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# OPTICAL CONSTANTS OF BRUSH ELECTRODEPOSITED $CuInTe_2$ FILMS

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Electrodeposition method has been used to deposit of $CuInTe_2$thin films on transparent glass substrate with thickness range from 200 to 400 nm at various temperatures ranging from 30° to 80°C by using the brush. UV visible spectrometer was used to record the transmission spectra of $CuInTe_2$ thin films in the wavelength rangebetween 900 to 1800 nm. It is revealed that the optical energy gap (Eg)is increased from 0.96 eV to 1.01 eV when the substrate temperature decreases. The variation in refractive index and extinction coefficient with photon energy werestudied and material properties such as dielectric constant, plasma frequency, and carrier density to effective mass, dispersion, oscillator energy and optical moments were estimated.

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## 1. Introduction

$CuInTe_2$ (CIT) is a novel material for solar energy application due to the following characteristics such as absorption co-efficient, near infrared band gap, non linear susceptibility [1, 2]. This material could have large tolerance to stochiometrycondition when compared to other ternary and binary compounds [3]. CIT thin films have been deposited by may methodssuch as slow thermal evaporation [4], spin coating [5], calcinationsof stacked elemental layers [6]and co-evaporation of elements [7], pulsed laser deposition [8], electro-deposition [9], pulse plating [10] and brush plating method [11]. Amongst all the methods, the brush plating technique is a good and simple method thin film deposition. It is an effective and cost effective.

Brush plating can be called as particular plating or swab plating technique. It is an extremely helpful and simple method for contact plating. In its least complex shape, the brush plating process is seems to be painting.Brush plating gear contains control packs, solutions,plating instruments, anode spreads, and assistant hardware. The power pack has two leads. One is correspondedwith the plating instrument and the other is corresponded with the workpiece to be plated. The anode is consists of a material which holds the necessary arrangement. The plate can be dipped in the solution and followed by the brushes against to the surface of the workpiece that will be done. At the particular point, the anode touches the work surface so as to frame the circuit and finally electrodeposit is produced. Plating occurs just when the anode contacts the workpiece. Besidesthe brush plating process and the plating instrument is fixed firmly in movement at whatever point it contacts with the work surface.

Therefore,Inthis work, CIT films were brush plated on tin oxide coated glass substrates in the (5 ohms sq). The complete procedure of depositing CIT films is explained in the literature [11]. In our previous work, results were obtained on CIT films deposited for 20 min [11]. In this work on the optical properties of CIT films deposited for 10 min at various substrate temperatures is reported and discussed. Finally optical constants were also established form the optical studies. The author were attempted to obtain result and deposited.

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## 2. Experimental methods

CIT films were brush plated for 10 min at different substrate temperatures ranging from 30 - 80°C with thickness of 1.0 Mama $cm^{-2}$ [11]. Thickness of the prepared thin film studies by Mitutoyo surface profilometer in the range between 200 nm to 400 nm. The films werestudied using by X-beam diffraction and opticalproperties such as band gapalso estimated by using Hitachi U3400 UV-VIS-NIR spectrophotometer. XRD technique was used to analyze the crystal structure by using PAnalyticalX'PertPro Pro Diffractometer with sifted CuKα radiation source.

## 3. Results and discussion

Fig.3.1 shows the XRD Pattern of the deposited CIT thin films deposited at various substrate temperatures. The deposited filmswere polycrystalline in nature with prominentpeaks namely (112),(204/220) and(116/312) planes. These are attributed to the CIT thin films. This is well agree with the JCPDS card No.10– 0421. The peak intensity was increased and peak width was narrowed due to increase in the substrate temperature. As the substrate temperature expanded, the intensity of the peaks expanded and the width of the peaks were diminished. The crystallite size can be calculated from the Scherrer's equation.

