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Synthesis and Characterization of Nanostructured PbS Thin film

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Abstract: In the present work, PbS Nanocrystals with rod shaped structure have been successfully prepared by chemical bath deposition method. The structure was determined by X-ray diffraction studies. The XRD data revealed the formation of cubic phase of PbS with the preferential orientation (2 0 0). The average crystallite size was found to be 7.82 nm. SEM images confirm the formation of nanorods of PbS. The optical properties were studied by recording absorption spectra in the wavelength range of 200-900 nm. The optical bandgap and refractive index was found to be 1.47eV and 2.97, respectively. The electrical resistance was measured using four probe method and it was found to be 0.67MΩ.
Keywords –Nanorods; Electrical properties; Optical properties.

Introduction

Semiconducting materials are attractive due to their outstanding optical and electronic properties. PbS is semiconducting material having narrow band gap of 0.41eV. It is widely used in IR detectors. PbS is an important material for a variety of applications such as electroluminescent devices, solar cells, gas sensors and other optoelectronic devices [1].

There are many techniques that have been used to prepare thin films. Among various deposition techniques chemical bath deposition technique (CBD) is the most convenient and frequently used deposition technique to grow PbS thin films. The properties of PbS thin film prepared by CBD is strongly depends on growth condition [2]. Different morphological structures strongly affect the electrical and optical properties.

Experimental

The PbS thin film was prepared by chemical bath deposition method. All the precursors were of analytical grade and used as procured. The PbS film was deposited on glass substrate. This was done in a 100 ml beaker by addition of 50 ml 0.01 M lead nitrate, 10 ml 0.146 M NaOH and 50ml 0.057M thiourea solution. The film was deposited on the substrate by immersing it vertically into the solution. The temperature of the solution was maintained at 40°C for 30 min. The resulting film was homogeneous, well adhered to the substrate with dark mirror like surface.

Results and Discussion

XRD Analysis

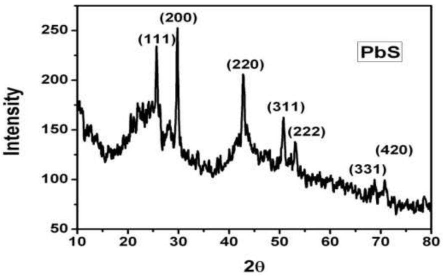

Figure 1: X- ray diffraction pattern of PbS Thin film

Figure 1 shows the XRD pattern of PbSNanorods. Looking at the peak broadening, it can be said that nanosized crystallites have been formed. This was confirmed by crystallite size calculation using Scherrer formula. The average crystallite size was found to be 7.82 nm. Diffraction peaks at 2θ values 25.66°, 29.80°, 42.77°, 50.76°, 53.05°, 68.77° and 70.76° are observed. All diffraction peaks can be indexed to the pure cubic phase of PbS. These peaks are originating from (1 1 1), (2 0 0), (2 2 0), (3 1 1), (2 2 2), (3 3 1) and (4 2 0) planes respectively. The highest intensity of the peak shows that the grains are preferentially oriented along (2 0 0) direction. The absence of any other phase indicates the purity of sample.

SEM Analysis

Figure 2 shows the scanning electron micrographs of as deposited PbS thin film. The surface of the film is smooth and covers the entire substrate surface. A clear rod like structure has been formed which can be seen in figure 2. The rods of almost equal size and shape are uniformly distributed over the film.

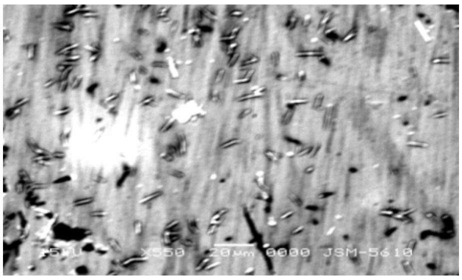

Figure 2: SEM images of PbS thin film

UV-Visible Spectroscopy

The optical absorption of the film was studied in the wavelength range 200 to 900 nm. Figure 3 shows the optical absorption spectra of as prepared PbS thin film. A good optical absorption up to 700 nm is observed. The optical bandgap was determined by Tauc's relation and it was found to be 1.47 eV. This bandgap is higher than the bulk PbSbandgap 0.41 eV. This may be attributed to confinement effect in PbSNanorods permitting the shifting of absorption edge from IR region to the UV-VIS region [3].The refractive index of thin films was evaluated by using the relation between refractive index (n) and energy gap (E_g),$n = KE_g^{\ C}$ proposed by Kumar and Singh [4], where n = refractive index, Eg = bandgap, K and C are the constants having values K = 3.3668 and C = -0.032234. The refractive index was found to be 2.97 which is very less than bulk PbS refractive index 3.91.

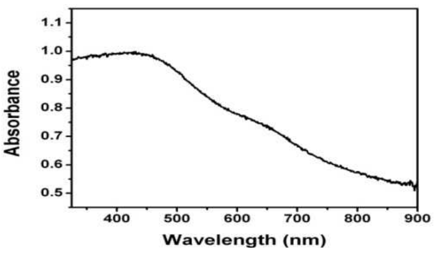

Figure 3: The optical absorption spectra

Electrical Properties

The electrical resistance of PbS thin film was measured using four probe technique at room temperature. Figure 4 shows I-V relation of PbS thin film.From I-V characteristic we found the film has linear relation between current and voltage so when voltage increased the current that cross in the film increased too. The Lead sulfide may be both n- and p-type, depending on stoichiometric: Pb-enriched materials are electronic conductors, and S - enriched materials are hole conductors [5].The linear relationship between current and voltage revealed that the prepared PbSNanorods has p-type conductivity [6]. The electrical resistance was calculated from the slope of linear region and it was found to be 0.67MΩ.

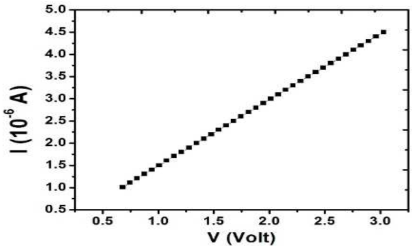

Figure 4: I-V Characteristic of PbS thin film

Conclusion

In this study, we have described a simple and cheap synthetic route to high quality PbSNanorods. From structural analysis we can conclude that the PbS film has polycrystalline structure with grains of 7.82 nm size. From SEM micrographs the formation of uniform Nanorods is confirmed. The optical absorption study reveals that PbS thin film has optical bandgap of 1.47 eV. The calculated refractive index is 2.97. TheI-V characterization confirmed the p-type nature of PbSNanorods. The electrical resistance was found to be 0.67 MΩ.

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