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Enhancement of Optical Characteristics of ZnS:Pb Thin Films

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Abstract— High quality for optical characteristics of ZnS:Pb thin films at 10% weight of Pb atoms. ZnS:Pb thin films were deposited by thermal evaporation method at room temperature onto glass substrates at 200 nm thickness. ZnS powder and ZnS:Pb films have polycrystalline structure as indicated by X-ray diffraction pattern. From the results of optical characteristics, the transmittance for the doped thin films of ZnS by Pb atoms decreases in a certain wavelength range and hence this decreases the optical energy gap for films. The refractive index for doped films of ZnS by Pb atoms increases has large value than the pure ZnS films, and then is nearly constant with the variation of wavelength range.

Keywords: ZnS, Thermal Evaporation, Doping, Thin Films, Compounds, Transmittance, Pb compoiund

1 Introduction

Over the last few years, semiconductors has been widely studied due to their fundamental structural, electrical and optical properties Among them ZnS with a direct gap (3.6 eV) displays a high refractive index , and a high transmittance in the visible range making this a strong candidate for use in photo electronic devices. ZnS compound from group II-VI is white pellets, has two crystalline structure which are (α wurtizte) with hexagonal structure and (β Zinc blend) with cubic structure, didn't passes in the liquid state i.e. it has low sublimation temperature, dissolves slightly in mixture of HNO_3 and H_2SO_4 but didn't dissolves in water, and has low toxic. It was found that the small crystallite of wurtizte phase composes at 1273 K i.e. Zinc blend changed to wurtizte phase at or before sublimation temperature, which affirm that the last phase is the most stable structure at high temperature [1]. Borah et al [2] studied ZnS films and investigated the nanostructure. In the Present work. The effect of doped Pb atoms at 10% on the structure and optical parameters of ZnS compound are studied.

2 Experimental Work

The system of thermal evaporation method is pumped down to a vacuum of 10^{-5} mbar, an electric current was passed through the boat gradually to prevent breakin it when the boat temperature reaches the required temperature the deposition of each pure ZnS and ZnS:Pb at 10% weight of Pb atoms thin films process starts with constant deposition rate. After these steps the current supply was switched off and the samples were left in the high vacuum [3], then the air was admitted to the chamber, and the films were taken out from the coating unit and kept in the vacuum desiccators until the measurements were made. All the samples were prepared under constant conditions (pressure, temperature of deposition R.T) at thickness 200 nm. Molybdenum boat was used to evaporate thin films.

The structure of ZnS powder, Pure ZnS thin films and doped ZnS:Pb thin films were examined by X-ray diffractions using a Philips X-ray diffractometer system. This system recorded the intensity as a function of Bragg's angle. The measurement conditions were as follows:

Target: Cu Kσ, Wavelength λ = 1.5406 Å, Voltage = 40 kV, Current = 30 mA, Scanning angle: (20° - 60°), Scanning Speed = 5 (degree/min).

The morphological characteristics of pure ZnS & doped ZnS:Pb thin films photographs were recorded by using (CSPM AA3000 AFM) supplied by Angstrom Company .The atomic force microscopy (AFM) is a member of the family of scanning probe microscopes which has grown steadily since the invention of the scanning tunneling microscope by Binning and Quate. The AFM measures the forces acting between a fine tip and a sample. The tip is attached to the free end of a cantilever and is brought very close to the surface. Attractive or repulsive forces resulting from interactions between the tip and the surface will cause a positive or negative bending of the cantilever. The bending is detected by means of a laser beam, which is reflected from the back side of the cantilever [4].

The optical properties of pure ZnS & doped ZnS:Pb films which evaporated in Room temperatures were studied in the wavelength range (300–1100) nm by using UV/Vis Centre 5 Spectrometer which is previous to GBC scientific equipment PTY ltd. This spectrometer contains two light sources Deuterium and Tungsten lamp within the wavelengths range 300–1100 nm of the spectrum respectively. The output data of wavelength, transmittance and absorbance are used in a computer program to deduce the optical energy band gap and fundamental optical edge and all optical constants.

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3 Results and Discussions

3.1 The Atomic Force Microscopic (AFM)

Figs 1 and 2 show that the surface morphology for pure ZnS thin films and after doping of Pb atoms. Fig. 1 for pure ZnS films indicates that the number of grains is 190 and the average grain size is 321 nm. Fig. 2 for doped ZnS:Pb thin films indicates 64 grain number and 125 nm grain size. Larger grains are more specified after the doping.