$$\text{Crystalline Size (D)} = \frac{0.95\lambda}{\beta \cos\theta} \tag{1}$$

where, λ is the wavelength of X-rays, β is the full width half maximum, θ is the diffraction angle. The crystallite size of the prepared CIT thin films were found to be from 10 nm to 40 nm as the substrate temperature increased from 30°C to 80°C. Fig.3.2 reveals the transmission spectra of the CIT films maintained at various substrate temperatures. The spectra produce interference fringes and the refractive index of the CIT thin film estimated by the envelope strategy [12] as follows,

$$n = [N + (N^2 - n_s^2)]^2 \tag{2}$$

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

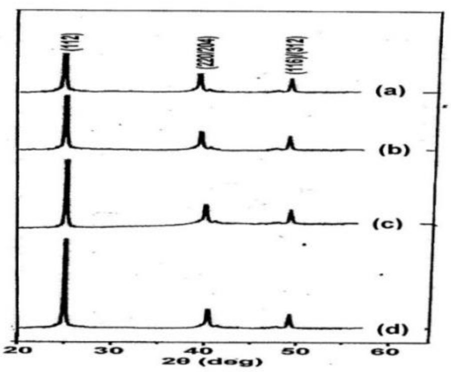


*Fig.3.1. X-ray diffraction profile of CIT films deposited at different substrate temperatures (a) 30°C (b) 50°C (c) 70°C (d) 80°C.*

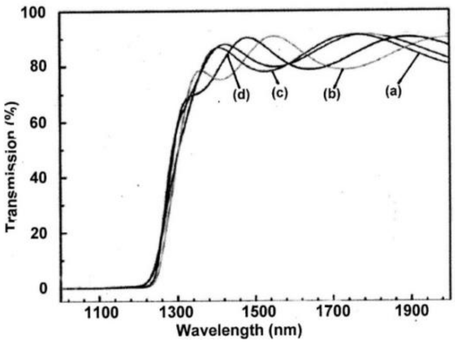


*Fig.3.2. Transmission spectra of CIT films deposited at different substrate temperatures (a)80°C (b) 70°C (c) 50°C (d) 30°Ca.*

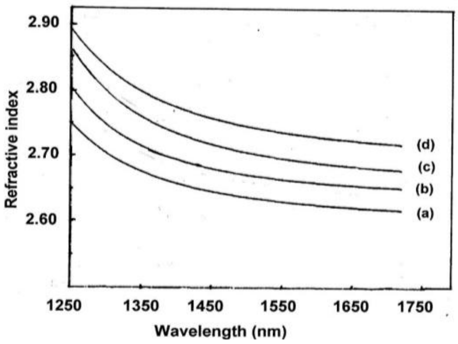


*Fig.3.3.Variation in Refractive index with wavelength for the preparedCIT films Depositedat different substrate temperatures (a) 30°C (b) 50°C (c) 70°C (d) 80°C.*

where $n_s$ is the refractive index of the substrate, $T_{max}$ and $T_{min}$ are indicating the maximum and minimum transmittances at a very similar wavelength in the fitted envelope curve on a transmittancepeak. The refractive index of the CIT thin films were found to be from 2.75 to 2.89 at 1250 nm wavelength as the substrate temperature is increased.

The estimation of the refractive record computed from the above conditions was in the scope of 2.75 – 2.89 at 1250 nm with increment of substrate temperature (Fig.3.3). The result indicating that the value of refractive index is decreased with increases of wavelength. These are well agree with the reported literature [6]. The refractive index diminishes with increment of wavelength. The esteem agrees with prior report [6]. The calculated of the absorption co-efficient (α) was ascertained utilizing the connection.

$$\propto = \frac{1}{d} \ln \left\{ \frac{(n-1)(n-n_s)}{(n+1)(n-n_s)} \right\} \frac{\left[ \left( \frac{T_{max}}{T_{min}} \right)^2 + 1 \right]}{\left[ \left( \frac{T_{max}}{T_{min}} \right)^2 - 1 \right]} \quad (4)$$

where 'd ' is the thickness of the thin film and alternate parameters have the importance as given in equation(4). Optical absorption peaks were recorded on the film maintained at various substrate temperatures. The prepared CIT thin films show a high absorption coefficient in the order of 104 $cm^{-1}$. Fig.3.4 shows the curve plotted between $(\alpha h\nu)^2$ and hν. It displays the linear behaviour in band edge, the band gap of the CIT films also were recorded to be in the range of 0.965 – 1.01 eV.

