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Study Effect of Annealing on Optical Constants of (As_{0.5}Se_{0.5} doped with Te at 1%) Thin Films

Rusul Adnan Al-Wardy

Department of Physics, College of Science, Al-Mustansiriyah University, Baghdad, Iraq.

e-mail:dr.rusuladnan @uomustansiriyah.edu.iq

ABSTRACT

In this work, thin films of (As_{0.5}Se_{0.5} doped with Te at 1%) were prepared by thermal vacuum evaporation on glass bases in (R.T) with (100±20)nm thickness deposition rate (1.6nm/s) and study effects of annealing temperature (T_a) (348,398,448)K for time (30min) on optical constants for prepared films. The X-ray diffraction technique showed that all prepared films are amorphous in structure at room temperature and annealing films at (348, 398,448)K. The optical constants (refractive index (n_0), extinction coefficient (K_0), dielectric constant (ϵ_r)) evaluated from transmission spectra in wavelength range (500-1100)nm and found that it increase with the increasing of (T_a) for the prepared films.

Keywords: optical constants, chalcogenide glass, annealing, As Se thin films, localized states.

1. Introduction

Thin film occupies a prominent place in theoretical and applied research for solid state physics. As a result of continuing research on the physical properties of the material at the last decades of the last century physics branch appeared thin films of materials science, which means easily study of systems with different elements and compounds. As it can be described in single layer or multiple layers of atoms in particular substance does not exceed a thickness $\sim 10^3$ Å, we know the physical and chemical properties of materials that cannot be studied in some cases, which is in its volumetric [1]. The glasses (As-Se-Te) is a great significance in terms represent a new classification for semiconductor and its thin films used in many technological and scientific applications, where used in optical memory devices, photographic printing to the advantage of its high sensitivity when exposed to a wavelength identical to the energy gap, (Popescu) [2] found that most chalcogenide glasses films that doped with (Te) uses in medical diagnosis and in pollution monitoring. The common feature of these glasses is the presence of localized states in the energy gap because of the absence of long-range order as well as various inherent defects. Recently, the investigation of electron transport in disordered system has gradually been developed and the investigation of gap states is of particular interest because of their effect on the properties of semiconductors [3]. Process of exposing the film to a certain temperature in a specific period of time called the annealing has been carried out either in vacuum or in presence of a particular gas or in air. The annealing granted atoms kinetic energy that necessary to rearrange itself in the crystalline lattice that is lead to organization of the crystal structure of the material and reduces the defects. The optical constants are related to the composition of the atoms and the installation of the electronic beam also the bonds between the atoms have to be through these constants such as absorption and transmission of the random



materials, knowing the optical constants for chalcogenide glasses films is necessary for the purpose of using them in optical fibers and in reflected coating [3, 4].

2. Experimental

The glassy alloys of ($\text{As}_{0.5}\text{Se}_{0.5}$ doped with Te at 1%) were prepared by applying melt quenching technique. The exact proportions of high purity (99.999%) arsenic (As), Selenium (Se) and tellurium (Te) elements, in accord with their atomic percentages, and put these elements within the quartz tube sealed at (10^{-2} torr). The tube was heated to (823K) for (4-5 hours) and shaken it in several times during the course of heating to attain uniformity. The molten samples were then rapidly quenched in cold water. The films of ($\text{As}_{0.5}\text{Se}_{0.5}$ doped with Te at 1%) of thickness (100 ± 20) nm were prepared by vacuum evaporation technique using molybdenum boat according to low [5]: ($m = 2\pi\rho_0 r^2 t$) where m : weight of alloy, r : the distance from boat to a substrate, t : the thickness of film. ρ_0 : the density of alloy ($\rho_0 = \frac{m_T}{V_T}$) where m_T : the alloy mass, V_T : the alloy volume. The films of ($\text{As}_{0.5}\text{Se}_{0.5}$ doped with Te at 1%) were annealed at (T_a) (348,398,448) K by using oven type of (Griffin Incubator), which reaches maximum degree of temperature at (473K).

Determination of optical constants

The optical constants (refractive index (n_0), extinction coefficient (K_0), dielectric constant (ϵ_r) for a prepared and annealed films of ($\text{As}_{0.5}\text{Se}_{0.5}$ doped with Te at 1%) with different annealing temperature ($T_a = 348,398,448$) K at (30 min) were calculated from transmittance curve which is obtained through a device (UV-visible Cintra 5) at range of wavelength (500-1100) nm, optical constants of the films are calculated based on Swanepoel method i.e., limitation of interference fringes, by calculation the maximum transmittance ($T_M(\lambda)$) and minimum transmittance ($T_m(\lambda)$) for the same wavelength [6,7], as shown in Fig. (1).

