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Hydrothermal synthesis of single-crystalline Bi_2Te_3 nanoplates

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ABSTRACT

Novel Bi_2Te_3 nanoplates with about 0.2–1 μm in diagonal and 100 nm in thickness have been facilely synthesized via hydrothermal routes in the presence of polyvinylpyrrolidone (PVP). Various techniques such as X-ray diffraction (XRD), scanning electron microscope (SEM), transmission electron microscope (TEM), and Fourier transform infrared spectrometry (FT-IR) have been used to characterize the obtained products. The results show that the existence of PVP is vital to the formation of the plate-like morphology. Other factors, such as the reaction temperature and the different surfactants also have influence on the morphology of the final products to some extent.

1. Introduction

In the past few years, preparation of nanoscale semiconductors with controllable morphologies has opened new opportunities to understand the relationship between the structure and properties of materials [1,2]. A number of methods are available for these given shapes, which include molecular-beam epitaxy process [3], pulsed electrodeposition [4], templates and surfactant assisted chemical routes [5–7], etc.

Among these studies, aqueous chemical route, as one of the most important synthetic strategies, has provided a more promising approach to nanostructures than conventional methods in terms of cost, throughput, and potential for large scale productions. Various chemical methods have been developed to prepare nanocrystals with controlled shape, and great achievement has been actualized successfully. However, compared with the fact that most reports were focus on the one-dimensional nanostructure, such as nanorod [7], nanowire [5], nanotube [8] and nanobelt [9]; few attentions were involved in two-dimensional structures. There were only a few papers about the fabrication of metal and compounds nanoplates or nano-flowers [10,11]. As we known, 2D nanostructures have potential applications in information storage, catalyst, transducer, etc, which may opens up a prospect of its application in future industry.

Up to now, Bi_2Te_3-based alloys are known as the best thermoelectric materials currently available for application near room temperature [12], and have received great attention for fabrication of nanocrystals due to the presence of strong quantum confinement and thermal conductivity reduction effects [13–15]. Hence, synthesis and assembly of uniform nanocrystals of Bi_2Te_3 is of great interest to enable the development of higher efficiency devices for thermoelectric application. Among these papers, Li et al. have prepared Bi_2Te_3 nanowire arrays by pulsed electrochemical deposition in the nanochannels of porous anodic alumina membranes [4]. The galvanic displacement reaction has been adopted to fabricate Bi_2Te_3 nanotubes [16]. Zhao et al. issued a notion to synthesize high-content Bi_2Te_3 nanowires under low temperature [17]. Purkayastha et al. adopted a low temperature, template-free synthesis method to obtain single crystal Bi_2Te_3 nanorods [18]. However, because of the complexity of structure, to obtain uniform shape of Bi_2Te_3 by chemical route is also a challenge to us. Only Lu et al. reported a synthesis of hexagonal Bi_2Te_3 nanoplates using a high-temperature organic solution approach [19]. Through a two-step epitaxial growth, the cylindrical strings of Bi_2Te_3 nanoplates on the surface of Te rod by packing them along *c*-axis in sequence could be obtained. So in this work, we developed a facile

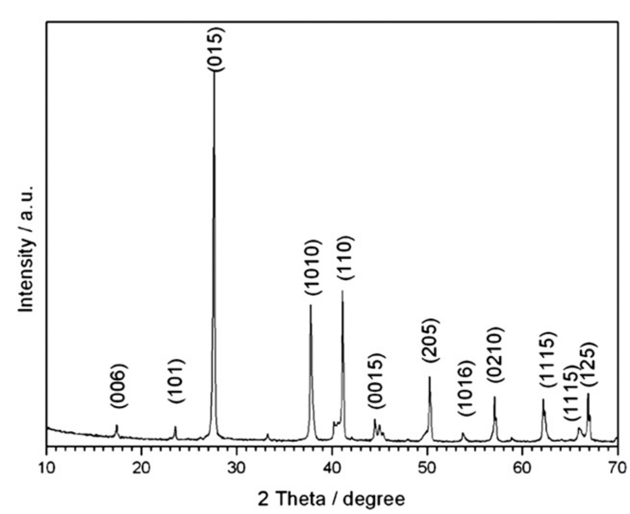

Fig. 1. XRD patterns of Bi_2Te_3 nanocrystal synthesized at 210 °C with 0.1 g PVP.

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hydrothermal route to fabricate large scale single crystal Bi_2Te_3 nanoplates. The potential growth mechanisms were also discussed.

