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OPTICAL, AND ELECTRICAL PROPERTIES OF ZnSe THIN FILMS

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Abstract

ZnSe thin films were prepared by vacuum deposition technique. The optical transmission has been measured in the wavelength range 400-1500 nm. Both the optical band gap and refractive index have been evaluated. The variation in refractive index with wavelength has been fitted to the single-oscillator model. The band gap width calculated from the absorption coefficient was found to be 2.65 eV. Electrical conductivity was measured as a function of temperature. A reduction in conduction activation energy with increase in film thickness is accounted for by the fact that ZnSe is inhomogenous semiconductor thin film.

Introduction

Zinc selenide is one of the II-VI compound having a zinc blende structure. The semiconductor and structure properties of this material depend not only on dopants or other impurities present, but also on the lattice defects [1-3], which were caused by crystal growth and/or preparing process.

Thin films of ZnSe are of great interest for their application in electro-luminescent devices [4,5] and photovoltaic application [6].

Previously, the author had studied [7] the crystal structure of ZnSe thin films by both X-ray diffraction and electron microscopy. The transmission electron microscopy (TEM) result were analysed using the technique of the computerized Image analysis system to obtain the statistical grain size distribution. These analysis showed that increasing the thickness leads to decrease in grain size and to an increase in the crystallinity of the film

The aim of the present work is to investigate the effect of the film thickness on the optical properties, and electrical conductivity of ZnSe thin films, which in tern can through more light about the best condition for preparing thin films for technical applications.

2. EXPERIMENTAL

Thin films of different thickness (t =110, 190, 320 and 360 nm) were prepared by thermal evaporation technique of specture material of ZnSe powder from a molybdenum boat on clean glass substrates under vacuum of 10^{-5} Torr at deposition rate of 45 nm/min using Lobold univex 300 coating unit. The film thickness was controlled with a quartz crystal monitor.

The electrical measurements were carried out by the conventional four probe method, using an electrometer type *(Keithely 600 B)* for measuring the current and the voltage across the potential leads.

Transmission measurements were performed with an accuracy of ±3% in the spectral range from 400–1500 nm using PMQ III Carl Zeiss spectrophotometer.

3. RESULTS & DISCUSSION

3.1 Optical Measurements

The transmission spectra of the films with different thickness (110, 190 and 320 nm) are shown in Fig. (1). The films of the different thickness show clear interference fringes with transparency above 80%. The number of the interference fringes were found to increase with the increase of the film thickness.

The absorption coefficient α shown in Fig.(2) has been evaluated using the Lambert's law :

$$\alpha = 1/t \ \ln \ 1/T \qquad (1)$$

where t is the thickness of the film and T is the transmittance.

The band gap value deduced from such a plot was found to be 2.65 eV, which is in fair agreement with the values reported before [9, 10].

The refractive index (for sample of thickness 110 nm) had been evaluated experimentally from the interference fringes using the following relation [11]

$$n = [N + (N^2 - n_2^2)^{1/2}]^{1/2}$$

where

$$N = 2n_2 \frac{T_M - T_m}{T_M \, T_m} + \frac{n_2^2 + 1}{2} \qquad \ldots\ldots \qquad (2)$$

T_M and T_m are the transmission maximum and corresponding minimum on the envelope at a certain wavelength and n_2 is the refractive index of the substrate. The calculated data as a function of wavelength are plotted as dotted points in Fig. (3).

Also, the variation of refractive index with wavelength for single oscillator model can be expressed as follows [8].

$$n^2 - 1 = \frac{S_o \, \lambda_o^2}{1 - (\lambda_o / \lambda)^2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (3)$$

where S_o and λ_o are the oscillator strength and position respectively. The parameters S_o and λ_o have been evaluated from the plot of $1/n^2-1$ vs λ^2 shown in Fig. (4). The slope of this plot gives S_o and the y-axis intercept determine the value of $1/S_o \lambda_o$. From this plot, it was found that the evaluated values of both S_o and λ_o are 9.1×10^{13} m^{-1} and 0.2 µm respectively.