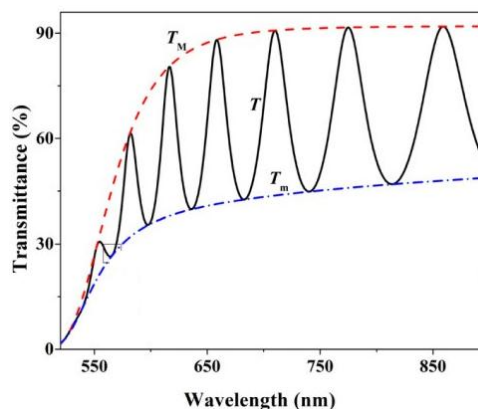


Fig.(1) Swanepoel method.

To evaluate the refractive index (n_o) for these samples as following [8,9]:

$$n_o = \left[N + (N^2 - S^2)^{1/2} \right]^{1/2} \quad \text{.....(1)}$$

Where

$$N = \left\{ 2S \left(\frac{T_M - T_m}{T_M T_m} \right) \right\} + \frac{(S^2 + 1)}{2} \quad \text{.....(2)}$$

S : is the refractive index for surface (1.446).

While the extinction coefficient (K_o) can be evaluated from the following equation[8-10]:

$$k_o = \frac{\alpha \lambda}{4\pi} \quad \text{.....(3)}$$

Where

λ : is the wavelength (cm).

α : is absorption coefficient (cm^{-1}) which can be calculated from the following equation:

$$A_o = \exp(-\alpha t) \quad \text{.....(4)}$$

A_o : is the absorbance which can be calculated from the following equation [8]:

$$A_o = \frac{E_M - \left[E_M^2 - (n_o^2 - 1)^3 (n_o^2 - S^4) \right]^{1/2}}{(n_o - 1)^3 (n_o - S^2)} \quad \text{.....(5)}$$

Where

$$E_M = \left(\frac{8n_o^2 S}{T_M} \right) + [(n_o^2 - 1)(n_o^2 - S^2)] \quad \text{.....(6)}$$

$$n_o = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in matter}} \quad \text{.....(7)}$$

And from eq. (7), we find that refractive index (n_0) appears when a difference in light velocity occurs between the medium and the vacuum, Which indicates a loss of energy due to the interaction of light with the charges of the medium and the resulting polarization the charges of that medium. This polarization is usually described by the constant electrical insulation of the medium, which is given by the following equation:

$$\epsilon_r = \epsilon_1 + i\epsilon_2 \quad \text{.....(8)}$$

Where

ϵ_1 : The real part of the insulation constant, represents the polarization limit.

ϵ_2 : The imaginary part of insulation constant, represents a measure of energy lost.

The complex electrical insulation constant is associated with the complex refractive index by the following equation:

$$\epsilon_r = n_0^{*2} \quad \text{.....(9)}$$

Where

$$n_0^* = n_0 - ik_0 \quad \text{.....(10)}$$

From equations (8), (9) and (10) we find:

$$\epsilon_1 + i\epsilon_2 = n_0^2 - 2in_0k_0 - k_0^2 \quad \text{.....(11)}$$

$$\epsilon_1 = n_0^2 - k_0^2 \quad \text{.....(12)}$$

$$\epsilon_2 = 2n_0k_0 \quad \text{.....(13)}$$

3. Results and Discussion:

Refractive Index (n_0):

Non-crystalline was tested of the film (As_{0.5}Se_{0.5} doped with 1%Te) by x-ray diffraction even after annealing films at ($T_a = 348,398,448$)K. The well-defined peaks characteristic of crystalline materials were absent, Fig. (2).