2. Experiment

All the regents were bought from Shanghai Chemical Reagents Co., analytical grade and used without further purification. In a typical synthesis, a 40 ml aqueous solution containing 2 mmol $BiCl_3$, 3 mmol Te, 0.1 g PVP and some sodium hydroxide (NaOH) was prepared in an open beaker, which was stirred with a magnetic stirrer for 0.5 h, then 0.35 g $NaBH_4$ were introduced into the solution. The mixture was transferred into a Teflon-lined autoclave (50 mL capacity), sealed, and maintained at 210 °C for 24 h, followed by cooling to room temperature naturally. The resulting products were filtered off, washed several times with distilled water and absolute ethanol, respectively, and then finally dried in a vacuum at 60 °C for 2 h.

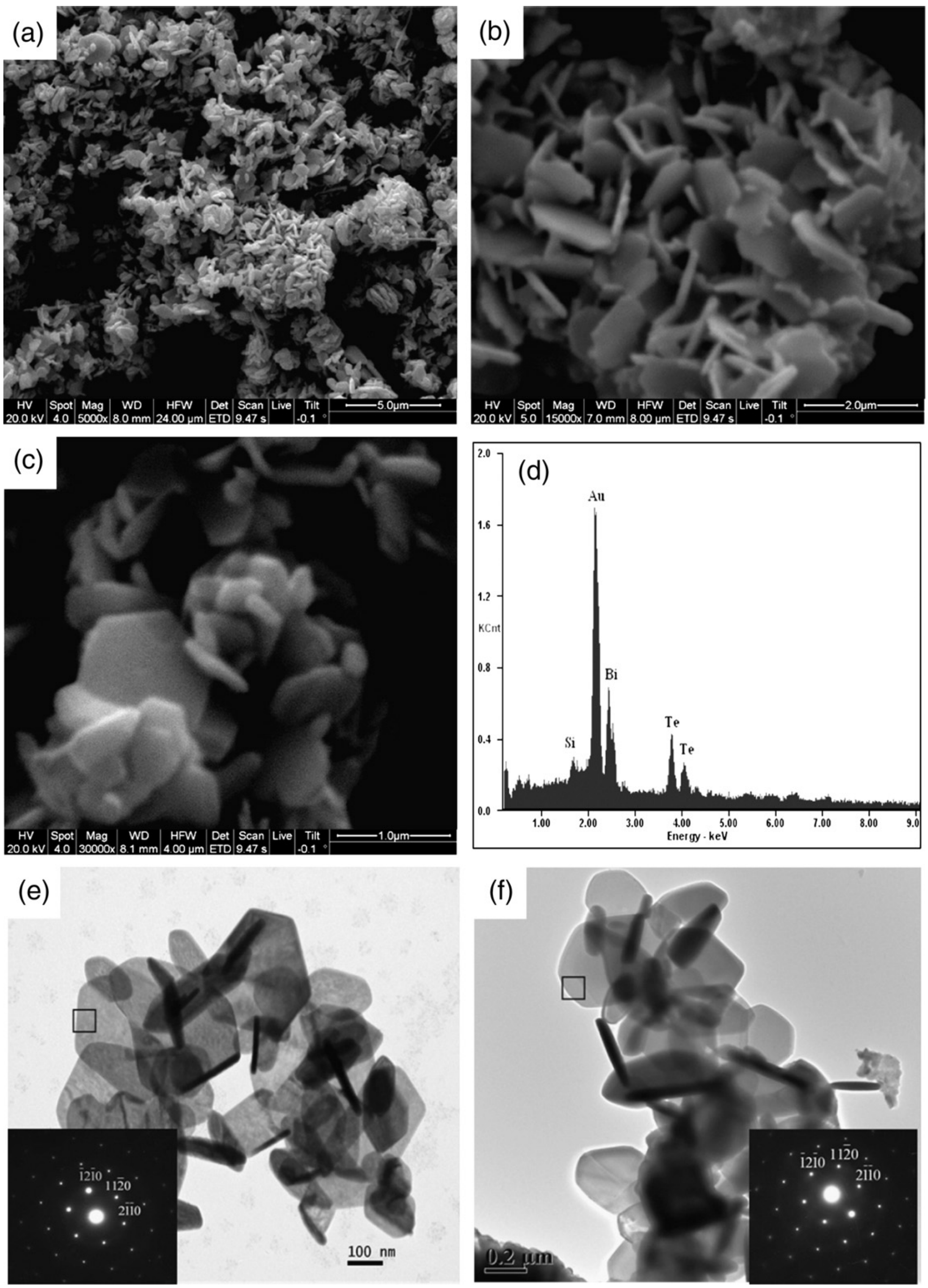

Fig. 2. SEM and TEM images of Bi_2Te_3 nanoplates: (a) low magnification SEM image; (b) and (c) high magnification SEM images; (d) EDS pattern from one nanoplate; (e) and (f) TEM images of obtained products.