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OPTICAL PARAMETERS OF NANOCRYSTALLINE $Zn_{40}Te_{60}$ THIN FILMS

Harinder Singh[1], Tejbir Singh[2], Anup Thakur[3] and Jeewan Sharma[1*]

[1]Department of Nanotechnology,
Sri Guru Granth Sahib World University, Fatehgarh Sahib, 140 407 (India)
[2]Department of Physics, Sri Guru Granth Sahib World University, Fatehgarh Sahib, 140 407 (India)
[3]Department of Basic and Applied Sciences, Punjabi University Patiala, Punjab, 147 002 (India)

ABSTRACT

Present paper deals with study of optical parameters of nanocrystalline $Zn_{40}Te_{60}$ thin films. The alloy with appropriate composition is synthesized using conventional melt quenching technique. Thin films of as prepared alloy are deposited on cleaned glass substrates by thermal evaporation technique (thickness ≈ 480 nm). The refractive index (n) and extinction coefficient (k) are calculated using Swanepoel's method. These two calculated values are further used to measure the optical parameters. The refractive index, extinction coefficient, dielectric constant, volume energy loss function (VELF), surface energy loss function (SELF) and dielectric loss function are measured.

Keywords: extinction coefficient, refractive index, swanepoel's method, zinc telluride

I INTRODUCTION

Among the various semiconducting materials, zinctelluride is an important member belonging to family of II-VIchalcogenides. Due to its wide and direct band gap (in 1.7 to 2.6 eV range),it findsapplications in photoelectrochemical cells, infrared and X-ray detector, laser diode, green LEDs, photovoltaic and switching devices [1-3]. It is reported that ZnTe thin films can be prepared by various techniques such as thermal evaporation, closed space sublimation, magnetron sputtering, electrodeposition and metal organic vapour phase epitaxy, etc. [4]. In present case thermal evaporation technique is used to deposit films as it has many advantages over other deposition methods [5].

Mahalingam et al. [1] has grown ZnTe thin films using an electrochemical technique. They reported the variation of refractiveindex, extinction coefficient, dielectric constant and optical conductivity as a function of bath temperature. Aboraiaet at. [6] studied the effect of exposure to the oxygen plasma-immersion-ion-implantation (*O^- PIII*) on thermally evaporated ZnTe thin films. It is found that refractive index reduces due to improvement in the transmission spectra. M.A.M. Seyam[7] reported the increase in refractive index as a function of substrate temperature, for the ZnTe thin films deposited by vacuum evaporation. This is due to improved packing density of thin films. Similarly, Shaaban et al. [8] found the increase in refractive index with increasing thickness of thin films. This might be attributed to increase in crystallite size and decrease in microstrain.

In the present study, thermally evaporated nanocrystalline $Zn_{40}Te_{60}$(ZnTe)thin films arestudied to explore its optical properties. The refractive index, extinction coefficient, dielectric constant, volume energy loss function (VELF), surface energy loss function (SELF) and dielectric loss function of these thin films is reported here.

II EXPERIMENTAL DETAILS

NanocrystallineZnTealloy samples were prepared by conventional melt quenching technique [4]. Thermal evaporation technique was chosen for thin film preparation. Thin film was prepared on glass substrate using Hind HIVAC BC-300 in a vacuum ~ 4 × 10^{-6} mbar.A double beam UV-Vis-NIR spectrophotometer (Perkin Elmer Lambda 750) was used in the transmission range 400-3200 nm, to measure normal incidence transmission spectra of thin films. The complete experimental detail is given elsewhere [2].

III RESULTS AND DISCUSSION

The refractive index and extinction coefficientare determined from transmission spectra (Inset of Fig. 1(a)) of ZnTe thin filmsusing Swanepoel's method [9]. In this method, an envelope is drawn through the interference maxima and minima in the transmission spectrum.It is supposed that the sample is a thin film prepared on a transparent substrate having a refractive index, *s*. The thin film is assumed to be surrounded by air, whose refractive index, n_0, is 1. The refractive index of the substrate is estimated by using the interference free transmission spectra of substrate alone in the absence of film as given by Swanepoel [10, 11].