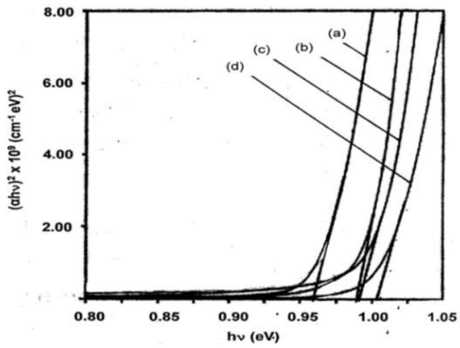


*Fig.3.4.Tauc's plot of CIT films at different substrate temperatures (a) 80°C (b) 70°C (c) 50°C (d) 30°C.*

The band gap gradually increases with decrease of substrate temperature, due to the small crystalline size. In Previous literature, it is reported that band gap values is 0.86 – 0.98 eV for the CIT thin films synthesized by other methods. The band gap of CIT in thin film prepared by other technique was in the range of 0.86 – 0.98 eV [6].

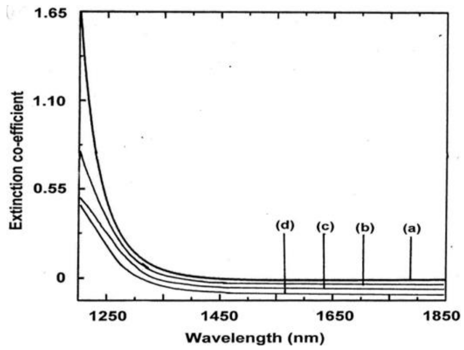


*Fig. 3.5. Variation in Extinction co-efficient with wavelength for prepared CIT films at different substrate temperatures (a) 30°C (b) 50°C (c) 70°C (d) 80°C.*

The following relation used to find the Extinction coefficient from the absorption coefficient.

$$K = \frac{\alpha\lambda}{4\pi} \tag{5}$$

where, α is the absorption coefficient and λ is the incident wavelength. As shown in the figure, the extinction constant decreases with increase in the wavelength. On contrary the decrease in extinction coefficient with increase of wavelength reveals that the fractionof lightlost due to decrease in scattering and absorbance. A basic intrinsic property of the material is the dielectric constant. The real part of dielectric constant shows percentage of absorption energy slow down the speed of light, whereas the imaginary part shows absorbs energy of electrical field due to dipole motion. The study of the real andhalf of imaginary part of a complex number of the dielectric constant explains information regarding the dielectric loss issue whichthe ratio of the imaginary part to the real part of the dielectric constant. The real and the imaginary parts of the dielectric constant can be calculated using the following equation [12].

$$\varepsilon_1 = n^2 - k^2 \text{and } \varepsilon_2 = 2nk \tag{6}$$

The phenomenon of reflectivity of a semiconducting material within the infrared region shows abnormal dispersion as the incident photon energy reaches the corresponding value of plasma wavelength λp. When $n_2 >> k_2$ and ωT< 1, the dielectric constant is given as [13].

