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Effect of thickness on the optical and dispersion parameters of $Cd_{0.4}Se_{0.6}$ thin films

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$Cd_{0.4}Se_{0.6}$ thin films have been prepared by chemical bath deposition technique.AFM images confirm the appearance of nanostructure. The optical constants represented by absorbance, reflectance, extinction coefficient , refractive index, real and imaginary parts of dielectric constant were studied as a function of thickness variation .It was found that all these constants were affected by thickness. Dispersion relation was applied in order to show the effect of thickness on these parameters which were discussed in details through this work.

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Keywords: Nanostructure, Cadmium compound, Inorganic compound, Semiconducting II-VI material

1. Introduction

A huge interested was employed for the physical characterizations of CdSe semiconductor due its wide applications [1-7]. $Cd_{0.4}Se_{0.6}$ thin films can be either n-type as well as p-type semiconductor depends on the kind of dopant used during the deposition process. The reported room temperature direct band gap of $Cd_{0.4}Se_{0.6}$was 1.74 eV [8]. It is suitable for many optoelectronic applications, laser diodes and solar cells with excellent efficiency. Many methods were adopted for the preparation of CdSe thin films like, Thermal evaporation [9], Spray Pyrolysis [10], mechanical alloying [11], chemical bath deposition [12], hot - injection method [13] and the solvothermal technique [14]. In a previous study of our group, Hazim *et al.* [15] had shown that the deposited films of the same thickness were contained nanostructure according to the data of XRD and AFM.

In the present work, the preparation $Cd_{0.4}Se_{0.6}$ thin film by chemical bath deposition method was performed in order to study some optical and dispersion parameters for different thicknesses of this compound.

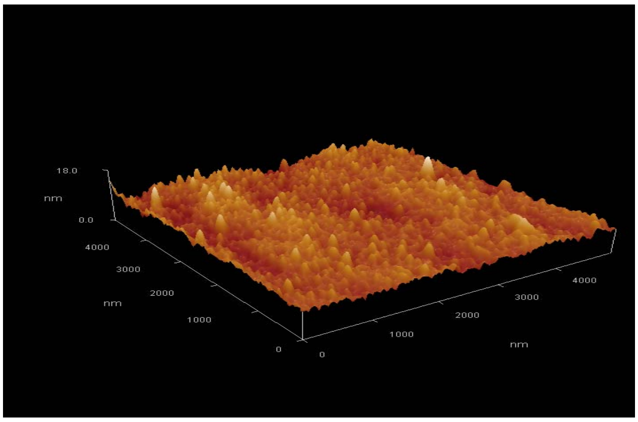
2. Experimental procedure

Different thicknesses of $Cd_{0.4}Se_{0.6}$ thin films were prepared utilizing chemical bath deposition technique. Cadmium chloride and sodium selenosulphate were used as a source of Cd^{2+} and Se^{2-} respectively. Malonic acid was used as a complex agent to obtain cadmium malonate in order to be used for slowing down the reaction and to get a uniform CdSe thin film. The PH value was fixed during the operation via the use of ammonia and sodium hydroxide, its value was 7.5.The substrates were subjected to a cleaning process, including boiling in chromic acid for 2 hours, washed by flowing water, rinsed in absolute ethanol, and finally cleaned in an ultrasonic bath filled with re-distilled water.

