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Research Article

PHYSICAL PROPERTIES OF CHEMICALLY GROWN NANOCRYSTALLINE LEAD SULPHIDE THIN FILMS

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ABSTRACT
In the current paper nanostructured lead sulphide (PbS) thin film were successfully deposited onto glass slide substrates via a simple, inexpensive and easily controlled method, proceeding large area films, using chemical spray technique at 573 K. The structural and surface morphological studies were carried out using X-ray diffractometry (XRD) and scanning electron microscopy (SEM). The structural study revealed that PbS thin films are nanocrystalline in nature with cubic lattice. The optical characterization shows that the band gap of the spray deposited PbS thin film is 1.2eV.

Keywords: *Thin Films; Nanostructures; Electrical Properties****;*** *Optical Properties*

INTRODUCTION
PbS is a direct narrow gap semiconductor very suitable for infrared detection applications. At room temperature, its energy band gap is approximately 0.37–0.4 eV (Pankove, 1971; Kanazawa and Adachi, 1998). This material has also been used as photo resistance, diode lasers, humidity and temperature sensors, decorative coatings and solar control coatings, among others applications (Pop *et al.*, 1997; Nascu *et al.*, 1996; Nair *et al.*, 1989; Nair *et al.*, 1991; Fainer *et al.*, 1996; Nair and Nair, 1990). For these reasons, many research groups have an increasing interest in the development and study of this material. It is well known that the chemical bath deposition technique (CBD) is the most convenient and frequently used deposition technique to grow PbS thin films. It has been found that the properties of chemically deposited PbS thin films depend strongly on the growth conditions. Typically, this type of PbS films are deposited at room temperature and have a well-defined grainy with somewhat loose compact structure, which has a marked influence on their photosensitivity properties (Blount *et al.*, 1973; Kothiyal *et al.*, 1980).

MATERIALS AND METHODS
In the present work, chemical spray pyrolysis method was utilized for the deposition of nanocrystalline PbS thin films onto glass substrates. The various deposition parameters were optimized to get good quality PbS thin films. The structural and morphological characterizations were carried out using X-ray diffraction (XRD) and Scanning electron microscopy (SEM). The optical and electrical properties were studied by using optical absorption, electrical resistivity and thermo-emf measurement techniques.

Experimental Details
Nanocrystalline lead sulphide thin films have been successfully deposited on glass substrate from lead acetate (Pb^{2+} ions) and thiourea (S^{2-} ions) precursors using SPT. Before deposition the substrates were boiled in the concentrate chromic acid (0.5M) for 1 hour and then kept in it for next 48 hours. The substrates were then washed with double distilled water.
The spray deposition method involves the decomposition of an aqueous solution of lead acetate and thiourea. The 0.15M solution was sprayed using compressed air as a carrier gas onto hot glass substrates kept at 573 ±5K temperature. Several trials were conducted to optimize the different deposition parameters such as substrate temperature, spray rate, concentrations of cationic and anionic sources etc. The optimized deposition temperature was found to be ≈ 573 K. The films deposited below this

temperature were discontinuous and less adhesive. The optimized spray rate was found to be 6 mL min^{-1}. The films deposited above this spray rate are discontinuous with cracks which may be due to incomplete thermal decomposition. However, films deposited at low spray rate are discontinuous due to insufficient quantity of sprayed solution.

The average thickness of the as deposited PbS thin film was measured by the gravimetric method. The structural studies were carried out using Philips PW 1710 diffractometer with Cu-Kα radiation of wavelength 1.5405 Å. The optical characteristics were studied using UV-VIS-NIR spectrophotometer (Hitachi-330), to find band gap energy of PbS thin films. The surface morphological studies were carried out using scanning electron microscope (JSM 6100)**.** The dc two-point probe method of dark electrical resistivity was used to study the variation of resistivity with temperature.

RESULTS AND DISCUSSION

Structural Analysis

X-ray diffraction patterns of the spray deposited PbS thin films at 573 K were recorded by varying diffraction angle (2θ) from 10 to 70 degree. Figure 1 shows the XRD pattern of PbS thin film. The pattern shows well defined (1 1 1), (0 0 2), (2 2 0) and (311) peaks due to cubic lattice.

