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OPTICAL AND ELECTRICAL PROPERTIES OF $Cd_xZn_{8-x}Te_{92}$CHALCOGENIDE THIN FILMS DEPOSITED BY THERMAL EVAPORATION AT LOW TEMPERATURE

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$Cd_xZn_{8-x}Te_{92}$chalcogenideglass is prepared by melt quenching technique. The thin films of as-prepared glass are deposited by thermal evaporation technique under the vacuum better than 10^{-5}torr. The optical parameters such as refractive index (n), extinction coefficient (k), the absorption coefficient (α), and optical band gap (E_g) are calculated from transmittance spectra in the 200-1800nm region. The evaluation of complex dielectric constant (ε^*) and influence of photon energy & composition on these parameters are also studied. The dc electrical conductivity is measured as a function of temperature in the range of 293-353K. It is observed that the electrical conductivity is increased with temperature & Cd concentration in the alloy composition.

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Keywords: Chalcogenide glasses, Optical band gap, Dielectric constant, Electrical conductivity.

1. Introduction

Chalcogenide alloysare applicable materials in modern optoelectronics& conventional storage devices applications [1, 2]. These alloysin binary or multi-component systems based on sulfide, selenide and telluride alloys are very promising materials for various optical and photonic applications in the spectral range 0.6 to 15 mm. Theyalso found important optical applications in the infrared region due to their high optical transparency in IR region [3]. In Particular, the physical properties of metal containing chalcogenide glasses are getting much attention owing to their interesting features and wide range structural modification. These alloys can be obtained by mixing the chalcogen elements, viz, S, Se and Te with elements of the periodic table such as Ga, Ge, Sn, As, Bi, Ag, Cu, Cd and Zn etc. The metal doped chalcogenide semiconductor thin films posses photo electronic properties, highly dependent on its structure and deposition parameters. These parameters are characterized by the properties of the material such as lattice constant, average stress & strain etc. When the measurements for the bulk & thin films materials are shown on a single plot, shows a difference greatly in average composition [4]. The optical properties of chalcogenide thin films such as optical band gap, absorption coefficient, refractive index, extinction coefficient, and dielectric constant provides knowledge about the suitability of the material for designing and fabrication of optoelectronic devices [5].Cd and Zn based chalcogenides (S, Se, Te) are technologically important materials due to their direct & rather large band gap [6]. The decrease in grain size of CdZnSe films with the increase of Zn concentration was discussed by A. Mahmood*et al*.[7] which further affect the optical properties of the thin films [8]. M.M. Hafiz et. al. reported the optical parameter of $Cd_{20}Se_{80-x}M_x$[M=Zn, In, Sn] chalcogenide thin film deposited by thermal evaporation [9]. CdZnTe or CZT based surgery probes are very useful in surgical oncology for patient management and excellent large field of view modules [10]. CZT alloys also possesses many of the physical properties required for detector operation, such as large enough band gap for high bulk resistivity, a large cross-section for the photoelectric absorption of gamma-rays, and reduced electronic noise. Many researchers [11-13] have studied the optical, electrical and structural, properties of CZT thin films prepared by different methods

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such as Chemical Vapor Deposition (CVD) [14], Molecular Beam Epitaxy (MBE) [15]etc. but no literature is found about the CZT thin films by thermally evaporatedCdZnTe alloys prepared by melt quench. The different conduction processes in II-VI semiconductors can be analyzed by the study of I–Vcharacteristic of a material. In 1982, Gogoi&Barua and later on in 1992 Gould and Ismail studied the I–Vcurves in the II–VI semiconductor films with a variety of methods.

We have made an attempt to prepare the $Cd_xZn_{8-x}Te_{92}$ (where x= 2, 4, 6 and 8) alloy by melt quench process and then deposit the thin film by thermal evaporation technique at low temperature. The present paper is concerned with the preparation of the above system by melt quenching process & systematic studies of the optical properties of as-deposited $Cd_xZn_{8-x}Te_{92}$ films is carried. An effort has also been made to study the temperature dependence of the conductivity of $Cd_xZn_{8-x}Te_{92}$thin films.