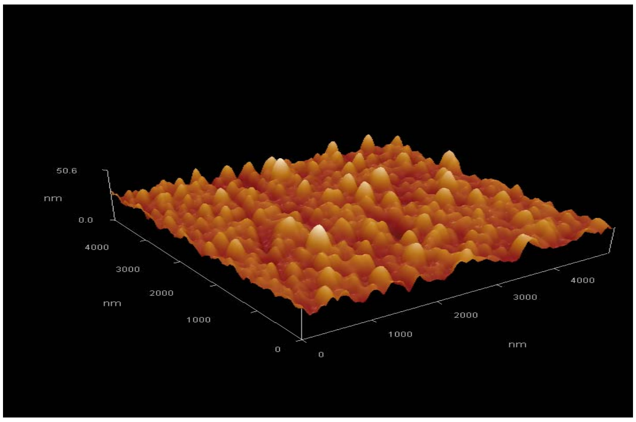
The substrates were put vertically in the reaction bath and were kept for (21,24,26,28and 30) hours at room temperature in order to obtain the desired thickness. For every period of time ,the substrate was removed from the bath, washed with re-distilled water several times and dried at ambient temperature ,and was kept in dark glass desiccators . The color of the obtained films was orange red. Gravimetric method was used to estimate the film thickness and their values were (300,350,400 and 450) nm. Transmittance and absorbance spectra were recorded using double beam (Shimadzu UV -Probe Japan) in the wavelength range from 350 to700 nm.

3. Result and discussions

In order to study the surface topography, AFM images with (4µm x 4µm) was used. Fig. 1 shows the AFM micrograph for 300 nm and 450 nm thickness. It can be seen from the graphs sharp peaks appeared in the domain and display densely packed columnor crystalline. No trace of pores and large interface defects was observed. The surface roughness increases from 0.93 nm to 3.16nm by increasing the thickness from 300 nm to 450 nm. The average diameter of the deposited films were 24 nm and 78 nm for 300 nm and 450 nm respectively, which falls in the category of nanostructure by using the UV-Visible spectrophotometer, the absorbance spectra in the range of 350-700 nm of $Cd_{0.4}Se_{0.6}$ thin films for various thicknesses had been recorded as shown in Fig. 2.



300 nm



450 nm

Fig. 1. AFM images for $Cd_{0.4}Se_{0.6}$ thin films for 300 and 450 nm thickness

From this figure, it can notice that the absorbance decreases with the increasing wavelength and increases with the increasing of thickness for all prepared thin films. Fig.3 shows the relationship between the reflectance and wavelength for various thicknesses of $Cd_{0.4}Se_{0.6}$ thin films. From this figure, it can be noticed that there was a decrease in reflectance with the increasing of film thickness until 570 nm . However, beyond this wavelength the situation was reversed .

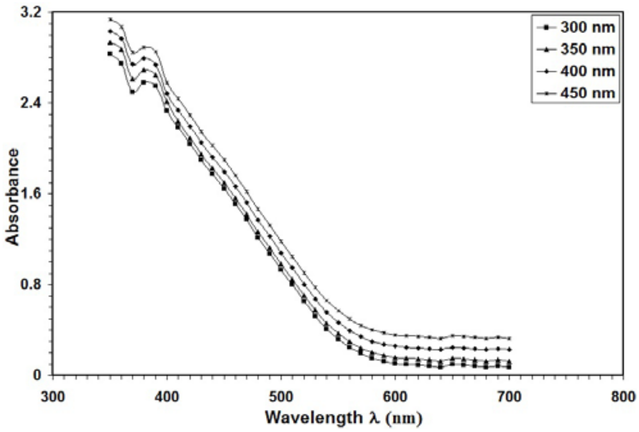


Fig. 2. Variation of absorbance with wavelength for $Cd_{0.4}Se_{0.6}$ thin films.

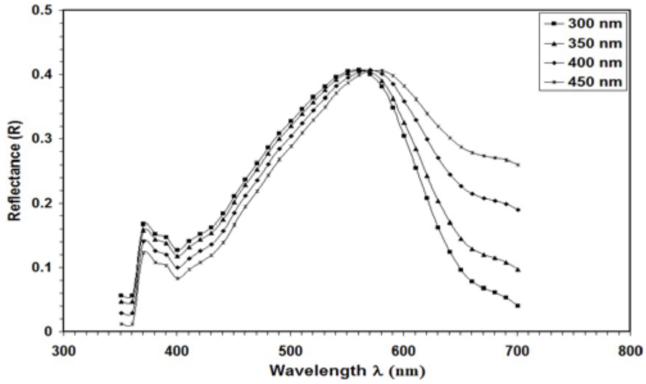


Fig. 3. Variation of reflectance with wavelength for $Cd_{0.4}Se_{0.6}$ thin films.

