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PREPARATION AND DETERMINATION OF OPTICAL CONSTANTS OF NANOCRYSTALLINE PbS THIN FILMS

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ABSTRACT
In this work, Nanocrystalline PbS thin films were deposited on glass substrate at constant room temperature, using the chemical bath deposition technique. The films were adherent to the substrate and well crystallized. The band gaps of the films were determined by transmission spectra and found 1.69 eV which is higher than that of bulk PbS. The other optical parameters, extinction factor, refractive index, real and imaginary dielectric constant and optical conductivity are calculated and discussed.

KEY WORD: Thin films, Chemical synthesis, Optical properties, Band Gap, Extinction Coefficient

INTRODUCTION

Nanocrystalline thin films are of significant interest for a large variety of electronic and optoelectronic devices [Popa A. et al 2006]. The growth techniques used to obtain nanocrystalline materials and the investigation of their properties are thus of considerable interest [Yang Y.J., and Hu S. 2008]. Lead sulphide (PbS) is a semiconducting chalcogenide with a direct band gap of 0.4 eV and has a cubic structure[Thangaraju B., and Kaliannan P. 2000]. These properties make PbS very suitable for infrared detection applications [Warner J.H. et al 2006]. PbS is such a material which has several applications in the fields of infrared photography, diode laser, humidity and temperature sensors, and solar control coatings [Hirata H., and Higashiyama K. 1971; Nair P.K. et al 1991]. For these reasons, many research groups have shown a great interest in the development and study of this material by various deposition processes. Among the several thin film deposition techniques [Yu Jun Yang 2006; Moreno-García et al 2011; Martucci A. et al 2004], chemical bath deposition (CBD) [Kumar Rajesh et al 2014] is the convenient and frequently used deposition technique to grow good quality thin films. In this work, nanocrystalline PbS thin film have been deposited using the CBD method and to investigate their optical properties.

EXPERIMENTAL DETAILS

Nanocrystalline PbS thin film was deposited on cleaned glass substrates by chemical bath deposition technique. The glass slide of dimensions 24mm x 75mm were previously degreased in nitric acid for 48 hours, and then cleaned in ultrasonic cleaner with tripled distilled water. The cleaned substrates were vertically dipped into a 50 ml beaker, containing an aqueous solution of lead nitrate, thiourea, sodium hydroxide and hydroxylamine hydrochloride [Das R., and Kumar, Rajesh 2012]. The films were deposited at constant room temperature for 90 min. The deposited films were smooth, homogeneous, well adherent to the substrate with darker surface like mirror. The thicknesses of the films were determined by gravimetric method. The optical constants of the deposited PbS thin films with the help of Chemito, double beam UV-VIS spectrophotometer (SPECTRASCAN-UV-2600).

RESULTS AND DISCUSSION

Optical studies

The optical absorbance and transmittance spectra of nanocrystalline PbS films deposited on amorphous glass substrates prepared at room temperature are displayed in Fig.1. Figure shows peak absorbance in the UV region between 300 and 650 nm and immediately after the peak value, absorbance decreased with increasing wavelength towards the NIR regions. All of the films exhibited high transmittance, throughout UV-VIS-NIR regions while exhibiting low reflectance within the same regions. The general behavior of these spectra is the increase of transmittance with wavelength while at low wavelength region the transmission was nearly zero.

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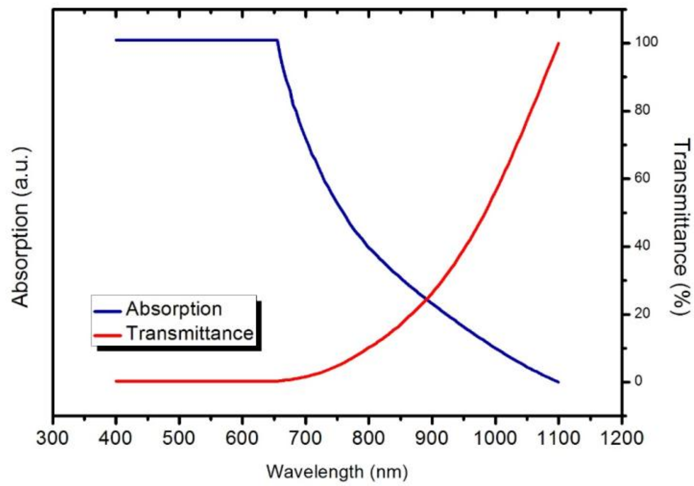

Fig.1 The absorption and transmission spectra for nanocrystalline PbS thin film.

The optical absorption coefficient α are of the order of 10^6 m^{-1} for near edge absorption given by $\alpha = -lnT/t$, where t is the thickness of the film. The values of α have been calculated, at different wavelengths, from these spectra. The optical data were analyzed from the following classical relation (Tauc relation) [Das R., and Kumar Rajesh, 2008]

$$(\alpha h\upsilon) = A(h\upsilon - Eg)^{n/2}$$

where, $h\upsilon$ is the photon energy, Eg is the band gap energy, A and n are constant. The variation of $(\alpha h\upsilon)^2$with $h\upsilon$ for different films is a straight line which confirms the direct transition. Fig. 2 shows plot of $(\alpha h\upsilon)^2$ against $h\upsilon$ of nanocrystalline PbS thin films. Band gap was determined by extrapolating the straight line portion to the energy axis. The band gap of nanocrystalline PbS thin film was found to 1.69 eV which is quite high as compared to the bulk PbS. This may be due to quantum confinement effect in nanocrystalline films.

