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STUDY OF OPTICAL PARAMETERS OF CHEMICAL BATH DEPOSITED $Cd_{1-X}Zn_XS$ THIN FILMS

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Abstract. The Chemical Bath Deposition Method (CBD) was employed for deposition of $Cd_{1-x}Zn_xS$ (x = 0.0, 0.2, 0.4, 0.6, 0.8, 1.0) thin films. The chemically deposited $Cd_{1-x}Zn_xS$ thin films were characterized by using UV-Visible spectrophotometer. Transmission spectra show the blue shifting of absorption edge as the Zn content increased. The x = 0.8 composition shows maximum 78 % transmittance. The reflection in the blue portion of the incident spectrum was decreased as the Zn content increased. The $(\alpha h\nu)^2$ versus photon energy *(hν)* curves shows tuning of band gap with Zn content. The observed band gap was 3.9 eV in the x = 0.8 composition. The effect of composition on refractive index, absorption index and other optical dispersion parameters were also investigated. The calculated values of average excitation energy E_o approximately obey the empirical relation (E_o=1.2 E_g) obtained from single oscillator model.

1. Introduction

Now solar cell devices plays vital role in converting solar energy into usable form. The selection of window material is often important in the fabrication of low cost, high efficiency solar cell devices. Cadmium sulphide (CdS) is a low direct band gap (E_g= 2.42 eV) n-type semiconductor and widely used as window layer material in solar cell devices (Tuttle J.R. et al., 1996 [1]). CdS absorbs blue portion of solar radiations and decrease the current density of solar cells (Chavhan S.D. et al., 2008 [2]). Addition of Zn to widely used CdS window material improves the electrical and optical properties. The CdZnS provides the wider band gap and higher optical transmittance as compared to CdS. The wider band gap and higher optical transmittance are essential requisite in solar cell applications (Chavan S.D. et al., 2005 [3]). The CdZnS is II-VI compound semiconductor potentially used as window material for fabrication of p-n junction without lattice mismatch in CdTe or $CuIn_xCa_{1-x}$ Se_2 solar cell devices (Ilican S. et al., 2007 [4]).

The knowledge of optical parameters such as optical band gap, reflectivity, optical transmittance, refractive index and dielectric constants etc. are essential prerequisite in using the suitable material for device applications

A number of thin film deposition techniques are available. Of the most, Chemical Bath Deposition (CBD) is practically attractive because of its simplicity in comparison with other techniques, requiring vacuum conditions and complex instrumentations. Production of large surface area CdS thin films by easy and low cost techniques for industrial use, is still of great importance (Rakhshani et al., 1998 [5]). CBD is fast, simple, inexpensive, non-vacuum and suitable for mass production.

such as extinction coefficients (k), refractive index (n), real and imaginary parts of dielectric constant (ε_1) and (ε_2) were calculated using fowling relations (Abeles F., 2007 [8]):

$$n = \frac{1+R}{1-R} + \left\{ \frac{4R}{(1-R)^2} - k^2 \right\}^{1/2}, \tag{2}$$

where R is the reflectance; and K is extinction coefficient,

$$k = \frac{\alpha\lambda}{4\pi}, \tag{3}$$

where α is absorption coefficient.

3. Results and discussion

Absorbance data of $Cd_{1-x}Zn_xS$ thin films was recorded by using UV-Visible spectrophotometer (Systronics Double Beam 2201).

Figure 1 is the plot of transmission versus wavelength. The transmission curves show the blue shifting of absorption edge (approximately from 450 – 350 nm). From Fig. 1, it is clear that, the optical transmittance is maximum in the visible region (450 - 800 nm) and found increased from 5 to 78 % with Zn content. In the composition x= 0.8, the observed transmittance was 78 %.

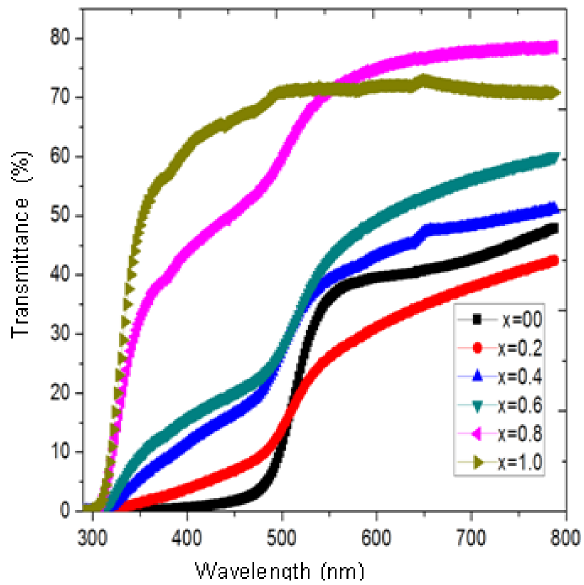

Fig. 1. Percent transmittance plotted versus wavelength for $Cd_{1-x}Zn_xS$ thin films.