2. Experimental details

Different compositions of bulk $Cd_xZn_{8-x}Te_{92}$ (where x= 2, 4, 6 and 8) chalcogenide glasses were prepared by melt quenching technique. Highly pure (99.999 %) Cd, Zn, &Te elements (Alfa AesarU.S.A.), were weighted according to their atomic percentages using an electronic balance (Citizen CX -265) with the least count of 10^{-5} gm. The material was then sealed in evacuated (10^{-5} Torr) silica tubes [16].The sealed silica tubes containing materials were kept inside a muffle furnace whose temperature was raised step by step at a rate of 4K/minute, then finally maintained at 1150^0C for 24 hours. To ensure the homogenization of the melt,the silica tubes were constantly rocked.After rocking for about 24 hours, the obtained melt was rapidly quenched in liquid nitrogen to avoid crystallization [17]. The chalcogenide thin films used in the present study of the system were deposited by thermal evaporation technique on to glass substrates at base pressure of $\approx 2\times10^{-6}$ mbar using a high vacuum coating unit (HIND HIGH VAC. 12A4D). The substrate is cooled with liquid nitrogen; the evaporated material is deposited on this cooled substrate. This implies that the material is further quenched at low temperature [18]. Before the deposition process to carry, the substrates were carefully cleaned. Commercially available glass slides (Blue Star, Mumbai India) are dipped in chromic acid for three hours, then washed with liquid detergent and finally ultrasonically cleaned with acetone [19].To attain thermodynamic equilibrium the films were kept inside the deposition chamber for 24 h as suggested by Abkowitz [20].

The optical transmission spectra were recorded at room temperature for all the samples using a double beam (Shimadzu UV 3600) computer controlled spectrophotometer, at normal incidence of light and in the wavelength range 200-1800 nm. All measurements were obtained at room temperature (300 K). The measured transmittance spectra were used to calculate the optical constants and optical band gap (E_g) of the different compositions of $Cd_xZn_{8-x}Te_{92}$thin films.

For the electrical measurements, pre-deposited thick indium electrodes on glass substrates are used. A planar geometry of the film (length=1cm; electrode gap=1mm) is used for the electrical contacts. The thickness of the film is 1500 nm. The d.c. conductivity measurement was done using KeithleySemiconductor Characterization System (Keithley-4200). For temp measurements, a copper-constantan thermocouple was used. A vacuum of about 10^{-3} mbar was maintained throughout these measurements.

3. Results and Discussion

For all the prepared thin film samples, optical transmission was measuredin the wavelength range 200–1800 nm. The optical constants are obtained by using only the transmission spectrum. The optical parameters are calculated by using Swanepoel's method [21,22], which is based on the approach ofManifacier et. al.[23].

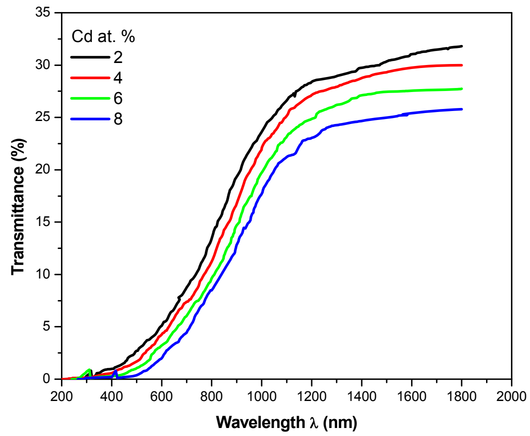

Fig.1. Transmission spectra of $Cd_xZn_{8-x}Te_{92}$ thin films.

