

Investigation of Presence Different Surfactant on Morphologies of PbTe Nanostructures

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PbTe nanostructures were prepared by a hydrothermal method on presence of different surfactant. Results show that in constant condition by changing the capping agent the morphology of as-obtained PbTe were revolutionize PbTe nanostructures show a strong photoluminescence peak at 402 nm at room temperature, also optical absorption spectrum of PbTe nanostructures exhibit an extreme blue-shift, which is attributed to the quantum confinement of charge carriers in the nanostructures. X-ray diffraction, scanning electron microscopy, transmission electron microscopy, photoluminescence spectroscopy, and Fourier transformed infrared spectroscopy were used to characterize the as-produced PbTe nanostructures.

Keywords: Nanostructures, Hydrothermal method, PbTe.

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1. INTRODUCTION

Thermoelectric (TE) technology is one of the energy exchange technologies that substitute heat and electricity, theoretical predictions and experimental results demonstrate that decreasing the size of the building blocks of TE materials is an efficient technique to improve TE properties [1-4]. PbTe with a large Bohr excitation radius (46 nm) in contrast with other semiconductors can exhibit excellent electrical transport properties. [5]. Because of these properties, it is an perfect applicant for investigating novel properties and behavior under quantum confinement conditions [6]. Therefore, adapting the size and morphology of PbTe is very important, to make novel behavior and properties. The fabrication different morphology of PbTe in a simple method have attracted much interest. Various structures of PbTe have been synthesized by different methods including magnetron sputtering, laser fragmentation liquid medium, chemical bath, solvothermal, microwave and sonochemical method [7-10]. Perceptibly hydrothermal is a only one of its kind method for preparation nanostructures with controllable morphologies. Principal morphology in other methods like sol-gel, microwave, sonochemical and etc is nanoparticle. Hydrothermal method because of some conditions; e.g., high temperature and pressure provides preferred orientation morphology [11]. In this paper different morphologies of PbTe such as nanoparticles, nanorods, nanocubes and nanosheets of PbTe were synthesized using of $\text{Pb}(\text{NO}_3)_2$, TeCl_4 and $\text{N}_2\text{H}_4 \cdot \text{H}_2\text{O}$ in presence of different surfactants.

2. EXPERIMENTAL

2.1 Materials and Methods

All of the material such as $\text{Pb}(\text{NO}_3)_2$, TeCl_4 , $\text{N}_2\text{H}_4 \cdot \text{H}_2\text{O}$ were purchased from Merck Company. All of the chemicals were used as received without additional purification. XRD patterns were recorded via a Philips, X-ray diffractometer by Ni-filtered Cu K α radiation.

FT-IR spectra were recorded on Galaxy series FTIR5000 spectrophotometer. Room temperature photoluminescence was deliberate by a Perkin Elmer fluorescence instrument. SEM images were gained using a LEO instrument model 1455VP. Prior to taking images, the samples were coated by a very thin layer of Pt to make the sample surface conductor and avert charge accretion, and obtaining an improved contrast.

2.2 Synthesis Method

In a typical synthesis, an aqueous solution of $\text{Pb}(\text{NO}_3)_2$, at presence of different surfactants, such as cetyltrimethyl ammonium bromide (CTAB), sodium dodecyl sulfonate (SDS), polyethylene glycol (PEG), and polyvinyl pyrrolidone (PVP) was mixed with TeCl_4 . After taht $\text{N}_2\text{H}_4 \cdot \text{H}_2\text{O}$ was added drop-wise. Then, the reactants were put into a 250 ml capacity Teflon-lined autoclave. The autoclave was maintained at 160 °C for 6 h and then cooled naturally to room temperature. The product was centrifuged, washed with alcohol and distilled water for several times, and dried in oven at 60 °C for 8 h.

3. RESULT AND DISCUSSION

One of the XRD pattern of these materials are shown in Fig. 1, as an example, which reveals the nanocrystalline nature of the as-prepared products because of the widening of the diffraction peaks. In presence of all of the surfactant PbTe were produced. These patterns are also indexed as a pure cubic phase (space group: Fm-3m) that have appropriate accordance with the literature value (JCPDS No. 78-1905). The crystallite size measurements were calculated by Scherrer equation and the estimated crystallite size of sample in presence of CTAB, SDS, PEG600, PVP25000 are 51, 25, 38 and 21 nm respectively.

SEM images of as product PbTe in presence of CTAB are shown in Fig. 2a, the morphology of products is nanorods, Fig. 2b shows SEM images of as synthesized PbTe nanostructures in presence of SDS.