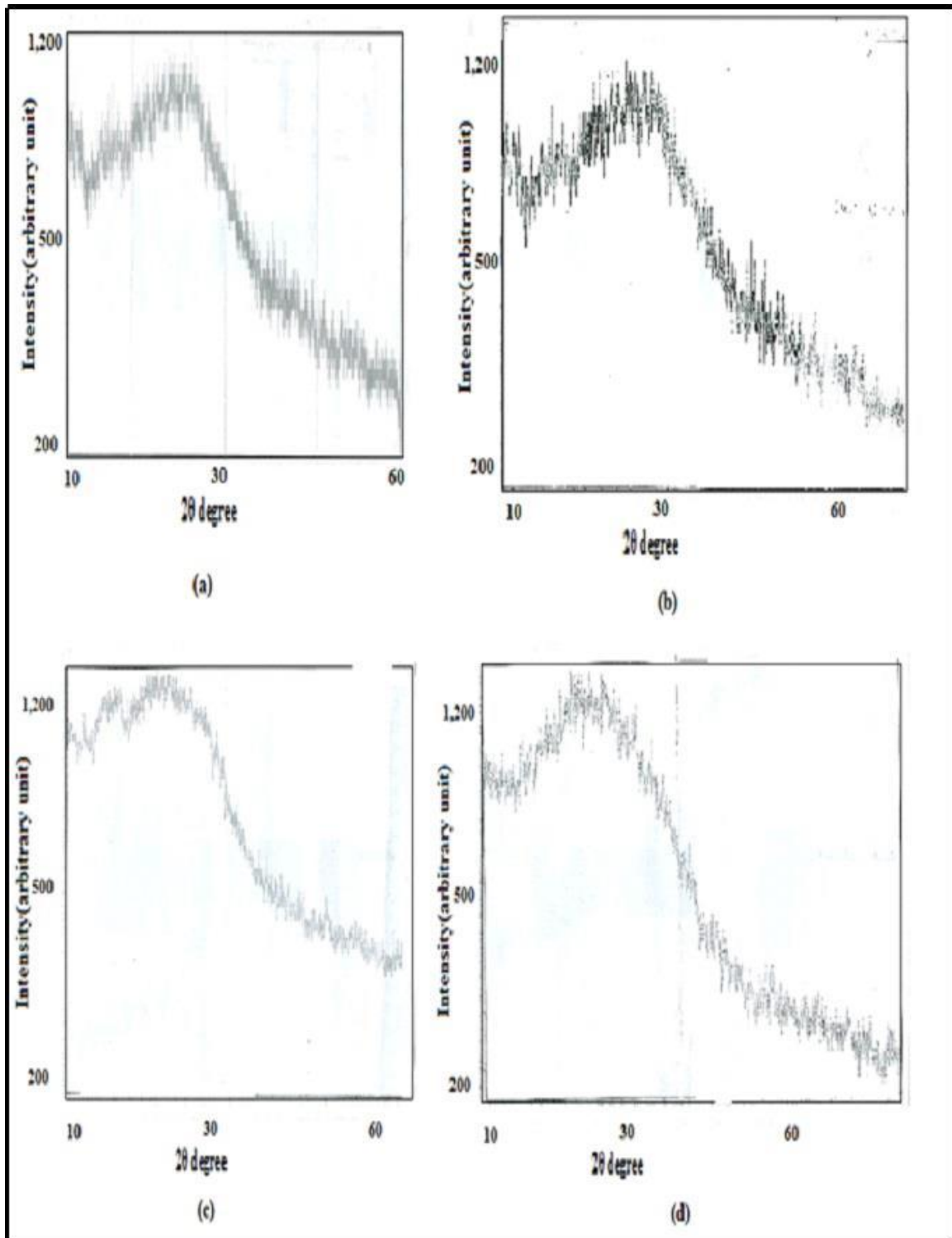


Figure (2): X-ray diffraction patterns for the films ($\text{As}_{0.5}\text{Se}_{0.5}$ doped with 1%Te): (a) at room temperature. (b) at 348k. (c) at 398k. (d) at 448k.

Fig. (3) shows refractive index as a function of wavelength of the ($\text{As}_{0.5}\text{Se}_{0.5}$ doped with Te at 1%) films deposited at room temperature and annealed at ($T_a = 348, 398, 448$)K. The refractive index decreases with increasing the wavelength of the falling photon and the refractive index values increase by increasing the temperature of annealing, as shown in table (1). This increase in refractive index is due to the fact that the temperature of annealing works on increase the packing density which reduces the speed of light in the thin film material, which leads to increase refractive index as eq. (7). These results are consistent with the findings of the researchers(A.M. Abd-elnaeim et al.)[11], (prince et al.)[12].