3.1. Determination of Optical Constants

For the method proposed by Swanepoel[21, 22], the optical constants are deduced from the fringe patterns in the transmittance spectrum. The refractive index in the transmittance region where $\alpha \approx 0$ was calculated by using the formula.

$$n = \sqrt{N + \sqrt{N^2 - s^2}} \tag{1}$$

where

$$N = \frac{2s}{T_{min}} - \frac{(s^2 + 1)}{2} \tag{2}$$

where T_{max} is the upper extreme transmission point and T_{min} lower extreme transmission point for particular wavelength and ‘s’ is the refractive index of the glass substrate (s =1.52). In the weak region where the absorption coefficient ($\alpha \neq 0$) the value of N is given by

$$N = 2s\frac{T_{max} - T_{min}}{T_{max}T_{min}} + \frac{s^2 + 1}{2} \tag{3}$$

If n_1 and n_2 are the refractive indices of two adjacent maxima or minima at wavelengths λ_1 and λ_2, then the thickness of the film is given by

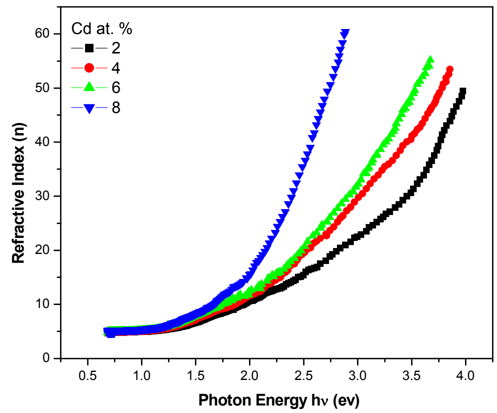

Fig.2.Variation of Refractive Index(n) vs Photon Energy (hv).

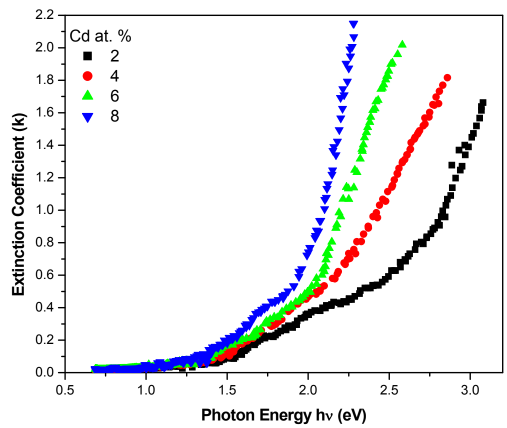

Fig.3.Variation of Extinction Coefficient (k) vs Photon Energy (hv.)

$$d = \frac{\lambda_1 \lambda_2}{2(\lambda_1 n_2 - \lambda_2 n_1)} \tag{4}$$

The extinction coefficient kcan be calculated from the following relation

$$k = \frac{\lambda}{4\pi d} \ln\left(\frac{1}{x}\right) \tag{5}$$

Where χ is the absorbance, given by

$$x = \frac{E_M - \sqrt{E_M^2 - (n^2-1)^3(n^2-s^4)}}{(n-1)^3(n-s^2)} \tag{6}$$

and

$$E_M = \frac{8n^2 s}{T_{max}} + (n^2 - 1)(n^2 - s^2) \tag{7}$$

3.2. Determination of dielectric constants

The real and imaginary dielectric constant of amorphous thin films has been calculated by the relation (8) and (9), respectively.

$$\varepsilon' = n^2 - k^2 \quad (8)$$

$$\varepsilon'' = 2nk \quad (9)$$

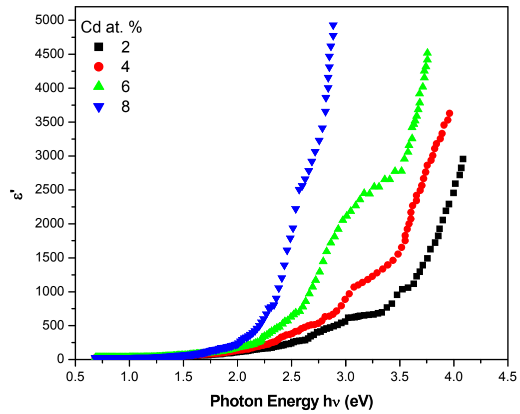

Fig.4.Variation ofReal dielectric constant(ε') with Photon Energy (hν).