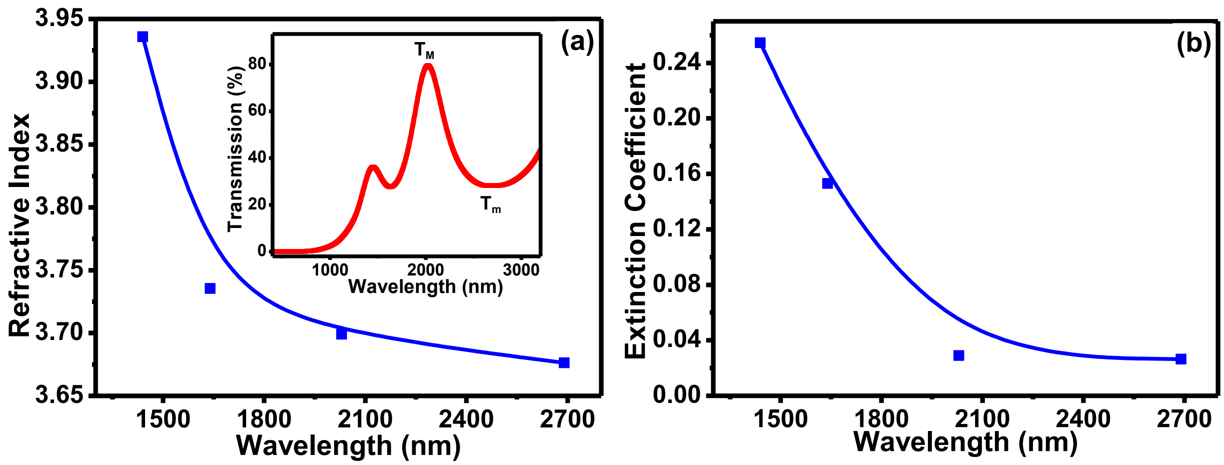

Figure 1: (a) Variation of refractive index and (b) extinction coefficient of ZnTe thin films with wavelength. Inset: Transmission spectra of ZnTe thin film [2].

The refractive index is a complex quantity, which can be written as $N^* = n + ik$, where n is a real part, measured as:

$$n = \left[\left[N + (N^2 - s^2)^{1/2}\right]\right]^{1/2} \quad (1)$$

where

$$N = 2s\frac{T_M - T_m}{T_M T_m} + \frac{s^2+1}{2} \quad (2)$$

Here, $T_M$andT_m are the maximum and corresponding minimum transmittance values at certain wavelength(λ) and s is the refractive index of substrate. The imaginary part of refractive index (k) is called extinction coefficient of absorption index. It can be calculated using relation:

$$k = \frac{\alpha\lambda}{4\pi} \quad (3)$$

Fig. 1 (a) and (b) representsthe variation of refractive index and extinction coefficient with incident photon wavelength, respectively. A decrease in values of n and k is observed with increasing wavelength. The decrease in refractive index shows the normal dispersion behavior of the material [12].The refractive index (n) has higher values of about 3.69–3.93 in the strong absorption region (lower wavelengths- 1000nm $\leq\lambda\leq$1500nm). Similarly, extinction coefficient has maximum values (0.15-0.25) in IR absorption region.