$$\varepsilon_1 = \varepsilon_\infty - \frac{[\varepsilon_\infty \omega_p^2]}{\omega^2} \tag{7}$$

where, ε∞ is the limiting value of the dielectric constant of the materials, Variation in $\varepsilon_2$ with $1/\omega_2$ for CIT films deposited at various substrate temperatures is shown in Fig.3.6. Plasma frequency $\omega_p$ and $\varepsilon_\infty$ were estimated from the slope and intercept of the linear portion of the $\varepsilon_1$ versus $1/\omega_2$ plot. The values of $\varepsilon_\infty$ and $\omega_p$ values are tabulated in Table 3.1.In transparent region, the relation between the optical dielectric constant ($\varepsilon_1$), the wavelength (λ), and also the ratio, n, is given by the following relation [14].

$$\varepsilon_1 = n^2 = \varepsilon_L - D\lambda^2 \tag{8}$$

where, $\varepsilon_1$is the real part of dielectric constant, $\varepsilon_L$ is the lattice dielectric constant and D is a constant depending on the ratio of carrier density.The concentration to the effective mass is given by this equation.

$$\varepsilon_1 = n^2 = \varepsilon_L - D\lambda^2 \tag{9}$$

where, ‘e’ is that the charge of the electron, N is the free charge carrier concentration ($\varepsilon_o$) is the permittivity of free space, m* is the effective mass of the hole and c is that the velocity of flight [15]. Fig.3.7 shows the relation between $n_2$ and $\lambda_2$ for the prepared CIT thin films deposited at various substrate temperatures. It is found that the dependence $\varepsilon_1$ (= $n_2$), on $\lambda_2$ is linear.

This linear part of this dependence to zero wavelength offers the value of $\varepsilon_L$by preparing. From the slope of this linear part, the constant D can be calculated, from that the value (N /m*) for the preparedthin films is obtained (Table-3.1).

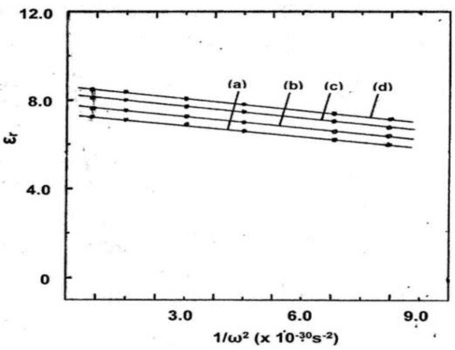


*Fig.3.6. Variation in real part of dielectric constant with wavelength for the prepared CIT films Deposited at different substrate temperatures (a) 30°C (b) 50°C (c) 70°C (d) 80°C.*

The Wemple and DiDomenico have proposed a single effective oscillator model [16],The optical properties can be calculated by extrapolating following approximation by the equation.

$$n^2 - 1 = \frac{(E_d E_0)}{(E_0^2 - E^2)} \tag{10}$$

where, E = hν is the photon energy, n is the refractive index, $E_0$ is the single-effective oscillator energy and $E_d$ is the dispersion energy that can be measured the average strength of the interband optical transitions. Plotting curve $(n_2 - 1)^{-1}$ against $E_2$provides the oscillator parameters by fitting a straight linear line. Fig. 3.8 shows the plot of $(n_2 - 1)^{-1}$ vs $E_2$ for the films deposited at different substrate temperatures. The slope $(E_0/Ed)$ is used to estimated the value of $E_0$ and therefore the intercept on the vertical axis $E_0/E_d)$ also can be found. The values of the static refractive index $(n_0)$ can be measured by analyzing the Wemple–Di Domenico dispersion equation (10) to $E \rightarrow 0$. The estimated values of $n_0$ are 2.65, 2.68, 2.72 and 2.76 for the prepared films deposited atvarious substrate temperatures.