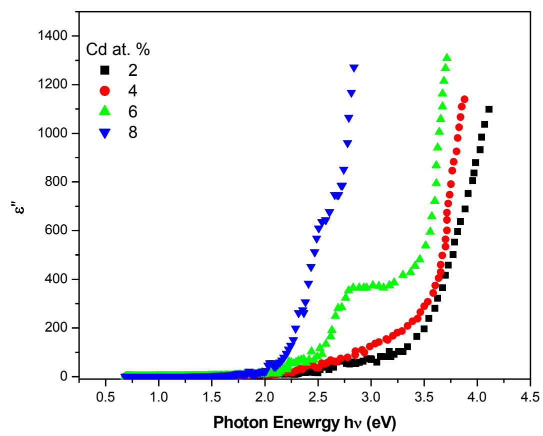

Fig.5.Variation of Imaginary dielectric constant (ε") with Photon Energy (hν).

And dissipation factor, tan δ, is expressed as

$$\tan\delta = \frac{\varepsilon''}{\varepsilon'} \quad (10)$$

The variation of ε', ε" and tan δ with photon energy are shown in figure 4, 5, and 6respectively. These are found to be increase with increase in photon energy.

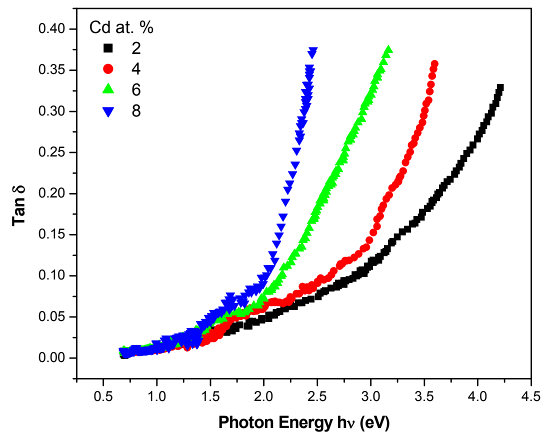

Fig.6. Variation of dissipation factor tan δ with Photon energy (hν).

3.3 Determination of optical Band gap

The analysis of absorption coefficient of the thin films was found suitable with the Tauc's [24] relation given as

$$\alpha h\nu = B\,(h\nu - E_g^{opt})^m \quad (11)$$

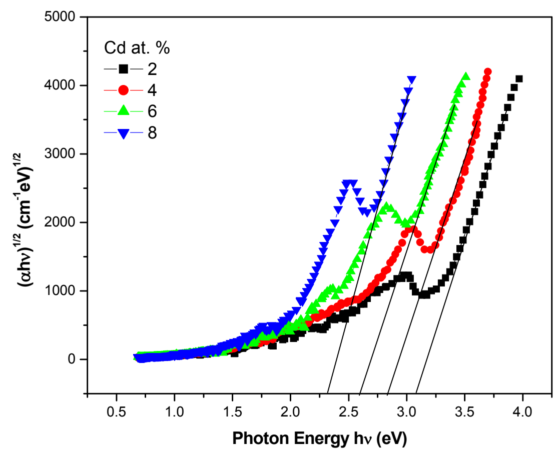

Fig.7.Variation of Band gap E_g^{opt} with Photon Energy(hν).

Where α is the absorption coefficient; B is the band tailing parameter that depends on the transition probability; hν is the photon energy;E_g^{opt} optical energy gap; m-index, depending on the nature of electronic transitions.

The variation of real and imaginary dielectric constants with photon energy follows the similar trend as followed by the refractive index and extinction coefficient respectively. The dissipation factor, tan δis found to be decreasing with photon energy. The decrease in E_g^{opt}may be attributed to the formation of defects centres and the increase in the disorder with the increase in Cd concentration.The optical transmission spectra of $Cd_xZn_{8-x}Te_{92}$thin films is shown in fig.1. clearly indicates that the band edges shifts towards the higher wavelength side with increasing the Cd content, indicating a decrease in band gap energy. The variation of band gap is almost linear with the Cd concentration into the alloy, which the confirmation is regarding to the formation of homogenous $Cd_xZn_{8-x}Te_{92}$thin films by the thermal evaporation method. The variation of optical band gap can be explained on the basis of grain size effect. The grain size increases with the increase in Cd concentration [25]which is acceptable because the atomic radius of Cd is greater as compared to Zn. Therefore, with the increase in grain size means increase in defect states which led a decrease in optical energy gap. All the above reason indicates that the band gap will decrease due to increase in Cd concentration in the $Cd_xZn_{8-x}Te_{92}$thin films composition.