Figure 2 shows the variation of optical reflection with wavelength. The reflection is found decreased from 0.02 to 0.005 (a.u.) in the visible and near infrared region. It supports the antireflection property of the $Cd_{1-x}Zn_xS$ thin films. In the compositions x=0.8 and 1.0, the optical reflectance was significantly decreased in the blue portion of the incident spectrum. Blue shifting of absorption edge indicate the decrease in optical absorption in the blue portion of the solar spectrum. (Borse S.V. et al., 2007 [9]).

The variation of film thickness with composition x is displayed in Table 2. Thickness of the films was found decreased from 6.63 to 1.13 µm.

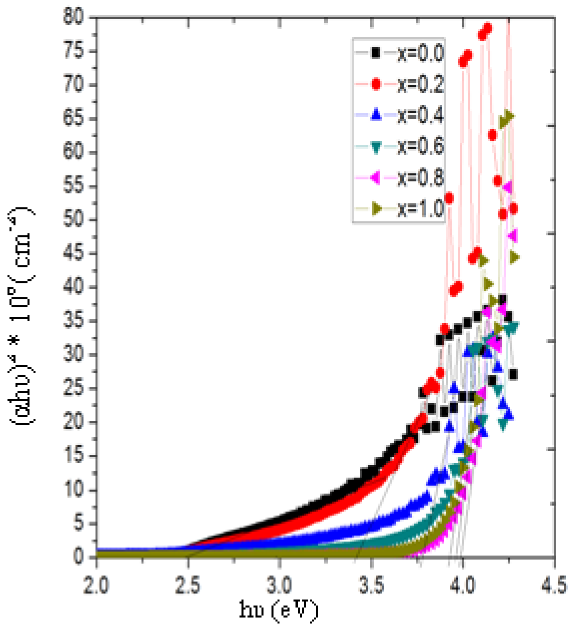

Fig. 3. plot of $(\alpha h\nu)^2$ versus $h\nu$ of $Cd_{1-x}Zn_xS$ thin films.

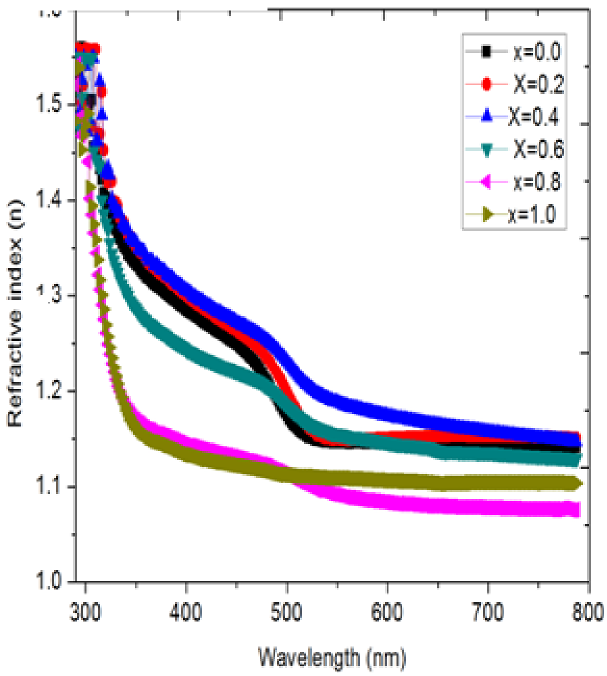

Fig. 4. Plot of refractive index (n) versus wavelength of $Cd_{1-x}Zn_xS$ thin films.

The investigation of complex dielectric constant is very important as it provides information about electronic structure of the deposited material onto the substrate. The dielectric constant is given as, $\varepsilon(\omega) = \varepsilon_1(\omega)+i\varepsilon_2(\omega)$, where, real $\varepsilon_1(\omega)$ and imaginary $\varepsilon_2(\omega)$ parts of dielectric constant are related to the n and k values respectively. The ε_1 and ε_2 were calculated using formulas:

$$\varepsilon_1 = n^2 - k^2, \quad (4)$$

$$\varepsilon_2 = 2nk. \quad (5)$$

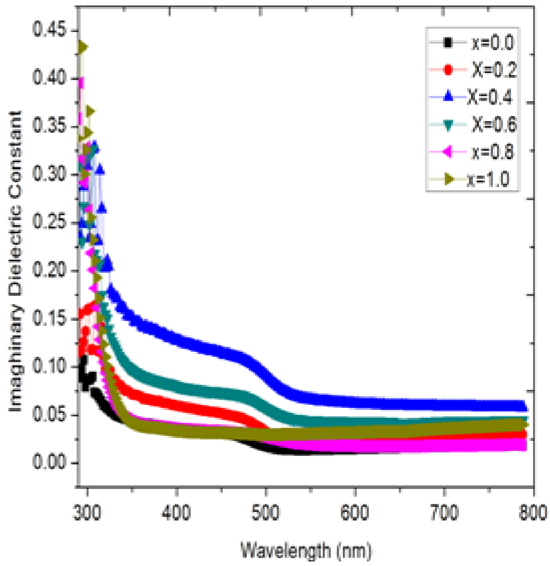

Fig. 7. Plot of imaginary part of dielectric constant (ε_2) versus wavelength of $Cd_{1-x}Zn_xS$ thin films.

