Structural and Optical Properties of Bismuth Sulfide Nanoparticles

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Abstract: ***Nano structured materials have become one of the most important research subjects and have established a remarkable development in a wide assortment of scientific fields. Despite all known successes, the control of the materials' intrinsic properties is still challenging. The synthesis of nano particles has been one of the most fruitful methods. Bismuth sulfide is attracting material in Solar cell applications. The synthesis of Bi_2S_3 nano crystalline semiconductor particles was investigated in this work. Crystallography investigation of these materials is done by X-ray diffraction (XRD) which reveals that average grain size is in nano region. Field emission Scanning Electron Microscope (FE-SEM) is used for topography study of these prepared nanostructures. Optical properties of the synthesized materials are studied by UV-VIS and FTIR in detail to check their potential applications for solar cell.***

Keywords: Bi_2S_3 Nanoparticle; Powder XRD, FE-SEM with EDAX

1. Introduction

During the last decades, a lot of attention was devoted to study nano crystalline materials due to their unusual properties and potential applications. However, the control over particle size and its morphology is still a challenge to science. In semiconductor area, bismuth sulfide (Bi_2S_3) has been considered a promising material to be applied in the field of photo electricity, sensors and thermoelectricity since its direct band gap (in range of 1.3-1.7 eV) can be tuned by different particle size and shape, resulting in different properties [1-5]. Bismuth sulfide is direct band gap materials with band gap Eg 1.3eV which is useful for photodiodes and Photovoltaics. It is belongs to family of photodiodes and solid state materials with applications in thermoelectric cooling based on peltier effect. Conventionally bismuth sulfide prepared from direct reaction of bismuth and sulphur in quartz vessel at high temperatures.

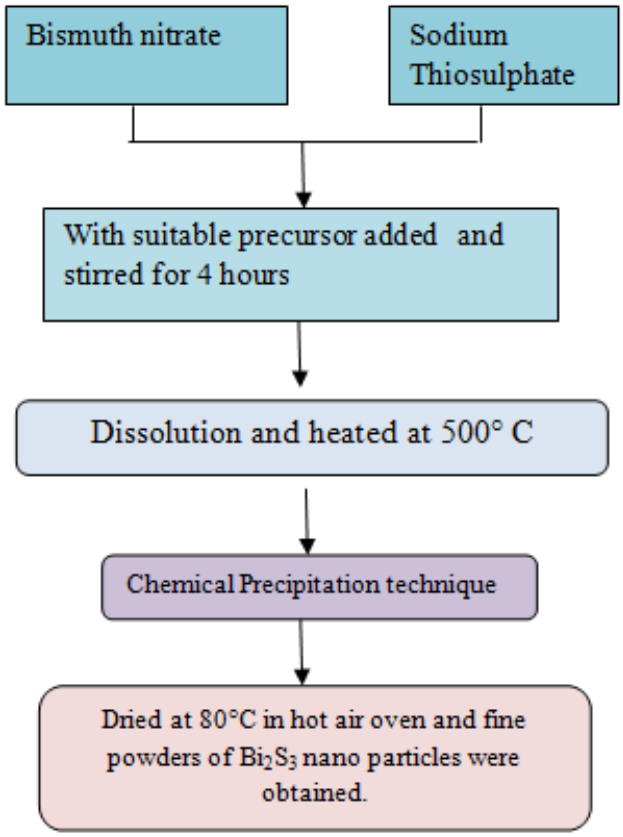
Traditionally, Bi_2S_3 is synthesized by reaction of bismuth and sulfur vapor in a quartz flask under high temperature .Several methods have been developed to prepare Bi_2S_3 with or presenting different size and morphology, such as thermal decomposition, hydrothermal or solvothermal methods, biomolecule-assisted pathways, microwave irradiation, evaporation method [6].Nevertheless, these methods usually spend too much time and use high temperature and pressure, besides most procedures are complex. In this direction, the development of fast and simple methods to prepare bismuth sulfide nanoparticlesis still required. The preparation of BiS_3 already reported by thermal decomposition of bismuth dithiocarbamate,metal ethyl Xanthate and bismuth thiourea complexes[7-10]. However all the methods require at high temperatures and some final product contained impurities. In recent years, Yu et al. conducted experiments in which Bi_2S_3nanorods were successfully prepared and Bi_2S_3 nano wires were obtained by the hydrothermal or solvothermal technique. The size and morphology of the products can be controlled by applying different reaction conditions including temperature, reaction time, and solvents. However, this method requires relatively high pressure, and it takes a long time for the reaction to be completed. Monteiro et al. also reported a novel single source method for the preparation of Bi_2S_3 nano fibers [11-17].

In this communication we report the synthesis of Bismuth sulfide nano powder by chemical precipitation method. Hence in terms of precursors and processing, this method is green, clean, fast and inexpensive. To the best of our knowledge hitherto there are no reports on the optical and structural studies of bismuth sulfide nano powders synthesized by chemical precipitation method. The as synthesized Bi_2S_3 nanopowder has been characterized by UV-visible, FT-IR Powder XRD, FE-SEM.The results obtained tally well with those reported in literature.