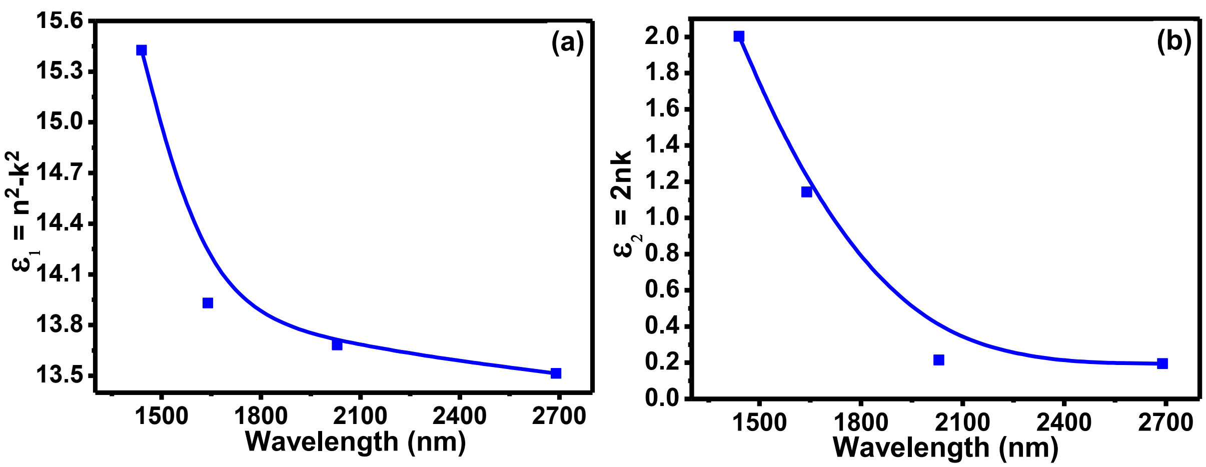

Figure 2: (a) Variation of real part and (b) imaginary part of dielectric constantof ZnTe thin films with wavelength.

The complex dielectric constant is given by$\varepsilon^* = \varepsilon_1 + i\varepsilon_2$. The real part is represented as$\varepsilon_1 = n^2 - k^2$whereas imaginary part is given by $\varepsilon_2 = 2nk$. The complex dielectric constant is known to be a fundamental intrinsic material property. The real part is related to the property of slowing down the speed of light in the material [1].Fig. 2 (a) and (b) shows the variation of real and imaginary parts of dielectric constant, respectively of ZnTe thin films with wavelength.$\varepsilon_1$has more values as compare to ε_2 because n>>k. The values of real and imaginary part of dielectric constant vary from 13.51 to 15.42 and 0.19 to 2.00 with wavelength, respectively.

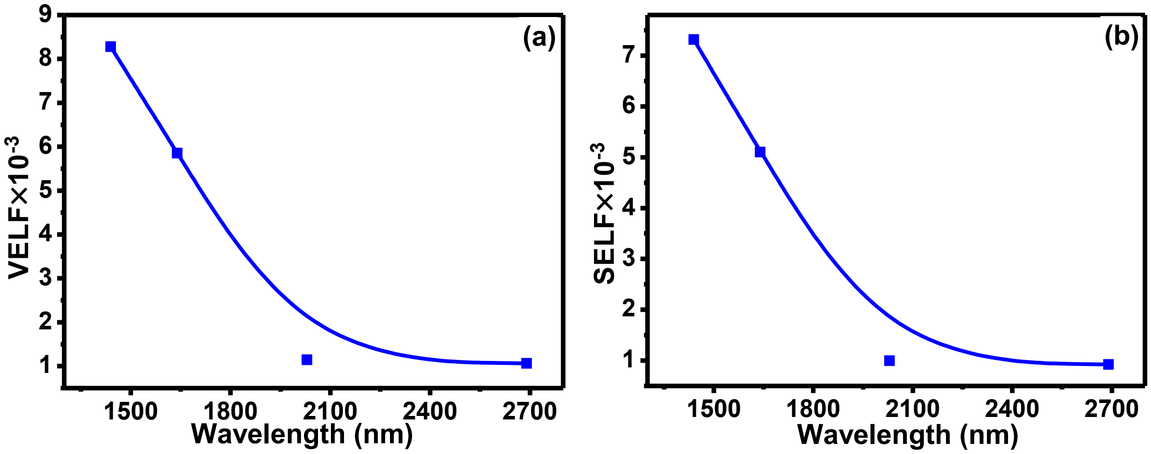

Figure 3: (a) Variation of volume energy loss function and (b) surface energy loss functionof ZnTe thin films with wavelength.

