Construction and Characterization of Photodiodes prepared with Bi_2S_3 Nanowires

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Research Highlights:

- Bi_2S_3 nanowire/ITO photodiodes have been constructed
- V-I characteristics of the diode show a photocurrent efficiency of 12 folds to that in dark
- 1D Bi_2S_3 nanowires in the form of 2D thin films
- XRD peaks reveal orthorhombic structure with good crystallinity

Introduction:

- This work discloses the characteristics of a Bi_2S_3 nanowire / ITO photodiode and a manufacture method thereof; wherein, the high-crystalline Bi_2S_3 nanostructures were prepared by an environmental friendly dip-coating method onto Indium-doped Tin Oxide (ITO) coated glass substrates using bismuth nitrate and thiourea as raw material with DMF as solvent [1, 2].
- The XRD spectra showed that the Bi_2S_3 nanowire exhibits orthorhombic structure, while the SEM images revealed the formation of uniform sized nanowires with diameter around 15.8 nm [3].
- The optical bandgap of the films had been estimated via Tauc plot and found to be in the range of 1.85 eV - 1.9 eV [4].
- In order to understand the I-V characterizations of the prepared diode showed prominent photo-response with a high photo-responsivity of 1.7 µA with a fast response time were reported in detail [5].

Experimental Procedure:

- ***Preparation of Bi_2S_3 Thin Film***

In this work, bismuth nitrate and thiourea were taken in the ratio of (1:2) and dissolved in 20 ml of N, N-dimethylformamide (DMF) by stirring the solution for 15 min (solution I). Similarly, 0.5g of Poly-Vinyl Pyrrolidone (PVP) was dissolved in 20 ml of DMF. This solution was slowly added to solution I with continuous stirring at 100 °C. The stirring was continued for 6hrs to ensure complete mixing. When the solution became sufficiently viscous, ITO substrates were dipped for required number of times at an interval of 5 min between each dip. The deposited thin films were dried at room temperature.

- ***Construction of Photodiode***

The Bi_2S_3 thin films consisting of nanowires prepared with two dips was deposited on the ITO substrates following the procedure mentioned above in order to construct a photodiode. A platinum layer deposited ITO substrate was held on the Bi_2S_3 thin film as shown in Fig. 3, to ensure better collection of charge carriers. Electrical contacts were made on the platinum layer and ITO layer below the Bi_2S_3 thin film in order to characterize the fabricated diode.

References:

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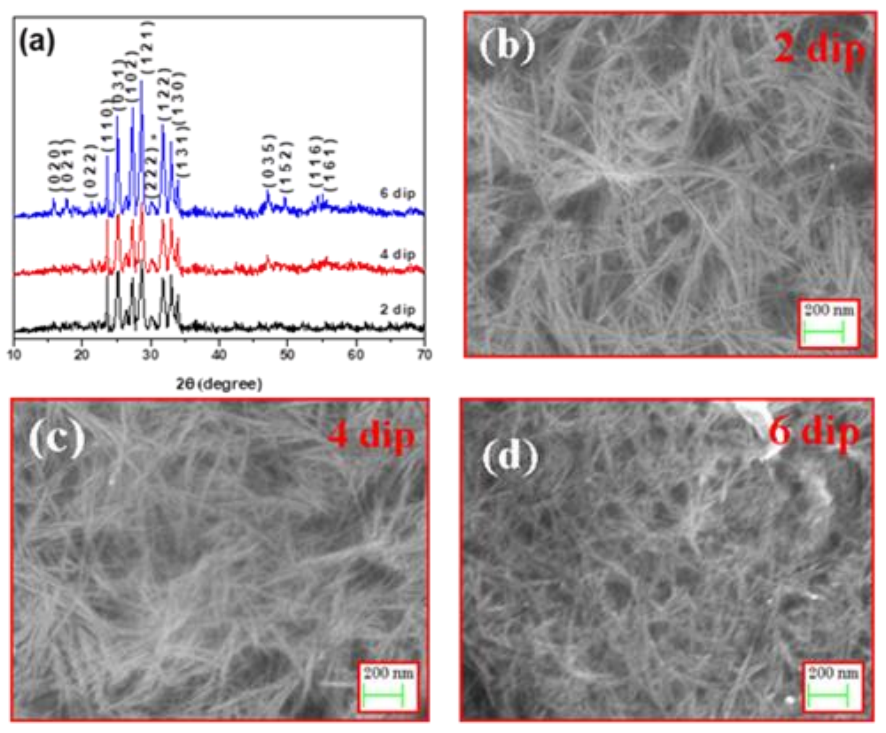
Results & Discussion:



The XRD pattern in Fig. 1(a) shows good crystalline nature of the deposited thin films. The appearance of multiple peak indicates the polycrystalline nature of the films and the exact match of diffraction peaks with JCPDS Card No. #84-0279 confirms the formation of Bi_2S_3 with orthorhombic structure [1] having cell constants a=3.981 Å, b=11.147 Å, and c=11.30 Å.

