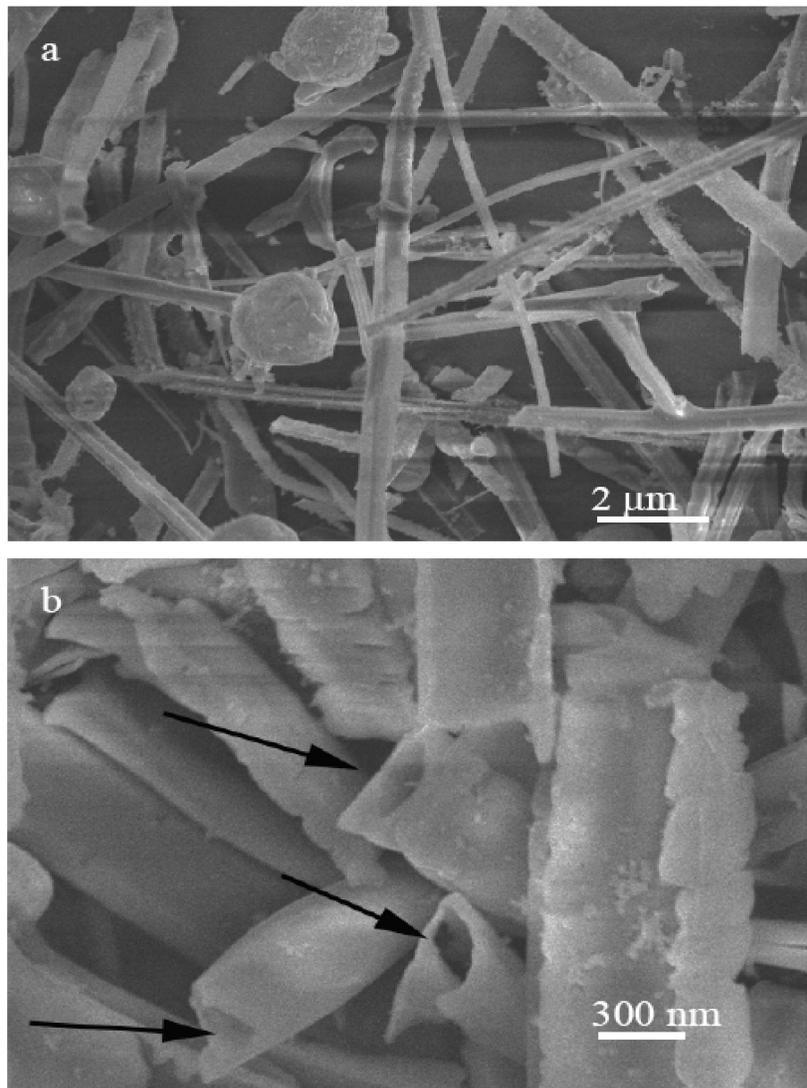


Figure 2: SEM images of SnS tubules. (a) Low-magnification view and (b) high-magnification view. The arrows in (b) mark the openings of the tubules.