2. Experimental Section

2.1. Synthesis of Nanoparticles

Bismuth sulfide nanoparticles were synthesized by the chemical precipitation method. Bismuth nitrate Aldrich, 98%) and sodium thiosulfate (NaOH, Merck, 99%) were used as the precursors, and Deionized water was used as the solvent. In a typicalprocedure to synthesize the, nanoparticles of Bi_2S_3 were Prepared By chemical precipitation method.Two aqueous solutions were prepared according to the mole composition salts soluble in 20ml Deionized Water. Solution A containing:(0.20M) $Bi(NO_3)_3{\cdot}5H_2O$, Solution B containing: (0.30M) $Na_2S.9H_2O$, The solutions A and B mixed with constant magnetic stirrer 4 hours for room Temperature. The solution of Bi_2S_3 constant stirring magnetic stirrer 40 min for 500C Temperature. After Cool this solution at room temperature. The product was heated in a hot air oven at a temperature 170-190 °C for 12 h. To remove water content and then annealed at a temperature of at ambient atmosphere. After cool the powder at room temperature. Finally resultant precipitates were washed several times with deionized water to remove the impurities. The obtained dark brown colour precipitate was dried in 60-80 °C for 3-4 hrs and washed with distiller water. The Preparation chart was given below.



3. Results and Discussion

3.1. UV–Vis spectroscopy Measurement

3.1UV-Absorption Spectrum Analysis

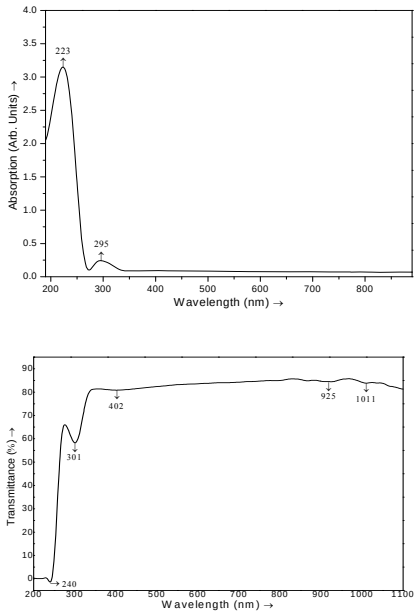


Figure 1: Absorption and Transmission Spectrum of Bismuth Sulfide

The figure 2 Shows the UV-Vis Absorption spectra of Bismuth Sulfide nanoparticles in the region from 200 to 400 nm. In these Absorption spectra there is a peak presented at 200 to 250 nm and 275 to 325 nm but there is a first maximum peak 223 nm. In the second minimum peak 295 nm. Figure 3 Shows the UV-Vis Transmittance spectra of Bismuth Sulfide nanoparticles in the region from 200 to 1100 nm.

In this Transmittance spectra there is a peak presented at 200 to 400 nm and 900 to 1100 nm but there is a first maximum peak 240 nm & 301. In the second minimum peak 925 nm & 1011 nm.

Table 1: Absorption and Transmission Peak of the Sample

Type of the Sample	*λ max-1 (nm)*	*λ max-2 (nm)*	*Transmission Peaks in nm*
Bi_2S_3	293	295	340 and 925

3.2 FT-IR Spectrum Analysis

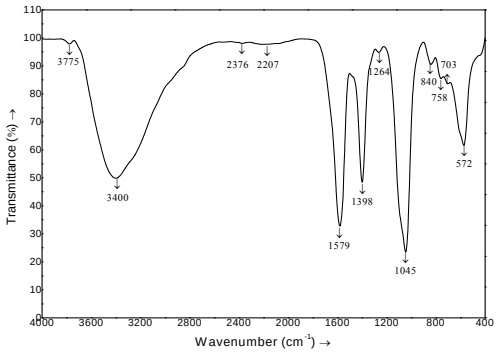


Figure 2: FTIR Spectra of Bismuth Sulfide nano powder

FT-IR spectrum of this compound was recorded in the region 400–4000cm−1 on IFS 66V spectrophotometer using KBr pellet technique is shown in Fig.2.FT-IR spectrum of Bi_2S_3 powder thermally treated at 170-190°C. The response a molecule has to irradiation depends upon the energy. The radiation contains and the pathways of energy dispersal available to the molecule. When a molecule is irradiated, it will absorb the energy. Remember, energy levels are quantized, so you need the right energy to effect an energy level transition. If, for example, the energy absorbed corresponds to an electronic energy level, an electron will be promoted from a bond orbital to an anti-bonding orbital. By examining how molecules interact with electromagnetic radiation of specific energy, we can learn about the structures and properties of the molecules. FT-IR spectrum is used to examine the functional groups are present in the sample.