Accordingly the calculated dispersion parameter E_o/S_o, where $E_o = hc/e \, \lambda_o$ (h,c,e are Plank's constant, the velocity of light and the electronic charge respectively) was found to be equal to 6.6×10^{-14} m^2.

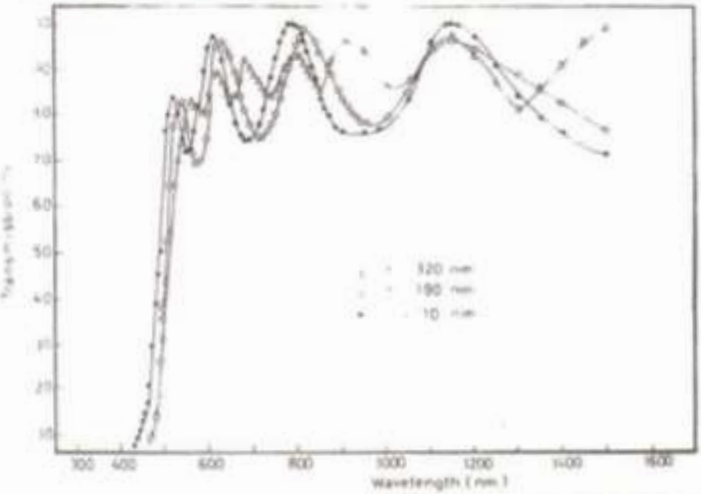

Fig. 1: Transmission spectra of thin films of thickness (110, 190 and 320 nm).

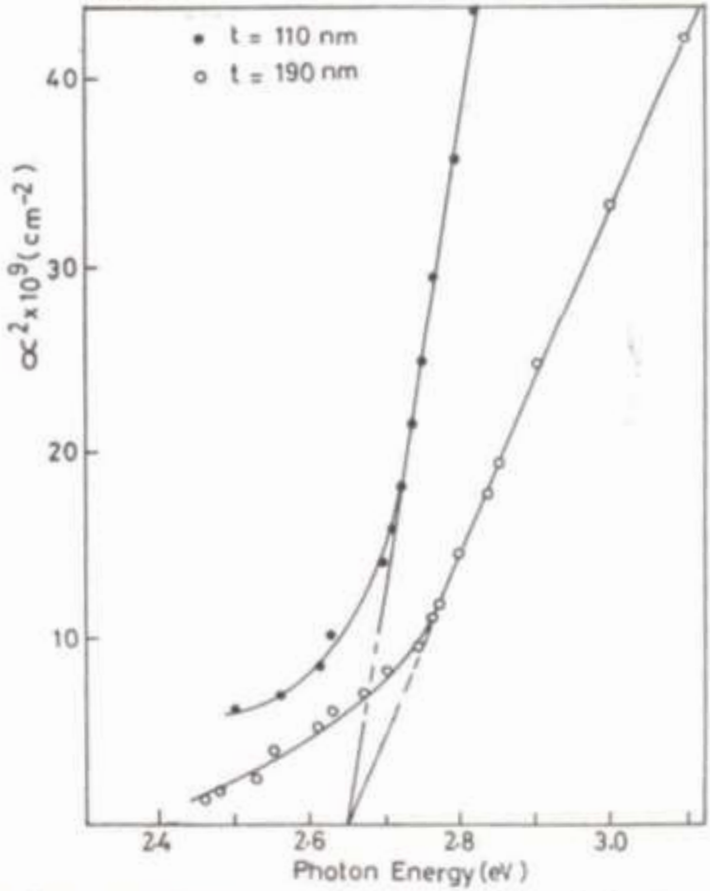

Fig. 2: Plots of the square of the absorption coefficient (λ^2) vs photon energy for thin films of thickness (110, 190 and 320 nm).