Table (1) the value of (n_0) of ($\text{As}_{0.5}\text{Se}_{0.5}$ doped with Te at 1%) thin films at different annealing temperatures.

$\text{As}_{0.5}\text{Se}_{0.5}\text{Te}_{0.01}$ Thin Film	at R.T=303K	T_a 348K	T_a 398K	T_a 448K
n_0	2.03	2.10	2.35	2.45

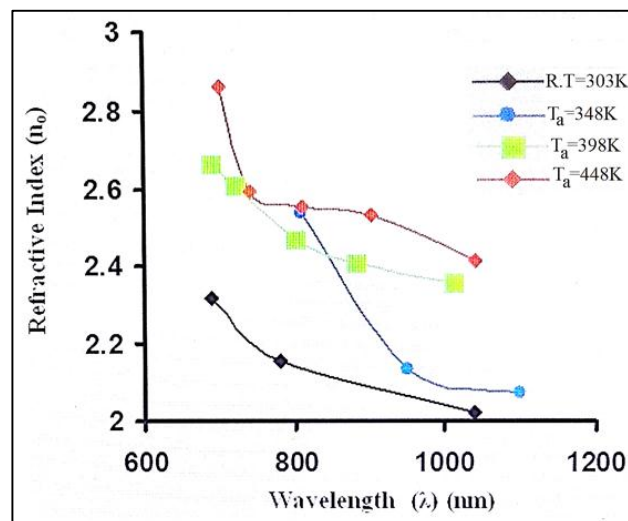


Fig. (3) the relationship between (n_0) and wavelength (λ) for a prepared and annealed films of ($\text{As}_{0.5}\text{Se}_{0.5}$ doped with Te at 1%) with different annealing temperature.

Extinction Coefficient (k_0):

Fig. (4) shows extinction coefficient as a function of wavelength of the films ($\text{As}_{0.5}\text{Se}_{0.5}$ doped with Te at 1%) deposited at room temperature and annealed at ($T_a = 348, 398, 448$)K. The extinction coefficient decreases with increasing the wavelength of the falling photon and the extinction coefficient values increase by increasing the temperature of annealing, as shown in

Table (2). This result is an agreement with (A.M. Abd-elnaim et al.)[11], This increase in the extinction coefficient is due to the fact that the temperature of the annealing increases absorption, where (k_0) depends on the absorption coefficient (α), which comes from the increase of the tails of the localized states within the energy gap [3] and then increase (k_0) according to eq. (3).

Table (2) the value of (k_0) of ($\text{As}_{0.5}\text{Se}_{0.5}$ doped with Te at 1%) thin films at different annealing temperatures.

$\text{As}_{0.5}\text{Se}_{0.5}\text{Te}_{0.01}$ Thin Film	at R.T=303K	T_a 348K	T_a 398K	T_a 448K
k_0	$3.4 * 10^{-3}$	$4.6 * 10^{-3}$	$5.6 * 10^{-3}$	$5.8 * 10^{-3}$

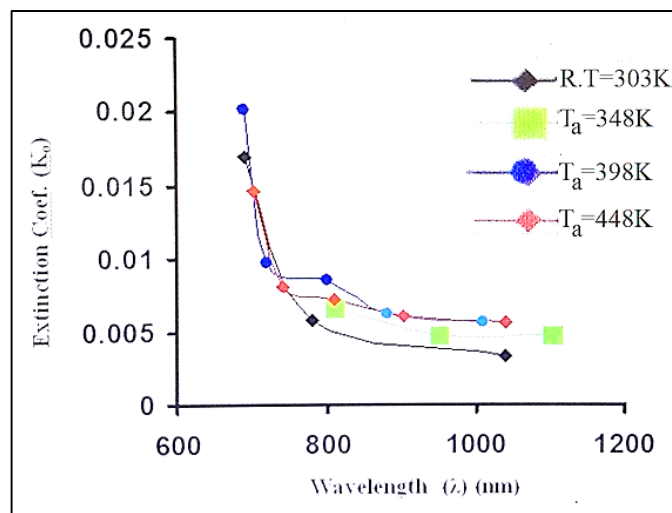


Fig. (4) (k_0) vs. wavelength (λ) for a prepared and annealed ($\text{As}_{0.5}\text{Se}_{0.5}$ doped with Te at 1%) films with different annealing temperature.