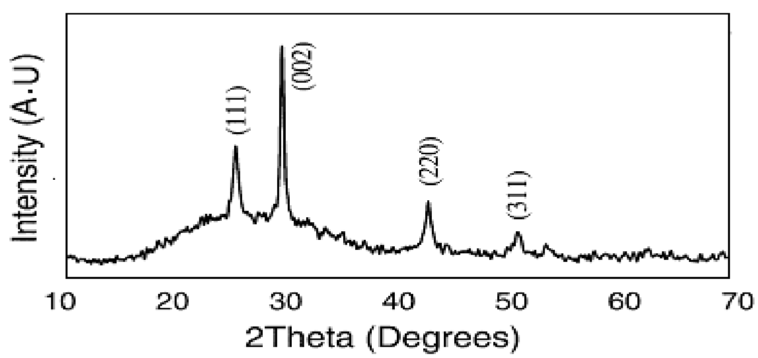

Figure 1: XRD Pattern of Spray Deposited PbS Thin Film

Morphology

The morphological analysis of the films was carried out using Scanning electron microscope. Figure 2 shows, SEM image of PbS thin film. A very adherent film with gray-black colour metallic aspect was obtained which reveal a continuous compact nanocrystalline nature. The film surface shows random distribution PbS material with porous morphology.

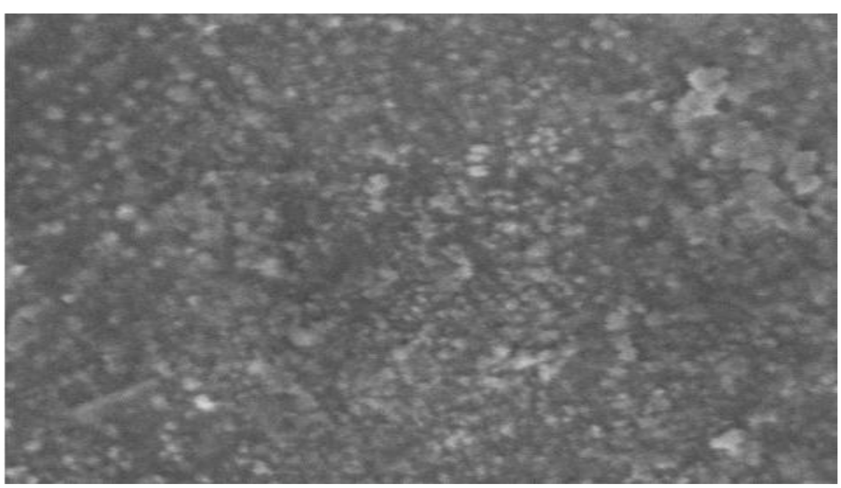

Figure 2: SEM Image of Spray Deposited PbS Thin Film

Optical Analysis

The energy gap "Eg" of the sample was determined from optical transmission. The photons with energies greater than the band gap energy are absorbed while photons with energies less than the band gap are transmitted. The optical absorption is characterized by the relation between the absorption coefficient (α) and the photon energy (hυ) for different allowed transitions as,

$$\alpha = \frac{A(h\upsilon - Eg)^n}{h\nu} \quad (1)$$

Where 'α' is absorption coefficient, A is constant, 'hυ' is photon energy and 'Eg' is the optical band gap energy.