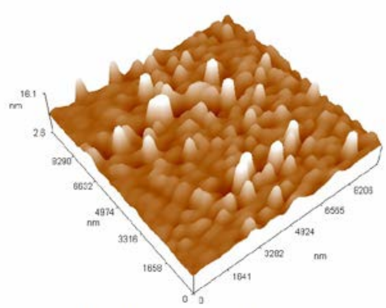

Fig. 1 AFM image for pure ZnS thin films

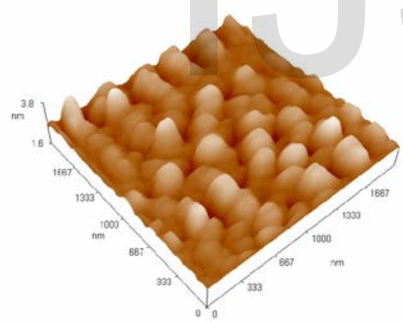

Fig. 2 AFM image for doped ZnS:Pb thin films

3.2 X-ray Diffraction Result of ZnS & ZnS: Pb Thin Films

Figure 3 shows X-ray diffraction pattern of ZnS powder which indicated that the ZnS compound has polycrystalline structure. From figure 4, it can be observed that the structure of ZnS powder was mixed of cubic with hexagonal system with peaks (111),(200),(220) and (311) for cubic system and (100),(101),(102),(103),(200),(112) and (201) for hexagonal structure. Fig. 4 represents the X-ray diffraction pattern for pure ZnS thin films which shows the preferred orientation (111) for pure ZnS structure as thin films at 2θ = 28.5°.

Fig. 5 shows the X-ray diffraction pattern for doped ZnS:Pb thin films and get from the figure that the structure of ZnS after doped by Pb atoms have the same preferred orientation with high intensity which means the improved structure for ZnS:Pb thin films which indicates the maker of (111) orientation between ZnS atoms and Pb atoms at 28.53°, this is a good agreement with Hoa et al [5], Ashraf et al [6] and Hwang et al [7].

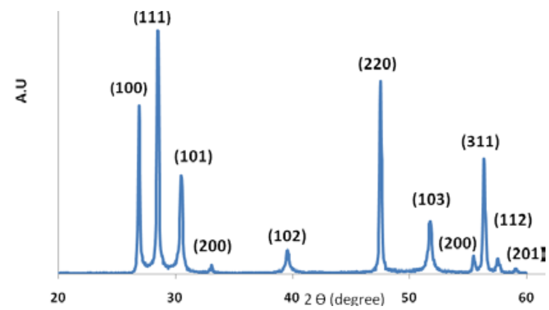

Fig. 3 X-Ray diffraction of ZnS powder

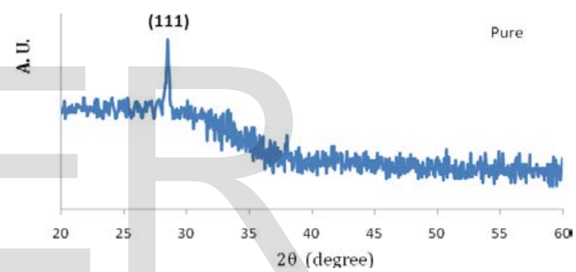

Fig. 4 X-Ray diffraction of ZnS thin film

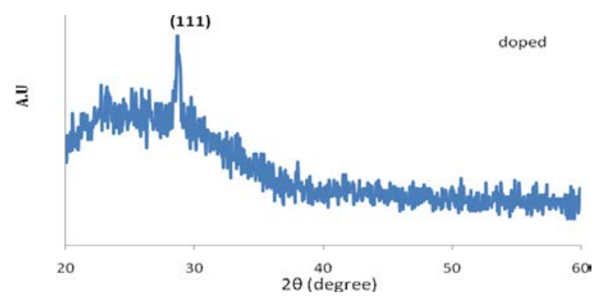

Fig. 5 X-Ray diffraction of doped ZnS;Pb thin films

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3.3 Optical Characteristics

3.3.1 The Transmittance Spectra

The Transmittance Spectra for pure ZnS and ZnS: Pb thin films is shown in Fig. 6, one can notice that the transmittance of ZnS:Pb thin film is decreasing between (340-680) nm but the transmittance for the pure ZnS thin film is higher than the transmittance for the ZnS:Pb thin film. The transmittance has constant value within wavelength range (680-1100) nm for both pure and doped ZnS:Pb films. This indicates the increasing of absorbance in wavelength region (340-680) nm which means the reduced value of energy gap for doped of ZnS by Pb atoms.