Dielectric Constant (ϵ_r):

Fig. (5) shows that both the real part (ϵ_1) and the imaginary part (ϵ_2) of the dielectric constant have changed as a function of the wavelength of the prepared films. It is clear that both (ϵ_1) and (ϵ_2) are increased by increasing the temperature of annealing, as shown in the Table (3), these results are consistent with the findings of (A.M. Abd-elnaim et al.)[11]. The behavior of (ϵ_1) with the wavelength and the temperature of annealing is the same as the behavior of the refractive index (n_0) to adopt (ϵ_1) on the refractive index, according to eq. (12), While the behavior of (ϵ_2) with the wavelength and the temperature of annealing is the same as the extinction coefficient (k_0), in order to adopt (ϵ_2) on the extinction coefficient, according to eq.

(13). This can be explained by the fact that the imaginary part of the insulation constant (ϵ_2) represents the energy scale lost from the radiation.

Table (3) The values of (ϵ_1) and (ϵ_2) of ($\text{As}_{0.5}\text{Se}_{0.5}$ doped with Te at 1%) thin films at different annealing temperatures.

$\text{As}_{0.5}\text{Se}_{0.5}\text{Te}_{0.01}$ Thin Film	at R.T=303K	T_a 348K	T_a 398K	T_a 448K
ϵ_1	4.12	4.41	5.52	6.00
ϵ_2	1.38×10^{-2}	1.93×10^{-2}	2.63×10^{-2}	2.84×10^{-2}

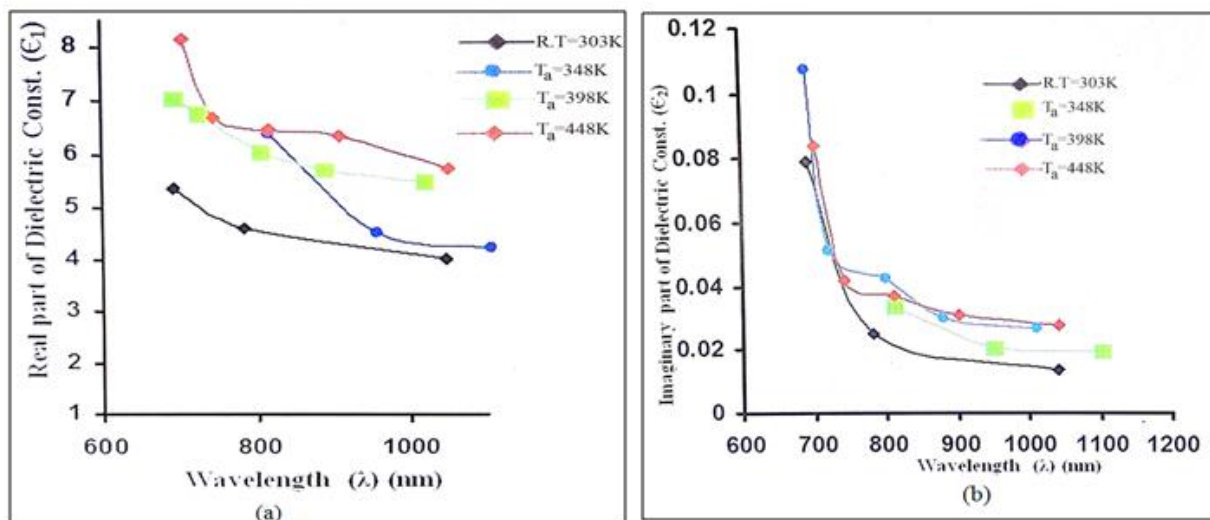


Fig. (5) (a) and (b) the relationship between (ϵ_1) and (ϵ_2) with wavelength (λ) for a prepared and annealed films of ($\text{As}_{0.5}\text{Se}_{0.5}$ doped with Te at 1%) with different annealing temperature.

4. Conclusions:

Amorphous thin films of ($\text{As}_{0.5}\text{Se}_{0.5}$ doped with Te at 1%) were obtained by thermal evaporation technique on glass substrates. From the study of optical constants (refractive index (n_0), extinction coefficient (K_0), dielectric constant (ϵ_r)) of the prepared films show that increasing the temperature of annealing ($T_a = 348, 398, 448$) K for (30 min) leads to increase these optical constants while it decrease with wavelength of falling photon. ($\text{As}_{0.5}\text{Se}_{0.5}$ doped with Te at 1%) thin films provide a promising alternative for solar cell.

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