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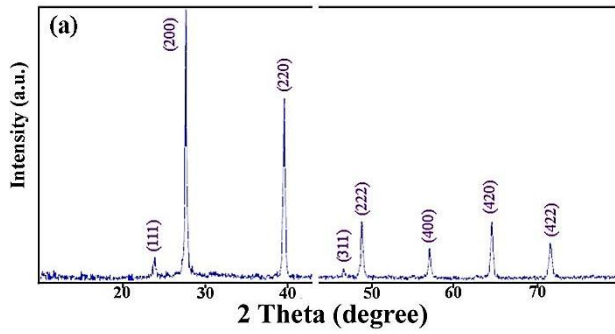


Fig. 1 – XRD pattern of PbTe

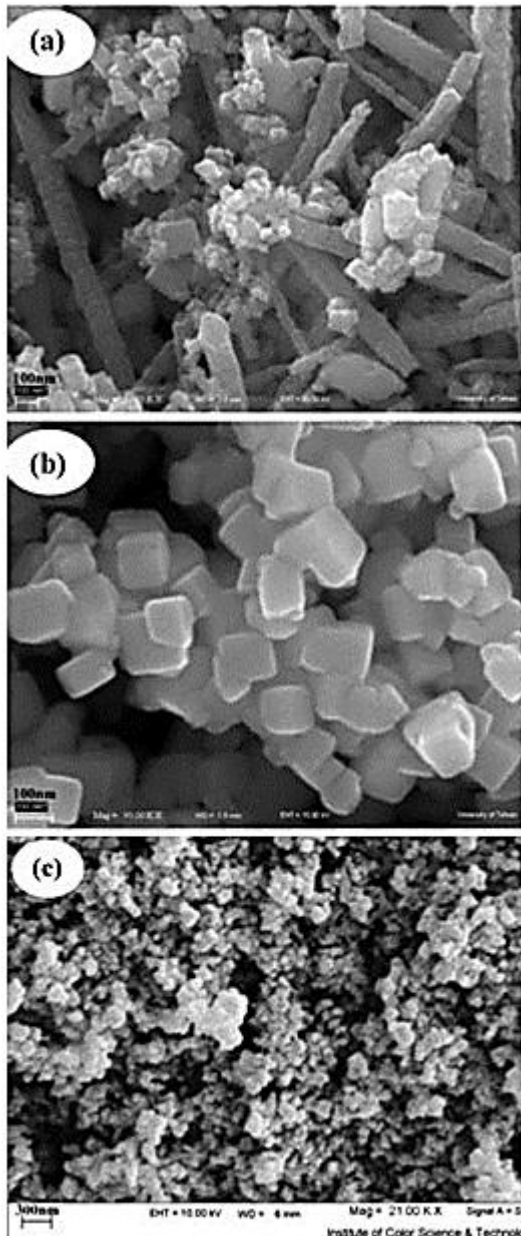


Fig. 2 – SEM images of PbTe in presence of (a) CTAB (b) SDS (c) PVP25000

The morphology of product is nanocube. Fig. 2c illustrate SEM images of PbTe that synthesized in the presence of polymeric surfactants. In presence of PVP nanoparticles are synthesized (Fig. 2c). there for by