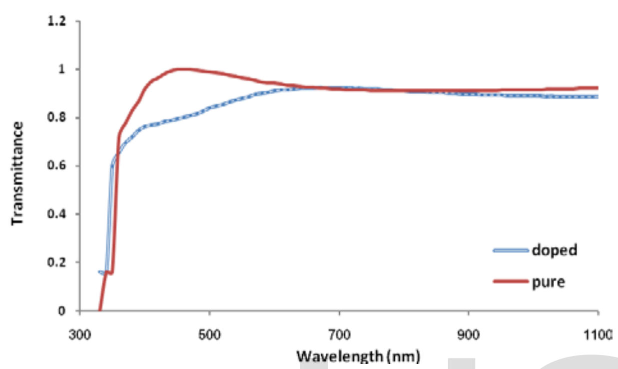

Fig. 6 The Optical transmittance of ZnS & ZnS:Pb thin films

3.3.2 The Optical Energy Gap

Figure 7 shows the optical energy gap of pure ZnS and doped ZnS:Pb thin films. The calculated energy gap for pure ZnS thin film is about 3.45 eV, but it reduces for doped ZnS:Pb thin films which is about 2.9 eV . This attributes to incorporate the Pb atoms within the structure of pure ZnS where the intensity of the preferred orientation is higher than the intensity of of pure structure as shown in Figs. 3 & 4 for X-ray diffraction pattern.

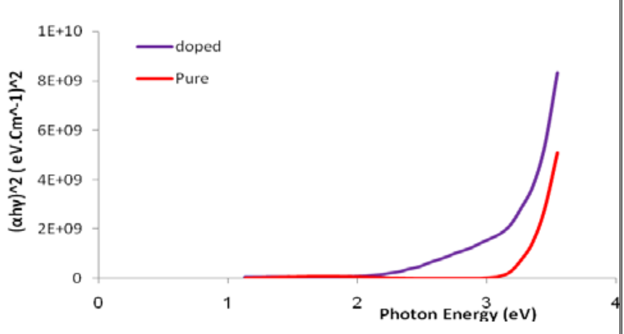

Fig. 7 The Optical Energy gap of pure ZnS & doped ZnS:Pb

3.3.3 The Real & Imaginary Part of Dielectric Constant

The real part ε_1 and imaginary part ε_2 of the dielectric constant were determined using equations [8]:

$$\varepsilon_1 = n^2 - k^2 \quad (1)$$

$$\varepsilon_2 = 2nk \quad (2)$$

where n , k are the refractive index and extinction coefficient. Figs. 8 & 9 illustrate the variation of the real and imaginary parts of the dielectric constant with the incident wavelength respectively. In Fig. 8 the real part of the dielectric constant for doped ZnS:Pb thin films have higher value than the pure ZnS thin films within the range (340-680) nm and both have the same behavior in the range (680-800) nm while the real part of the dielectric constant for the ZnS thin films decreases and dropped in (440) nm, later increases to the be constant value in (680- 800) nm. The imaginary part represents the absorption of radiation by free carriers. From figure 9 one can see that the imaginary part have minimum values because of the higher values of real dielectric constant.