The approximate relation between refractive index n, average excitation energy for electronic transition (E_o), the dispersion energy (E_d) and incident photon energy *(hv)* was described by Wemple and DiDomenico (Wemple S.H., 1971 [10]) means of single oscillator:

$$n^2 - 1 = E_d E_o / (E_o^2 - (h\nu)^2). \quad (6)$$

Plot of $(n^2-1)^{-1}$ against $(h\nu)^2$ gives the oscillator parameters E_o and E_d which are determined by fitting a straight line to the points and shown in Fig. 8.

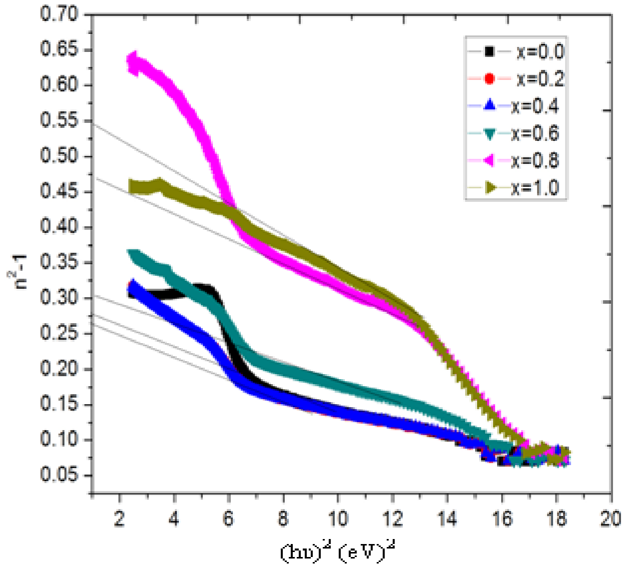

Fig. 8. Plot of $(n^2-1)^{-1}$ versus $(h\nu)^2$ of $Cd_{1-x}Zn_xS$ thin films.

The values of E_o and E_d can be directly determined from the gradient $(E_oE_d)^{-1}$ and intercept on vertical axis, (E_d/E_o). The values obtained for dispersion parameters, E_o and E_d are displayed in Table 3. Caglar M. et al. (2006) [11] and Ilican S. (2006) [12] reported that the oscillator energy E_o was related to lowest direct band gap empirically by E_o= 1.2 E_g. The calculated values of E_o satisfies the empirical relation approximately obtained from single oscillator model.

Table 3. Variations of oscillator parameters with composition.

Composition of $Cd_{1-x}Zn_xS$ film	E_o, eV	E_d, eV	M_{-1}	M_{-3}, $(eV)^{-2}$
0.0	3.72	23.1	6.71	0.49
0.2	4.082	25.9	6.31	0.38
0.4	4.08	26	6.32	0.38
0.6	4.378	22	5.0	0.26
0.8	5.17	14.78	2.89	0.118
1.0	5.26	14	2.66	0.096

The moments M_{-1} and M_{-3} of the optical transitions can be obtained from relationships:

$$(E_o)^2 = M_{-1}/M_{-3}, \quad (7)$$

$$(E_d)^2 = M^3_{-1}/M_{-3}\,. \quad (8)$$

The calculated values of E_o, E_d and M_{-1}, M_{-3} were found decreased with Zn content. As compared with values reported (Ilican S. et al., 2006), the obtained values of E_o, E_d and M_{-1}, M_{-3} are found higher. This may be because of technique of deposition. The values of moments of optical transitions are tabulated in Table 3. Table 3 shows the decreasing trend with Zn content.

The compositional and structural studies are the future scope of the work, to confirm the initial and final content of elements.

4. Conclusions

The transparent $Cd_{1-x}Zn_xS$ thin films have been synthesized by low cost simple Chemical Bath Deposition Technique. It was concluded that, Zn content changes the optical properties of the $Cd_{1-x}Zn_xS$ thin films. The film of composition x= 0.80 and 1.0 gives maximum 78 % transmittance. The maximum transmittance and low reflection property indicate that the prepared thin films are antireflective. The band gap shows the increasing trend with Zn content. The film composition x = 0.8 shows maximum 3.9 eV band width. The variation of ε_1 as a function of wavelength follows the similar behavior as n whereas the variation of ε_2 follows the behavior of *k*. The values of E_o, E_d and M_{-1}, M_{-3} decreased with concentration of Zn. The calculated values of average excitation energy E_o approximately obey the empirical relation obtained from single oscillator model.

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