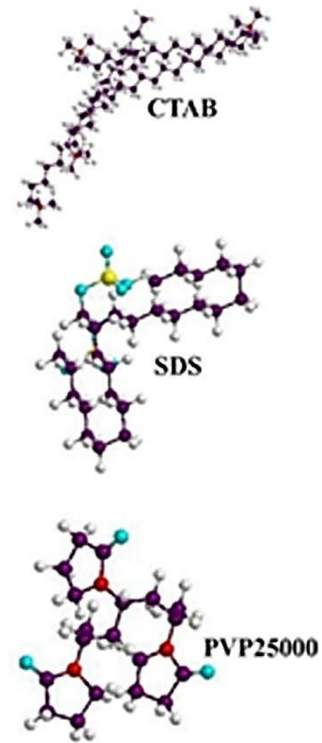


Fig. 3 – Probably mechanism for preparation of PbTe

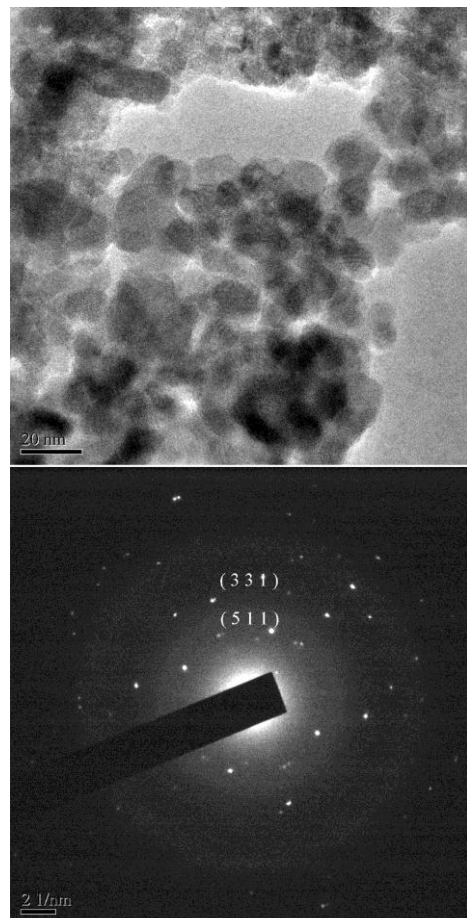


Fig. 4 – TEM and SAED of PbTe nanoparticles

changing of capping agent in constant other conditions the morphology of product were deformed.

Fig. 3 demonstrate probably orientation of surfactant for preparation of suitable micelles that formed the PbTe nanostructures schematically.

Fig. 4 show TEM image of PbTe nanoparticles in presence of PVP with average diameter of 5 nm. The noticeable grain boundaries among a little amorphous region in this figure prove the poly-crystallinity. Selected area electron diffraction of PbTe nanoparticles also is shown in Fig. 6g which supports poly crystallinity of the product. Diffused halo ring and several sharp spots in the SAED pattern indicate that the sample is composed of an amorphous structure with many crystallines embedded within. The halo ring were originated from (511) and (331) crystalline plates.

The optical absorption spectrum of PbTe nanostructures is shown in Fig. 5. It illustrates three excitonic absorption peaks at 234, 335 and 390 nm, and the value of band gap energy is ~ 2.9 eV [12]. These values for optical absorption exhibit an extreme blue-shift in comparison with bulk PbTe. (Bulk PbTe has a band gap in 3859 nm (0.31 eV)), which is caused to the quantum confinement of charge carriers in the nanostructures [13].

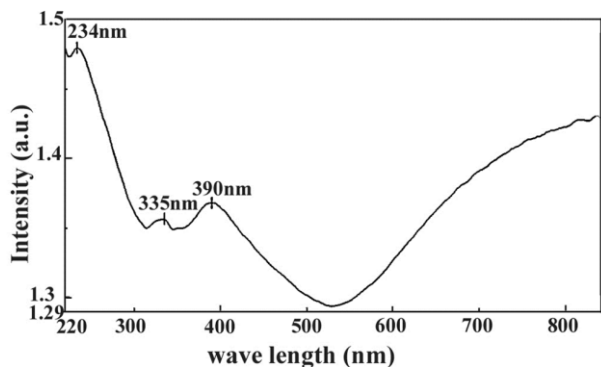


Fig. 5 – Optical absorption spectrum of PbTe

Fig. 6 shown photoluminescence (PL) measurement of PbTe with excitation wavelength 250 nm at room temperature. The PL spectrum shows a strong peak at

400 nm that can be related to a high level transition in PbTe semiconductor crystallites. Therefore this reports, the kind of band edge luminescence results from the recombination of excitons and/or shallowly trapped electron-hole pairs [12]. An extra weak peak is recognizable at 664.5 nm that appears to be related to structural defects or light scattering of solvent. The band gap energy for these nanostructures were calculated to be 3.0 eV that larger than the band gap energy of bulk PbTe structures and has appropriate conformity to the value of band gap appraised based on UV-vis.

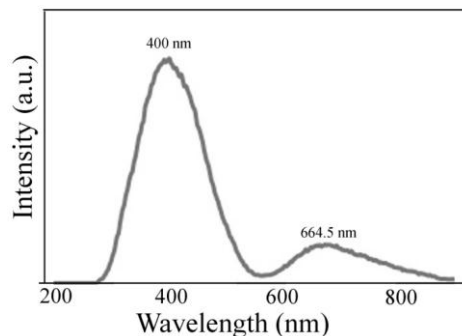


Fig. 6 – PL spectrum of the PbTe sample

4. CONCLUSIONS

PbTe nanostructures were prepared via a simple hydrothermal method. Nanostructures were characterized using XRD, SEM, PL and UV-vis techniques. The effects of presence various surfactants such as cationic, anionic, and polymeric surfactant on the morphology and purity of the products were investigated. According to these results by changing the capping agent achieved different morphologies. It was found that at room temperature the as-obtained PbTe nanostructures show a strong PL peak at 400 nm.

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