FT–IR spectrums of Bi_2S_3 nanoparticles are shown in figure 4. The IR spectrum of the precursor exhibits absorption peaks. The broad absorption band centered at 3775 cm^{-1} and 3400 cm^{-1} is attributed to the band O-H stretching vibrations, and the band at 1579 cm^{-1} is attributed to bending mode (H–O–H). The band at 1398 cm^{-1} is primarily due to the banding vibration of ionic CO32-. The three bands appearing around 1264, 1045 & 572 cm^{-1} confirm the presence of C–O in the precursor. The strong band at 840 & 758 cm^{-1} corresponds to the banding vibration of Bi-S band.

3.3 XRD Diffraction Studies

The obtained samples are characterized on a Rikagu X-ray diffractometer (XRD) with Cu Ka radiation (1.540 Å).The XRD pattern of the Final product shows above fig 3.

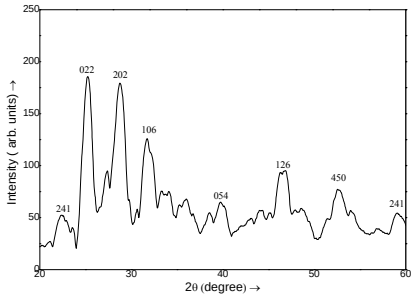


Figure 3: XRD pattern of Bismuth Sulfide nano

Powder

Almost all peaks in the pattern could be indexed to orthorhombic Bi_2S_3 with cell constants of a = 3.981 Å , b = 11.140 Å , c = 11.305 Å , which are closed to the reported literature. The diffraction peaks Bi correspond to the (0 7 2) , (1 0 4) and (1 4 8) at corresponding 2θ value of 26.6° , 31.3° and 52.6° respectively. On the other peaks sulphur corresponding (7 2 1) , (3 4 2) , (2 6 1) and (0 4 1) corresponding 2θ value 29.2° , 44.4° , 48.2° and 55.8° respectively . The diffraction peaks were narrow and sharp; indicating that the products were of high degree of crystallinity with their atoms residing in crystalline lattice.The sharpness of all the peaks implies that the sample is crystalline even at room temperature. The purity of the sample is established by the complete absence of impurity peaks. The particle size was calculated using the Scherrer equation,

$$D = \frac{k\lambda}{\beta \cos\theta} \quad \text{_____(1)}$$

Where D is the particle size, K is the Scherrer constant (~0.9), λ is the wavelength of X-rays, β is the Full Width Half Maximum and θ is the Bragg angle [18-19]. The average crystallite size was found to be in the range 6-10nm.

3.4 Morphological Analysis

FESEM-EDAX Analysis

The microstructure of obtained Bismuth sulfide were studied by field emission scanning electron microscopy (FESEM Zeiss Ultra Plus) equipped with energy dispersion spectroscopy (FESEM with EDAX with detector Bruker AXS, software: Genesis). Surface and surface related structures, topography and morphology of the specimens are investigated with FE-SEM. The morphology of Bi_2S_3 nano particles including particle size and structure was determined by FE-SEM in the figure 4 shows the sample.

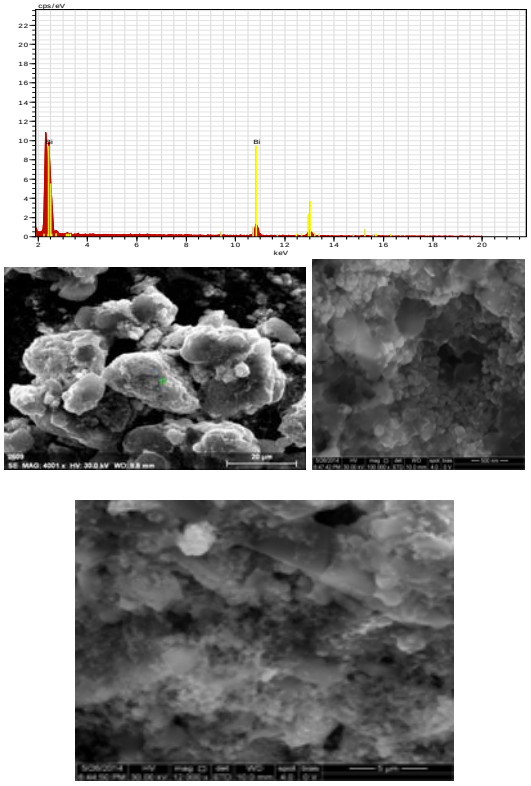


Figure 4: FESEM with EDAX micrograph of Bi_2S_3

4. Conclusion

In the present work, the nano sized Bi_2S_3 particles were successfully generated by direct precipitation method using Bismuth nitrate as bismuth source and sodim thiosulphate as precipitating agent in aqueous solution. In XRD analysis, the size range of the generated Bi_2S_3 powder was approximately 6-10 nm. The FE-SEM analysis shows that the particles morphology was spherical structure of Bi_2S_3 nanoparticles and that they are well crystallized in the nanosize of 30–50micro meter scale. The FT-IR spectrum shows the existence of OH-, CO_2, and CO groups in uncalcined sample.The band gap was lower for synthesized Bi_2S_3 nanoparticles than their bulk counterparts.Thus,the synthesis of Bi_2S_3 nanoparticles by direct precipitation method is simple, fast and eco-friendly in nature.

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Author Profile

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