When the values of both S_o and λ_o are substituted in equation (3), a plot of the refractive index vs wavelength is obtained as represented by the solid line in Fig. (3) together with the experimental points.

The good agreement between the experimental points (dotted one) and the theoretically evaluated values (solid line) shows that the single-oscillator model can adequately describe the refractive index dispersion in ZnSe thin film.

3.2 Electrical Conductivity

The temperature response of resistivity for the same samples used for the optical measurement with the different thickness was recorded in the temperature range from (300-450 K) and shown in fig. (5).

It is clear from this figure that in the temperature range between (300-400) the resistivity decrease linearly with increasing the temperature while above 400 K more marked decrease started. Moreover, for any certain temperature the resistivity decreases with increasing film thickness.

The resistivity dependence on thickness can be explained if we put into consideration what was found before by the present authors [7], namely that the degree of crystallinity was enhanced by increasing the film thickness, while the grain size was decreased. Accordingly, it is interesting here to note that the higher the resistance of the sample, the larger its grain size and vice versa, the smaller the grain size of the sample the better its electrical conduction [12].

Since smaller grains were oftently more uniform [12], so it can be deduced that they are associated with lower inhomogenities of the impurity or defects distribution and consequently lower resistivity may be expected. On the other hand, large grain size are associated with lower homogeneity which may leads to higher resistivity.

This agrees with our result obtained for ZnSe. So the variation of resistivity with film thickness could be attributed to both the effect of the degree of crytallinity and the grain size variation.

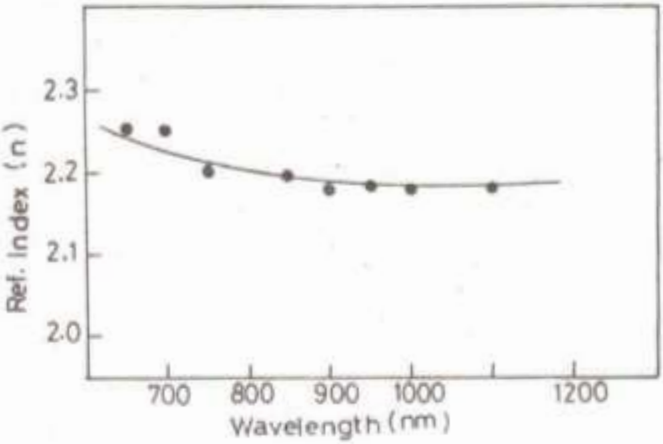

Fig. 3: Refractive index (n) variation with wavelength (film thicknss 110 nm).
o Experimental data ; - Theoretical plot.