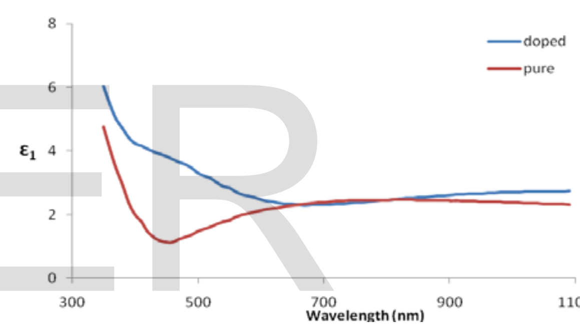

Fig. 8 Real dielectric constant (ε_1) for pure ZnS & doped ZnS:Pb thin films

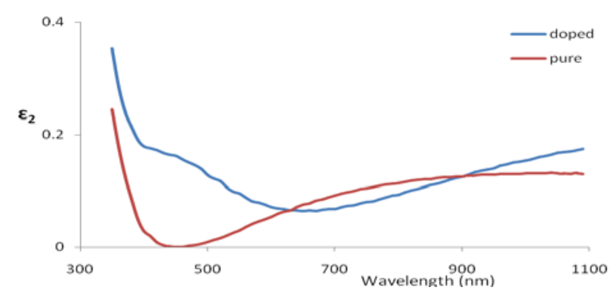

Fig.9 Imaginary dielectric constant (ε_2) for pure ZnS & doped ZnS:Pb thin films

3.3.4 The Refractive index

The Refractive index was determined from the reflectance data using equation [8]:

$$n = [4R / (R-1)^{1/2} - k2]^{1/2} - [(R+1)/(R-1)] \qquad (3)$$

R is the reflectance.

The variation of the refractive index versus wavelength in the range (300–1100) nm for pure ZnS & doped ZnS:Pb thin films at thickness (200) nm are shown in Fig. 10. One can notice from the figure that the effect of doped Pb in the structure of pure ZnS appears evidently within wavelength range (340-680) nm as shown in Fig. 11 for the refractive index which is greater for the doped ZnS:Pb thin films than the pure ZnS thin films within such range and this is due to the mentioned reason above.

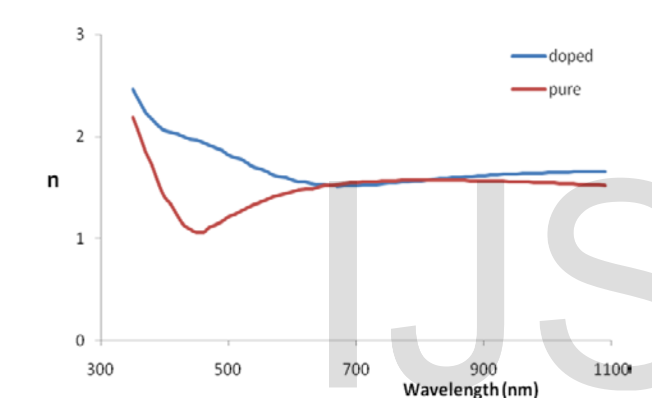

Fig. 10 the Refractive index for pure ZnS & doped ZnS:Pb thin films

3.3.5 Extinction Coefficient

The extinction coefficient was determined by using the equation [8]:

$$k = (\alpha\lambda / 4\pi) \qquad (4)$$

Where α, λ are the absorption coefficient and the wavelength of the light. Figure 11 shows the variation of extinction coefficient with the photon wavelength. The value of Extinction Coefficient (k) for the pure ZnS is lower than the doped ZnS:Pb thin films and one can notice that the value of k has dropped to zero for pure ZnS thin films from (440 to 465) nm .

4. Conclusion

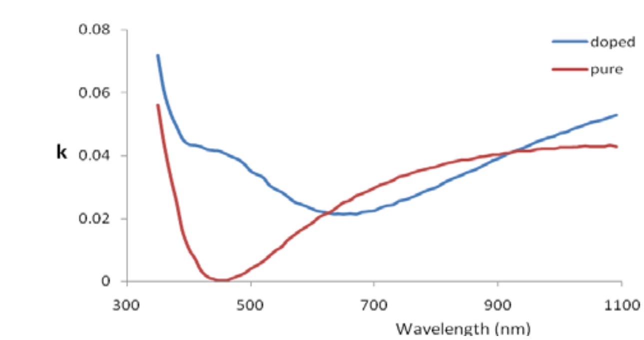

Fig. 11 The extinction coefficient for ZnS & ZnS:Pb thin films

The structure of the ZnS thin films enhanced after the doped by Pb atoms. The Transmittance decreases between the region (340-680) nm after the doping and The maximum value for ZnS: Pb thin film at the wavelength (490nm). The energy gap for the ZnS thin film was decreases to 2.9 eV after the doping. The real part of the dielectric constant for films increases after the doping within wavelength range (400-690) nm. The minimum value of imaginary part of dielectric constant shifts to 680 nm after doping by Pb atoms.

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