The refractive index (n) is related to the electronic polarization of ions. Fig.4 represent the relationship between the refractive index and wavelength. From this figure, it can be noticed that, there was a decrease in refractive index with increasing $Cd_{0.4}Se_{0.6}$ thin film thicknesses until 570 nm, and then the refractive index increases with increasing film thickness.

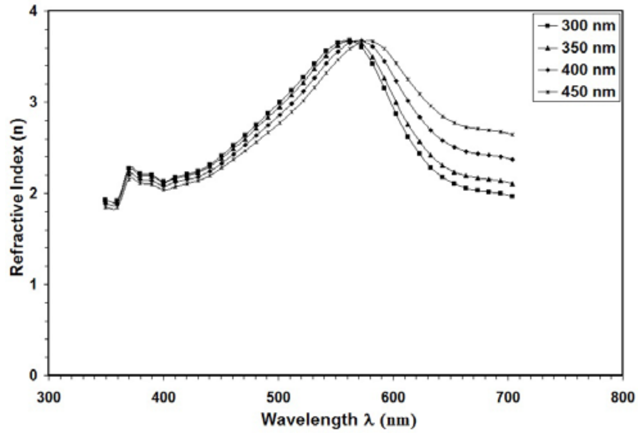


Fig. 4. Variation of refractive index with wavelength for $Cd_{0.4}Se_{0.6}$ thin films.

From Fig. 5, it can be noticed that the behavior of extinction coefficient (k) of $Cd_{0.4}Se_{0.6}$ thin film with wavelength was the same as the behavior of refractive index and reflectance .

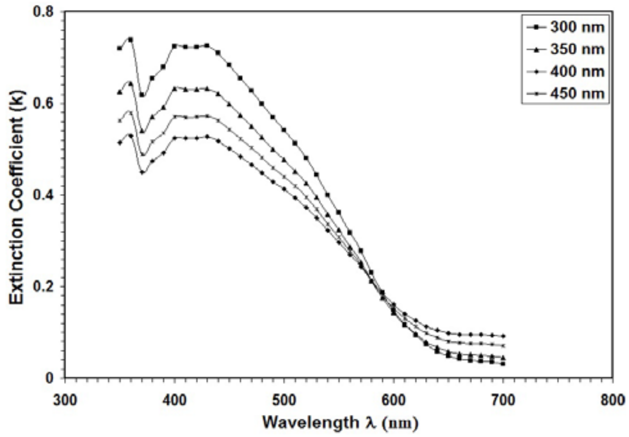


Fig. 5. Variation of extinction coefficient with wavelength for $Cd_{0.4}Se_{0.6}$ thin films.

Real (ε_r) and imaginary (ε_i) dielectric constants are represented in Figs. 6-7 which were depended on the wavelength. From these figures, it can be noticed that there was a shift in the peak maxima toward higher wavelength for the real part while the shift in the peak maxima for imaginary part was toward lower wavelength.

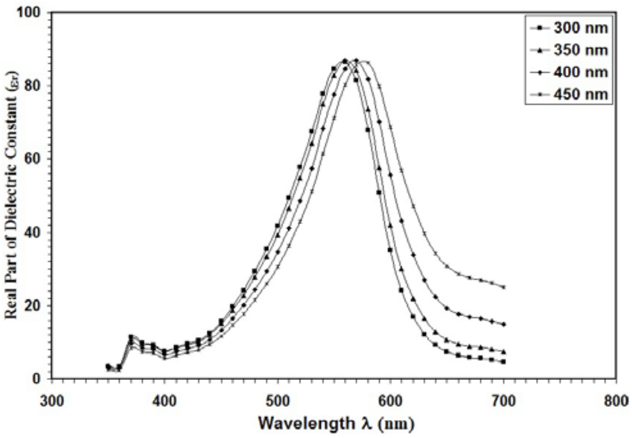


Fig. 6. Variation of Real part of dielectric constant with wavelength for $Cd_{0.4}Se_{0.6}$ thin films.