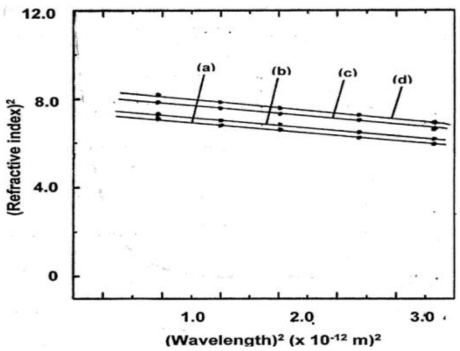


*Fig.3.7. Variation in square of refractive index with square of wavelength for prepared CIT filmsdeposited at different substrate temperatures (a) 30°C (b) 50°C (c) 70°C (d) 80°C.*

The calculated values of $n_0$, $E_0$ and $E_D$ are listed and tabulated in additionally, the optical band gap $(E_g)$ was determined from the Wemple–Di Domenico dispersion parameter E0 using the relation $E_g = E_0/1.4$. The calculated energy gap valued are found to be 0.96, 0.98 and 1.01 electron volt for the prepared CIT thin films for the different substrate temperatures. It is well agreement with the value estimated from Tauc's plot.

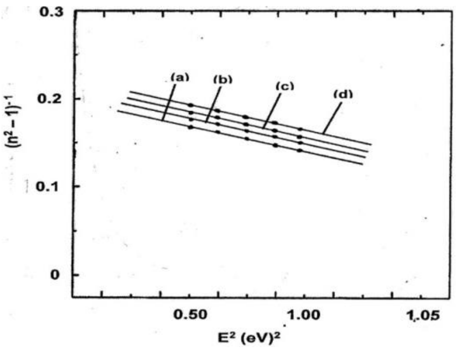


*Fig.3.8. Variation of $(n_2 - 1)^{-1}$ against $E_2$ plot for the prepared CIT films deposited at different substrate temperatures (a) 30°C (b) 50°C (c) 70°C (d) 80°C.*

$M_{-1}$ and $M_{-3}$are corresponded to the Moments of the Optical Spectra for the CIT thin films. These are obtained from the following relations [17],

$$E_0^2 = \frac{M_{-1}}{M_{-3}} \tag{11}$$

$$E_0^2 = \frac{M_{-1}^3}{M_{-3}} \tag{12}$$

The single-oscillator parameters such as $E_o$ and $E_d$ are associated to the imaginary component $\varepsilon_i$ of the complex dielectric constant. Thus, finding the moments is playing role in very vital developing optical devices of the optical material. The estimated values also are tabulated in Table 3.1. The obtained obtained result result show that $M_{-1}$ and $M_{-3}$ moments decreased with increase of substrate temperatures.

*Table3.1.Calculated Band gap, refractive index, plasma frequency, Oscillator energy, dispersion energy, optical moments of CIT films deposited at different substrate temperatures are tabulated.*

| **Subs. Temp. (°C)** | **$n_o$** | **$E_g$ (eV)** | **$E_o$ (eV)** | **$E_d$ (eV)** | **$\varepsilon_\infty$** | **$\omega_p$** | **$M_{-1}$** | **$M_{-3}$** |
|---|---|---|---|---|---|---|---|---|
| 30 | 2.65 | 0.96 | 1.35 | 6.05 | 7.5 | 3.73 | 5.26 | 2.89 |
| 50 | 2.68 | 0.98 | 1.37 | 6.37 | 7.9 | 3.55 | 4.76 | 2.54 |
| 70 | 2.72 | 0.982 | 1.373 | 6.52 | 8.1 | 3.51 | 4.65 | 2.49 |
| 80 | 2.76 | 1.01 | 1.41 | 7.42 | 8.3 | 3.47 | 4.44 | 2.23 |

## 4. Conclusions

$CuInTe_2$thin films 0.96 eV to 1.01 eV were successfully prepared by using brush plating technique. Transmission spectra were recorded for the CIT films and shown interference fringes. Optical constants like index of refraction, band gap, extinction co-efficient, dispersion energy, oscillator energy, and ratio of carrier concentration to effective mass, plasma frequency, limiting value of dielectric constant, optical moments were estimated. The variation in index of refraction and extinction co-efficient with wavelength were calculated. Band gap values obtained from Tauc's plot fitted well with analysis of the oscillator model.

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