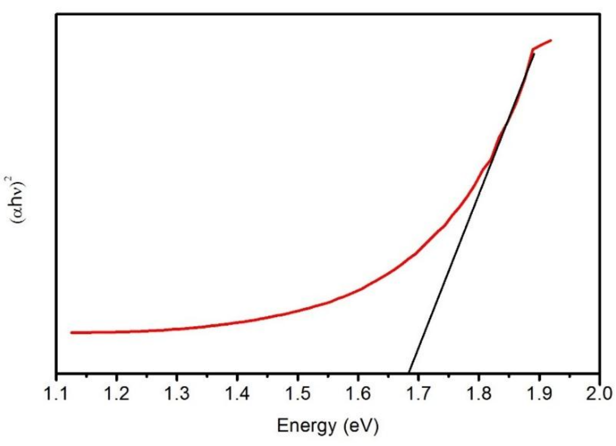

Fig.2 The variation of $(\alpha h\upsilon)^2$ with $h\upsilon$ for nanocrystalline PbS thin film.

The extinction coefficient, k is measure of the fraction of light lost due to scattering and absorption per unit distance of the penetration medium. The extinction factor (k) of the film was determined from the relation $k = \lambda\alpha/4\pi$ where, α = absorption coefficient and λ= wavelength of light [Ezema F.I. and Asogwa P.U. 2004]. The variation of k with $h\upsilon$ for PbS thin film is shown in Fig. 3. The value of k initially increases with wavelength and reaches to maximum at around 650 nm. This observation confirms the decrease in the loss of light due to scattering and absorbance with increase in wavelength**.**

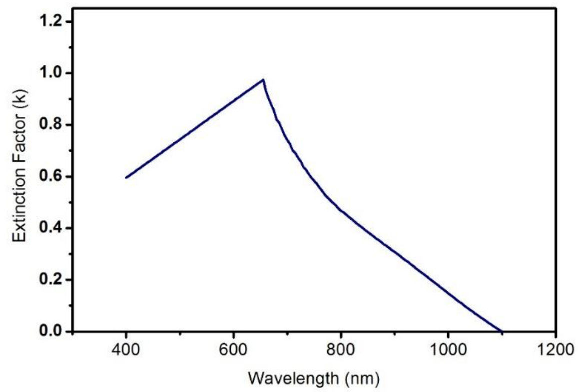

Fig.3 The variation of k with wavelength (λ) for nanocrystalline PbS thin film.

The real and imaginary parts of dielectric constant can be calculated with the help of n and k values. The real dielectric constant (ε_r) can be calculated as: [Ezema F.I. and Asogwa P.U. , 2004]

$$\varepsilon_r = n^2 - k^2$$

While the imaginary dielectric constant (ε_i) can be calculated as: [Ezema F.I. and Asogwa P.U. , 2004]

$$\varepsilon_i = 2nk$$

The variation of the real and imaginary dielectric constants with wavelength is shown in Fig. 4. It is clear from the figure that the real and imaginary parts of the dielectric constant show a similar behavior.

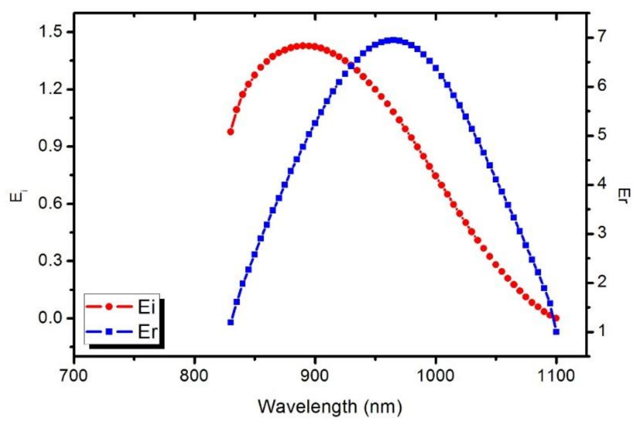

Fig.4 The variation of ε_i and ε_r with wavelength (λ) for nanocrystalline PbS thin film.

Optical Conductivity σ can be used as follows: [Pankove, J.I., 1971]

$$\sigma = \alpha nc/4\pi$$

where, α is the absorption coefficient, n is the refractive index and c is the speed of light. Fig. 5 shows the variation of σ as a function of wavelength. It is clear from the figure that the optical conductivity decreases with increase in wavelength, which is due to high absorbance of the film or due to the electrons excited by photon energy.

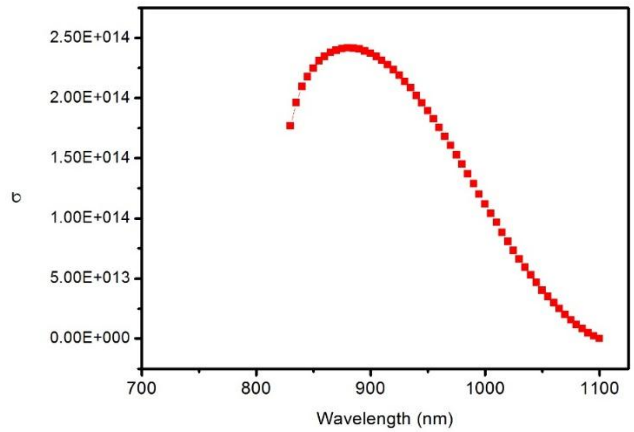

Fig.5 The variation of σ with wavelength (λ) for nanocrystalline PbS thin film.

CONCLUSIONS

The present investigation demonstrates the synthesis of nanocrystalline PbS thin films by chemical bath deposition technique. The band gap of nanocrystalline PbS films was determined 1.69 eV, which is higher than bulk PbS (0.4 eV). This showed the quantum confinement of the material. The optical constants were found to vary significantly with wavelength of the light.

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