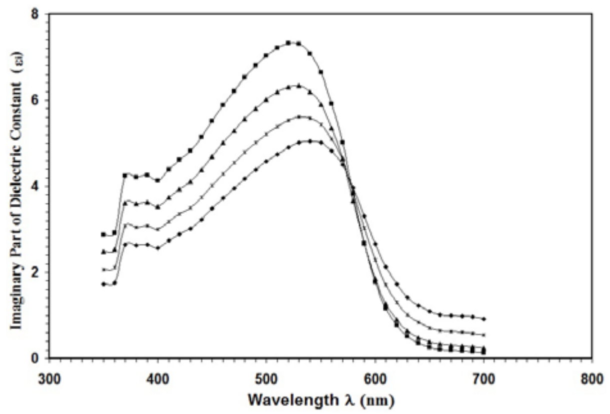


Fig. 7. Variation of Imaginary part of dielectric constant with wavelength for $Cd_{0.4}Se_{0.6}$ thin films.

Urbach energy was estimated from the known formula utilizing Fig. 8 and their values are presented in Table (1) ,which shows an inverse relation between their values and the optical energy gap , which confirms that there was an enhancement in the order of crystallanity during the increase of thickness.

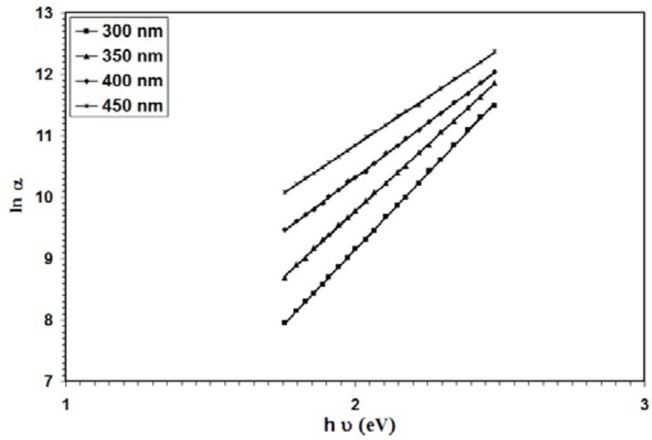


Fig. 8. Variation of (lnα) with (hυ) for $Cd_{0.4}Se_{0.6}$ thin films.

Wemple and DiDomenico [15-16] used a single oscillator description of the frequency-dependent dielectric constant to define dispersion energy parameters E_d and E_o. The model describes the dielectric response for transitions below the optical gap. The single oscillator model can be interpreted using the following relation [16]:

$$n^2 - 1 = \frac{E_o E_d}{E_o^2 - E^2} \tag{1}$$

where n is the refractive index, E_o is the single-oscillator energy for electronic transitions and E_d is the dispersion energy which is a measure of the strength of inter band optical transitions. From the plotting of $(n^2-1)^{-1}$vs. $(h\upsilon)^2$, the oscillator parameters E_o and E_d values can be determined from the slope and intercept on the vertical axis of $(n^2-1)^{-1}$vs. $(h\upsilon)^2$ plot, as shown in Fig. 9. These values are listed in Table (1). It can be noticed that E_o and E_d were decreased with increasing thickness, and also E_g that represent $E_o/2$.