The probable loss in energy of any fast moving electron, travelling through the material, can be estimated byvolume and surface energy loss function energy loss function [13].Volume energy loss function energy (VELF) and surface energy loss function (SELF) are calculated by the following relations:

$$\mathrm{VELF} = \frac{\varepsilon_2}{(\varepsilon_1^2+\varepsilon_2^2)} \quad (4)$$

$$\mathrm{SELF} = \frac{\varepsilon_2}{((\varepsilon_1+1)^2+\varepsilon_2^2)} \quad (5)$$

Fig.3 (a) and (b) shows the variation of VELF and SELF with respect to wavelength, respectively. It is observed that VELF and SELF decreases with increasingwavelength. This may be due to decrease in transmittance of $Zn_{40}Te_{60}$ thin films. VELF and SELF varies from 1.06×10^{-3} to $8.27\times10^{-3}$and 0.92×10^{-3} to 7.31×10^{-3} respectively.

The dielectric loss function provides the dissipation of electromagnetic energy in dielectric materials. It can be estimated by using following relation:

$$tan\ \delta = \frac{\varepsilon_2}{\varepsilon_1} \quad (6)$$

Variation of dielectric loss functionfor ZnTe thin films is represented in Fig. 4 (a). It is observed that dielectric loss function decreases with increasing wavelength and it has maximum value equals to 0.1298 at 1440 nm wavelength. The optical conductivity of thin films is measured by using equation (7):

$$\sigma = \frac{\alpha n c}{4\pi} \quad (7)$$

It is found that optical conductivity also decreases with wavelength (Fig. 4(b)). The optical conductivity is observed to vary from 1.08×10^{13} to 20.85×10^{13}.

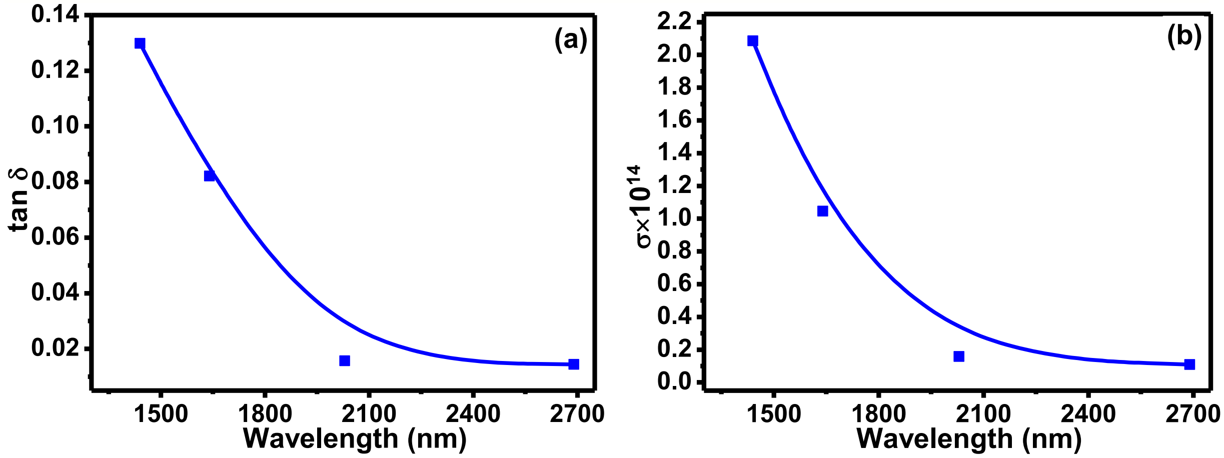

Figure 4: (a) Variation of dielectric loss function and (b) optical conductivityof annealed ZnTe thin films with wavelength.

IV CONCLUSIONS

Nanocrystalline $Zn_{40}Te_{60}$ thin films were prepared by thermal evaporation technique. Swanepoel's method is used to measure refractive index and extinction coefficient.It is found that refractive index and extinction coefficient has maximum value in strong absorption region and these parameters decrease with increasing wavelength. The other optical parameters such as dielectric constant, volume energy loss function (VELF), surface energy loss function (SELF) and dielectric loss function are also found to be decreasing with increasing wavelength. The good refractive index values make films more suitable for antireflection multilayer.

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