3.4 D. C. Conductivitybehaviour of $Cd_xZn_{8-x}Te_{92}$ thin films

Fig. 8 Shows theI–Vcharacteristics of the samples for different composition of$Cd_xZn_{8-x}Te_{92}$thin films at room temperature. It shows the ohmicbehaviour of the samples. From the I–Vcharacteristics of the samples, the electrical conductivity has been determined. The I-V curves were used to calculate dc conductivity of these glasses at 10V. Fig.9 shows the variation of conductivity at different temperature for all composition of $Cd_xZn_{8-x}Te_{92}$thin films.

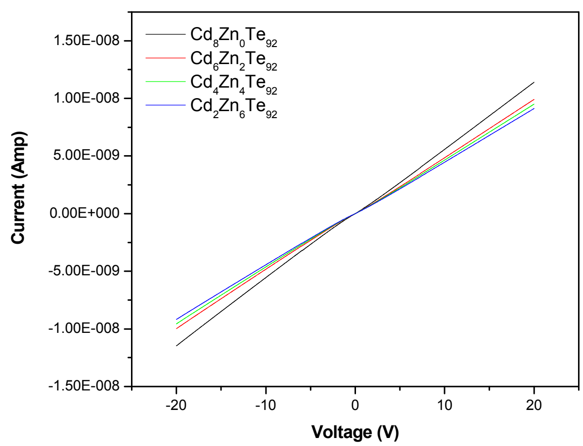

Fig.8.Shows the variation of Current with applied Voltage.

The d.c.conductivity was recorded in the range 293-353K as a function of temperature, in accordance with the formula given:

$$\sigma_{dc} = \sigma_0 \exp\left(\frac{-\Delta E}{KT}\right) \quad (11)$$

whereΔE is the activation energy of the conduction, σ_0 is the pre-exponential factor.

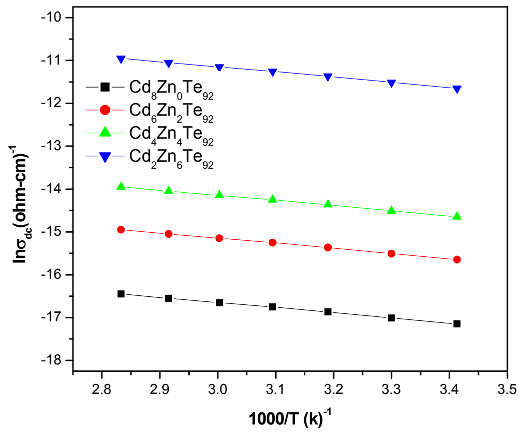

Fig.9. Plot $\ln\sigma_{dc}$ *(ohm-cm)*$^{-1}$ *vs 1000/T (K)*$^{-1}$.

It is clear that the conductivity increases with the increase in temperature and also increases with the increase in Cd content in the alloy composition. It is also observed that the conductivity curve retains it trend for all concentrations of Cd in the alooy composition. It is evident from fig.7 that the band gap decreases with the Cd concentration which also supported by the increase in conductivity (fig.9) and I-V measurement (fig.8).

4. Conclusions

Thin films were prepared by thermal evaporation technique. The transmission analysis reveals that the optical parameters**,** namelyreal and imaginary dielectric constants with photon energy follows the similar trend followed by the refractive index and extinction coefficient respectively. The dissipation factor, tan δ is found to be decreasing with photon energy. The grain size increases with the increase in Cd concentration, means increase in defect states which led a decrease in optical energy gap. The decrease in optical energy band with increase in Cd concentration in the $Cd_xZn_{8-x}Te_{92}$ thin films alloy composition is also supported by the I-V and conductivity measurements.

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