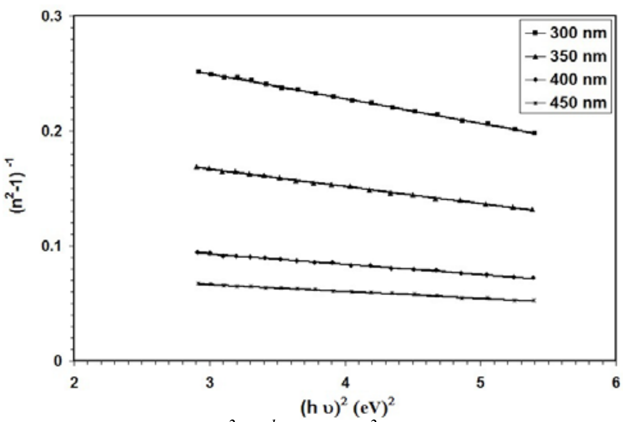


Fig. 9. Variation of $(n^2-1)^{-1}$ with $(h\upsilon)^2$ for $Cd_{0.4}Se_{0.6}$ thin films.

The refractive index has been studied in order to maintain static refractive index at infinite wavelength (n_o) can be calculated by the relation:

$$n_o = \sqrt{1 + \frac{E_d}{E_o}} \qquad (2)$$

and the static dielectric constant represented by ($\varepsilon_\infty = n_0^2$) [15-16]. The calculated values were shown in Table 1 .By using the single oscillator at wavelength (λ_o) at high frequency. The average oscillator wavelength (λ_o) and the average oscillator strength S_o a can be calculated by applying the following simple dispersion relation [17]:

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

where λ is the wavelength of the incident light. From Fig (10) S_o and λ_o values were obtained from the slope of $1/S_o$ and intercept of $(S_o \lambda_o^2)^{-1}$ of the plotted curves. The values of S_o and λ_o were listed in Table (1).

The interband transitions can be obtained with he help of M_{-1} and M_{-3} moments, which can be expressed as follows:

$$E_o^2 = \frac{M_{-1}}{M_{-3}} \qquad E_d^2 = \frac{M_{-1}^3}{M_{-3}} \qquad (4)$$

Their values were listed in Table 1.

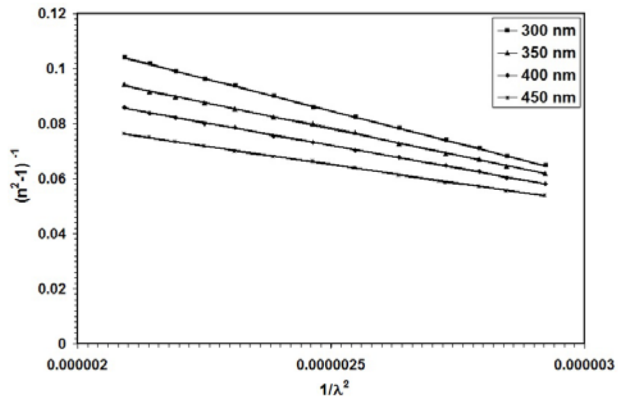


Fig. 10. Variation of $(n^2-1)^{-1}$ with $1/\lambda^2$ for $Cd_{0.4}Se_{0.6}$ thin films.

Table (1) the optical parameters of $Cd_{0.4}Se_{0.6}$ thin film.

Sample	E_d (eV)	E_o (eV)	E_g (eV)	ε_∞	n(o)	M_{-1}	M_{-3} eV^{-2}	S_o x10^{13} m^{-2}	λ_o nm
300 nm	13.1	3.54	1.77	4.70	2.17	3.70	0.296	1.26	848
350 nm	19.3	3.48	1.74	6.56	2.56	5.56	0.460	1.55	803
400 nm	34.5	3.45	1.72	11.00	3.32	9.00	0.840	1.82	779
450 nm	48.8	3.41	1.71	15.29	3.91	14.28	1.220	2.17	758

4. Conclusion

In this work, the preparation of $Cd_{0.4}Se_{0.6}$ thin films with various thicknesses by chemical bath deposition was done , and the effects of thickness on optical and dispersion parameters were analyzed. From this study, we have shown that the increase of absorbance with increasing thickness while the reflectance and refractive index were decreasing with increasing thickness for wavelength (λ≤ 570 nm). Dispersion parameters such as E_d, E_o and λ_o are decreased with increasing thickness and also the energy gap, while ε_∞, n(0), and S_o are increased with increasing thickness.

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