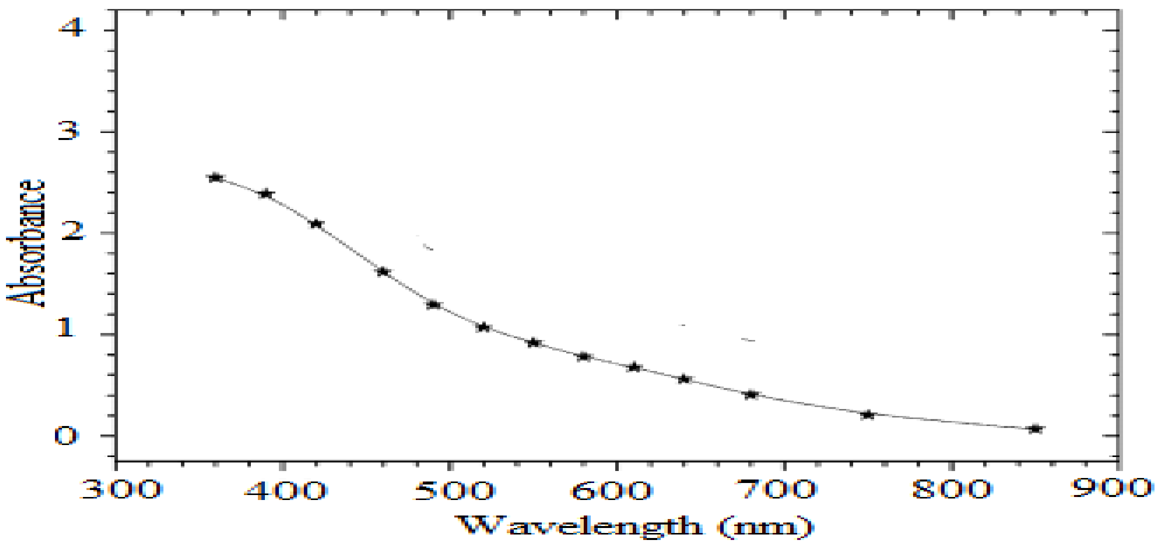

Figure 3: Variation of Optical Absorption vs. Wavelength for Spray Deposited PbS Thin Film

The plots of $(\alpha h\upsilon)^2$ versus hυ is shown in Figure 4. Since the variation of $(\alpha h\upsilon)^2$ with hυ for PbS thin film is a straight line it indicates that the involved transition is direct one. Band gap energy, Eg was determined by extrapolating the straight line portion to the energy axis for zero absorption coefficient (α). The value of Eg for as deposited film was found 1.2 eV.

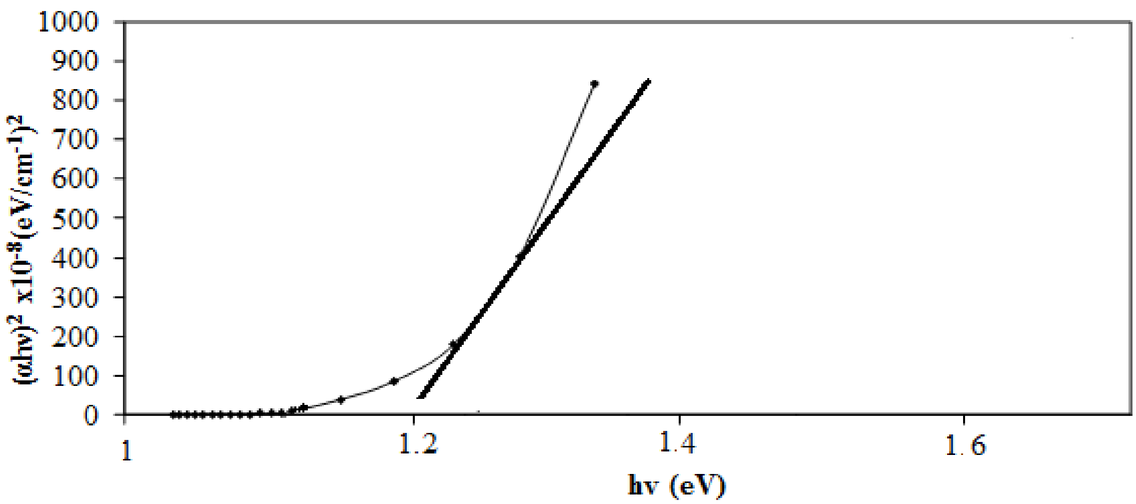

Figure 4: Plot of $(\alpha h\upsilon)^2$ Versus hυ for Spray Deposited PbS Thin Film

Conclusion

In the present paper, physical properties of nanostructured lead sulphide thin films deposited by chemical spray pyrolysis technique have been reported. Lead sulphide films are nanocrystalline in nature with cubic phase. The electrical characterization shows that lead sulphide films are semiconducting in nature with p-type conductivity. The optical studies confirmed that spray deposited PbS exhibits 1.2eV band gap energy.

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