Fig. 1. (a) XRD pattern and (b, c & d) SEM micrographs of the Bi_2S_3 nanowires

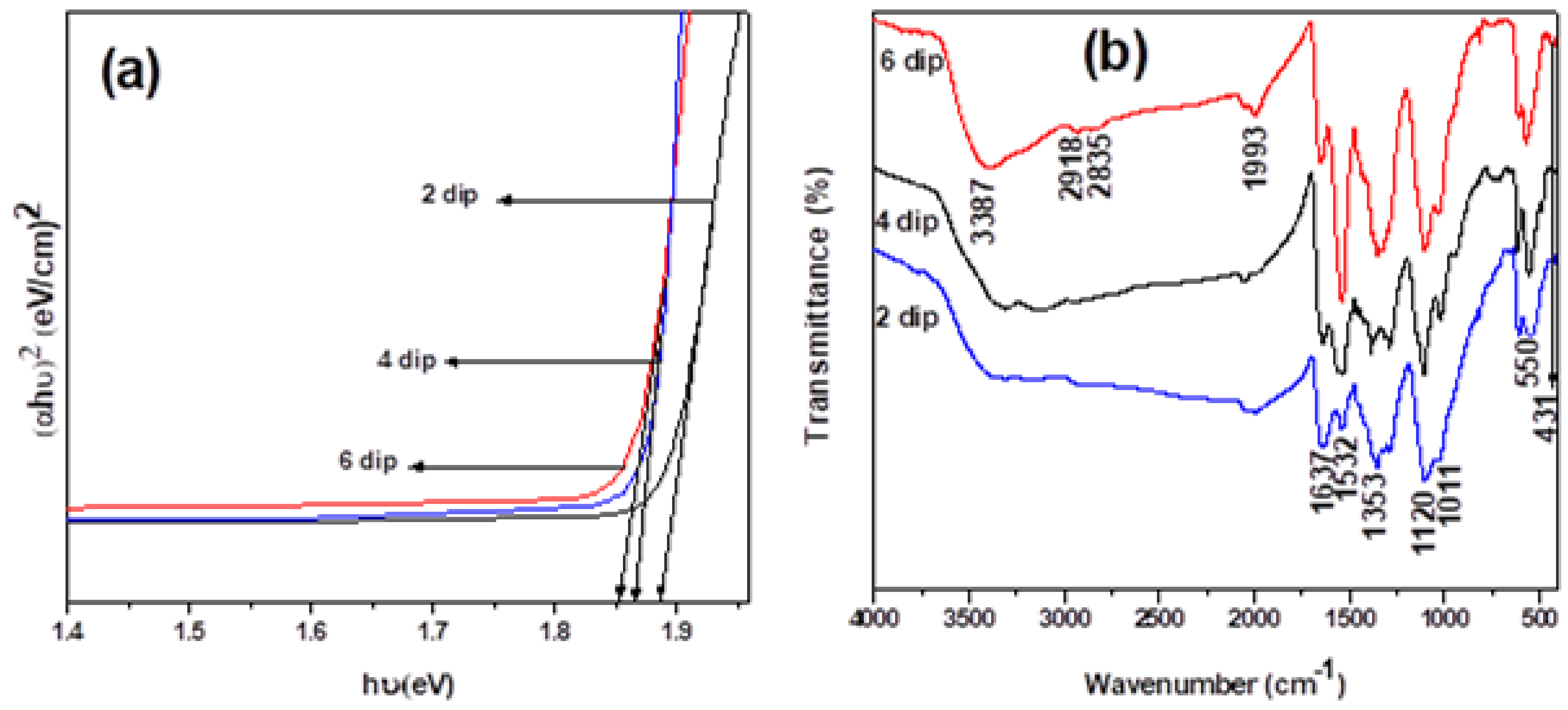


Fig. 2. (a) Tauc plot and (b) FTIR spectra of the Bi_2S_3 nanowires

Bandgap of a material plays a vital role in optoelectronic applications. A graph was plotted between energy (hν) and $(\alpha\eta\nu)^2$ to determine the energy bandgap of Bi_2S_3 as depicted in Fig. 2(a). The bandgaps of the material were found out from the Tauc plot for 2, 4 and 6 dipping. From the image, it is very well noted that, bismuth sulphide owns a bandgap in between 1.85 eV to 1.9 eV. The bandgaps of the material increased a little while reducing the number of dipping of the material. The FT-IR spectrums of the prepared Bi_2S_3 was presented in Fig. 2(b).

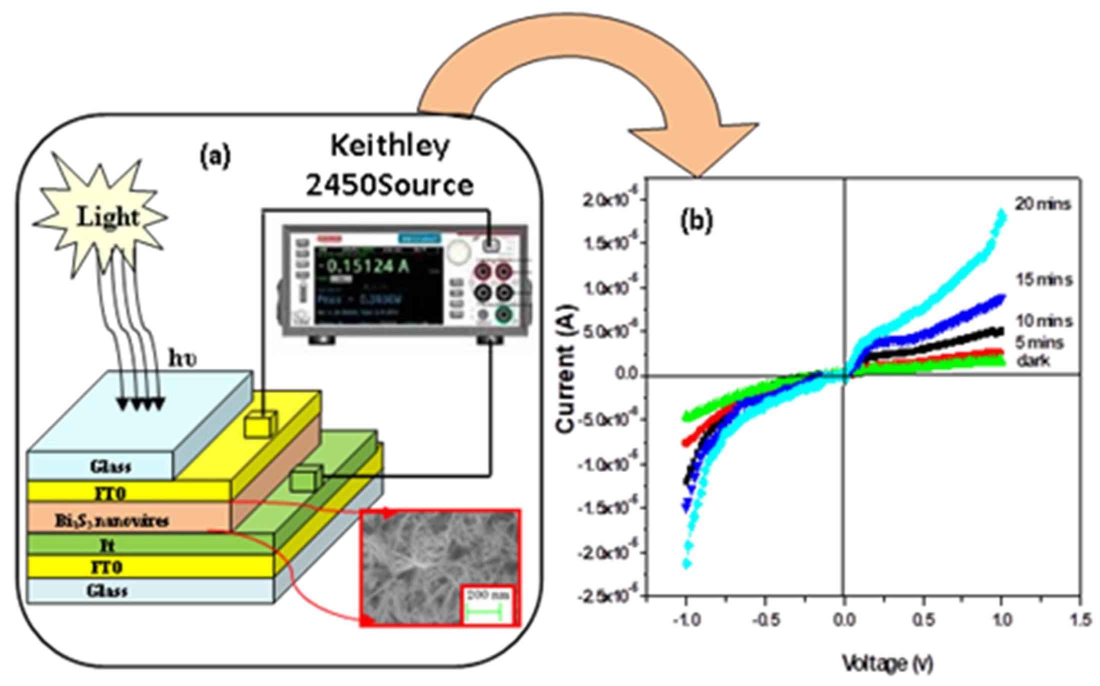


Fig. 3. (a) Schematic diagram of Bi_2S_3 nanowire diode; (b) I-V characteristics of the prepared Bi_2S_3 nanowire diode

The prepared Bi_2S_3 nanowire based photodiode was connected as shown in the schematic diagram in Fig. 3(a) for characterizing it. The voltage was varied in the Keithley 2450 source measure from -1V to +1V and the current value was recorded simultaneously. The diode was first studied under dark environment and then under the illumination of halogen light. The dark current value was found to be around 1.7 µA for a bias voltage of 1V. A nonlinear behaviour is witnessed during the I-V measurements with exposure to light [19].

Summary:

The Bi_2S_3 nanowires / ITO photodiode was successfully constructed after analyzing the basic properties of the Bi_2S_3 nanowires deposited on ITO for different dips. An optical bandgap of ~1.87 eV was witnessed for the samples. The diode characteristic graphs revealed an increase in photocurrent to around 12 folds on exposure to light. Thus, Bi_2S_3 nanowires are best candidates for photodiodes. However, the tuning of electrical properties by controlling other parameters are under further investigation.