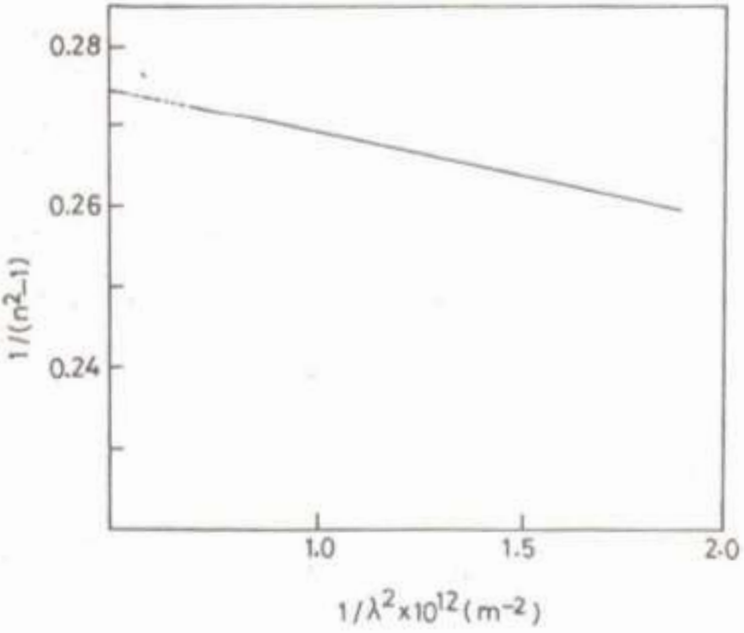

Fig. 4: The plot of $1/n\ (n^2-1)$ vs $1/\lambda^2$

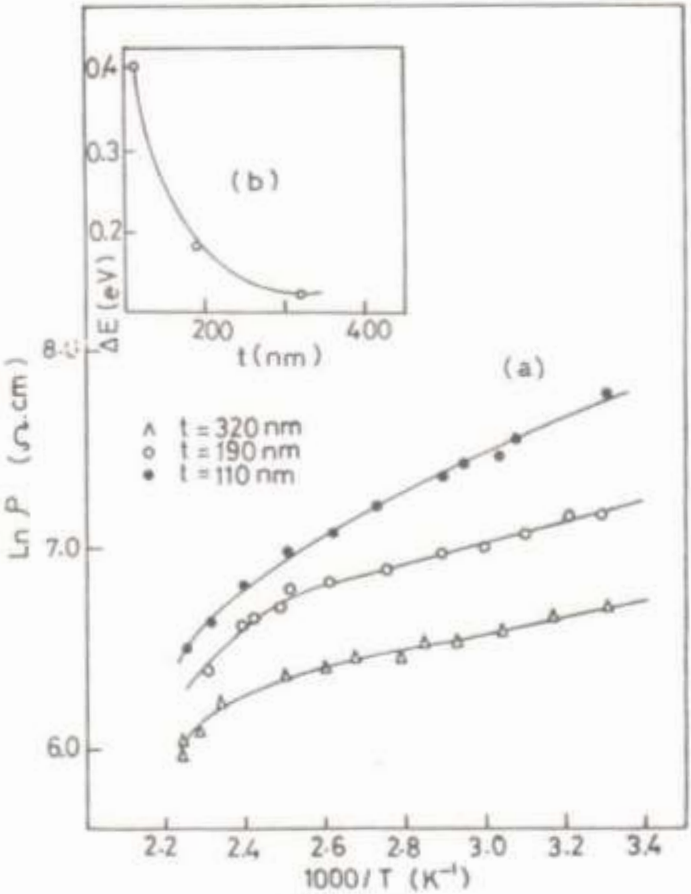

Fig. 5: (a) Resitivity (ρ) of thin films of different thickness as a function of temperature.

(b) Activatioin energy against film thickness.

The conduction activation energy was calculated from the slope of the linear part of ln ρ against 1/T plot. It has been established that as the film thickness increases the crystallinity improves very much, which results in the reduction of barrier width [13]. This will reduce the energy needed to activate the charge carriers to the mobility edge of ZnSe thin films.

So, as the film thickness increases, one should expect that the conduction activation energy will accordingly decrease. This agrees well with our results as shown in Fig. (5b).

Also, Fig. (5b) shows that for film thickness lower than 200 nm the activation energy strongly depends on the film thickness, while this dependence is very weak for films of thicknesses greater than 200 nm. This may indicate that the degree of crystallinity and consequently, the grain size reaches a saturated values at large thicknesses ($t \geq 320$ nm).

CONCLUSION

From the optical measurements, it can be concluded that ZnSe thin film has a direct gap of 2.65 eV.

The refractive index variation with wavelength has been fitted to the single oscillation model only for small thicknesses ($d = 110$ nm), while there is a deviation from that model for higher thicknesses.

The conduction activation energy was found to decrease with increase of film thickness as a result of the improving the crystallinity, which results in the reduction of the barrier height, and consequently more homogeneity with impurity distribution, reaching a saturated value for thicknesses higher than 320 nm.

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