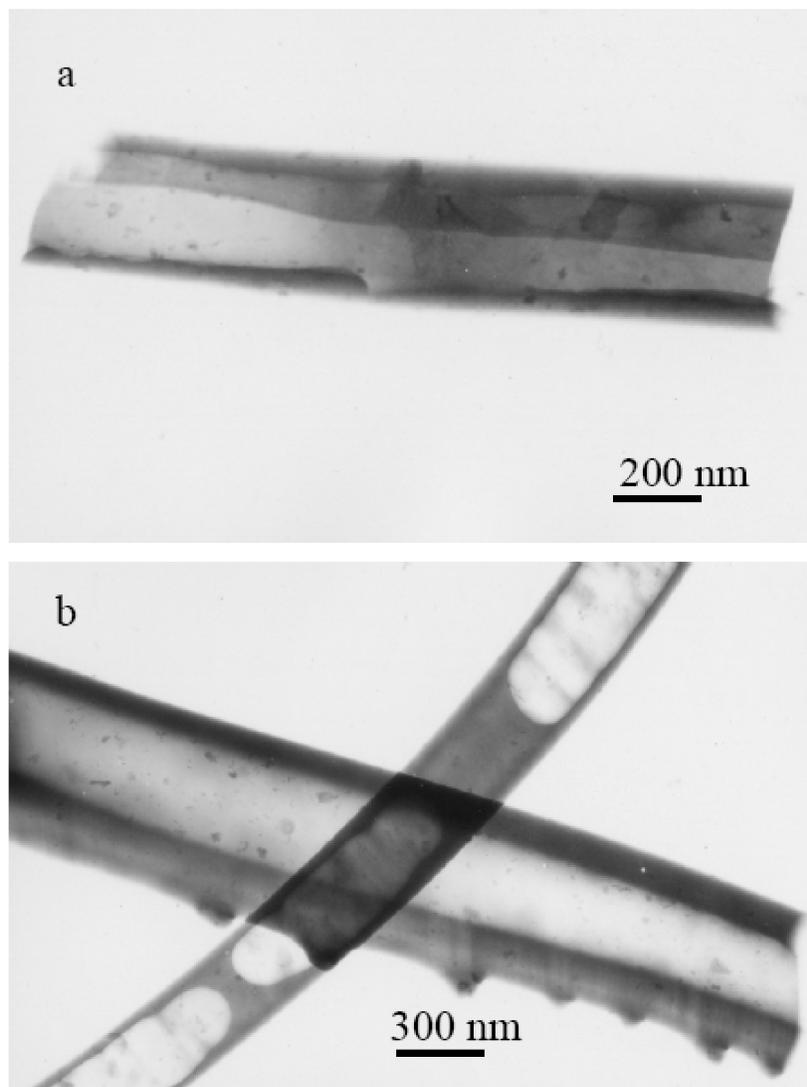
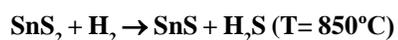


Figure 3: (a) and (b) TEM images of SnS tubules.

Figure 2b is another image of the product, where the circular opening at the end of some nanostructures clearly reveals that the products are tubules. The SnS tubules in the present study are in a typical outer diameter of 200 to 600 nm and a wall thickness of 80 nm, with length up to hundred micrometers. To further study the structure of the SnS tubules, transmission electron microscopy (TEM) was carried out and typical TEM images were shown in Figure 3. One 400 nm thick SnS tubule was displayed in Figure 3a and two SnS tubules with outer diameter of 300 and 700 nm were exhibited in Figure 3b, respectively.

The hydrogen-assisted thermal decomposition process can be expressed as following:



The process is similar to that adopted by Rao *et al.*^[7] in synthesis of NbS₂ and TaS₂ nanotubes.

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SnS₂ and SnS can form layered structures and a superlattice with polyhedral shape self-assembled from SnS₂/SnS fullerene like nanoparticles have been reported recently by Tenne *et al.*^[22]. Actually, as early as in 1989, Kaito *et al.*^[23] observed the formation of β-SnS₂ nanotubes although they did not name them as nanotubes. Li *et al.*^[24] suggested a rolling of layered structures to achieve nanotubes, and provided strong evidence for their model. In addition, Mallouk *et al.*^[25,26] and Domen *et al.*^[27,28] also provided clear evidences of chemical transformation of lamellar oxides into tubular structures, and interpreted as rolling process of the layered structures. Moreover, it has also been proposed that one of the driving forces to form tubules is the annihilation of dangling bonds at the rim of the layered

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structure^[22], where thermodynamic considerations dominate and the total free energy of the tubular configuration is lower than that of the layered one that has unsaturated dangling bands at the periphery of the nanoparticles and/or the nanoplatelets.

CONCLUSIONS

In conclusion, orthorhombic SnS tubules have been synthesized through a hydrogen-assisted thermal decomposition approach at 850°C. The method is facile and highly reproducible and could be extended to synthesize other sulfide tubules.

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