

Effect of Aluminum on Optical Properties of Aluminum Doped ZnTe Thinfilms Prepared By Vacuum Thermal Evaporation Technique

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ABSTRACT: Aluminum doped zinc telluride (ZnTe:Al) thin films of (500nm) thickness for with (0.5, 1,1.5 and 2) wt.% ,were deposited onto glass substrates by using thermal vacuum evaporation technique under vacuum 2.1×10^{-5} mbar. The optical absorption coefficient (α) of the films was determined from transmittance spectra in the range of wavelength (400-1100) nm. The spectral transmission decrease from 59.5 % to 23.2 % , and the optical energy band gap decrease from 1.92 eV to 1.54 eV, depending upon the Al ratio in the films, also our studies include the calculation of the optical constants (refractive index, extinction coefficient, real and imaginary part of dielectric constant) as a function of photon energy. Evaluation of these parameters may help in view of their technological applications in selective surface as well as in optoelectronic devices.

KEYWORDS: ZnTe thin films, optical measurements, thermal evaporation, transmittance spectra.

I. INTRODUCTION

ZnTe is a low cost semiconducting material of the II-VI family. This crystal is usually a cubic, zincblende type in structure with lattice constant $a = 6.1034 \text{ \AA}$. ZnTe has direct transition of wide band gap of 1.7 to 2.4 eV. Usually, it is a material of high absorption coefficient and shows a p-type in nature [1]. ZnTe has recently been focused of great interest due its low cost, wide band gap and high absorption co-efficient for application to photovoltaic [2] and photoelectrochemical cells [1]. It is a promising compound for development of various solid state devices including the blue light emitting diodes [3, 4], laser diodes [5], solar cells [3, 5], microwave devices and various optoelectronic devices [1]. The electrical and optical properties of a semiconductor change greatly by the incorporation of impurities, the selection of impurity has critical importance. Impurity atoms incorporated in a host crystal not only contribute to conductivity by adding additional carriers but also give rise to lattice strain. There are several reports on deposition of polycrystalline ZnTe thin films by various techniques, most of the previous research has focused primarily on the structural, electrical and optical properties of ZnTe both in the form of bulk crystals and sub-micron thin films [6]. In the present work, we focus on the study of the influence of Aluminum on optical properties of ZnTe thin films.

II. EXPERIMENTAL PART

Al-doped ZnTe thin films have been deposited on glass substrate by thermal vacuum evaporation using (Edwards-Unit 306) system with 2.1×10^{-5} mbar. The thickness of films were determined with (Precisa-Swiss) microbalance by using weighing method and found to be about (500 ± 10) nm, with deposition rate about (1.2 ± 0.1) nm/sec. The material was placed into molybdenum boat with a small dimple at the center to act as a point source. The boat was heated indirectly by passing current through the electrodes. Cleaned glass slides were used as a substrate. These glass slides were cleaned with chromic acid, ultrasonic cleaner, soap water, distilled water and then with acetone. The material evaporated in

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vacuum at room temperature onto cleaned glass substrates with $(2.5 \times 2 \times 1) \text{ cm}^3$ size. The distance between the substrate and the boat is (18) cm. After reaching high vacuum in the vacuum chamber, slowly current was applied to the electrodes to heat the substance. So that Al atomic percentages doping in the films were (0.5, 1, 1.5 and 2) %wt. Optical transmission measurements were performed with (UV/Visible 1800 spectrophotometer). The band gap (E_g) and optical constants of the transparent films were determined from the optical transmission spectra.

III. RESULTS AND DISCUSSION

optical transmittance spectra with wavelength was show in Fig (1) from 400nm to 1100 nm of the ZnTe thin films pure and doped with Al. It is seen the transmittance value decreases with the increase of Al doping concentration, there is sharp fall from 59.4% to 23.2% in the transmittance as the Al doping concentration rises, this decrease in the transmission can be attributed to the introduction of impurity level between valance band and conduction band [7, 8]. This behavior is well agreed with the report of other worker [9].

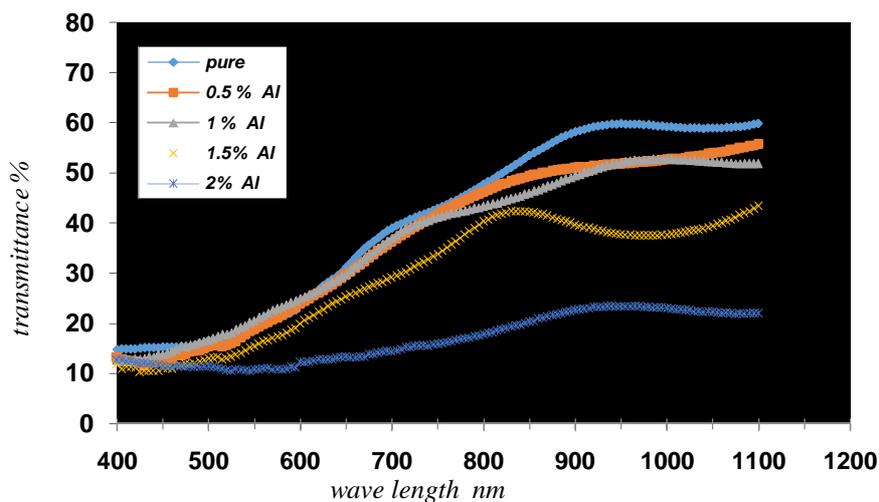


Figure (1): Transmittance spectra of Pure and Al doped ZnTe thin films

For the same reasons as we mentioned before, the absorption edge shifts to higher wavelength for higher Al percentage and it changes with Al doping, and that are show in Fig (2) of pure and Al doped ZnTe films.

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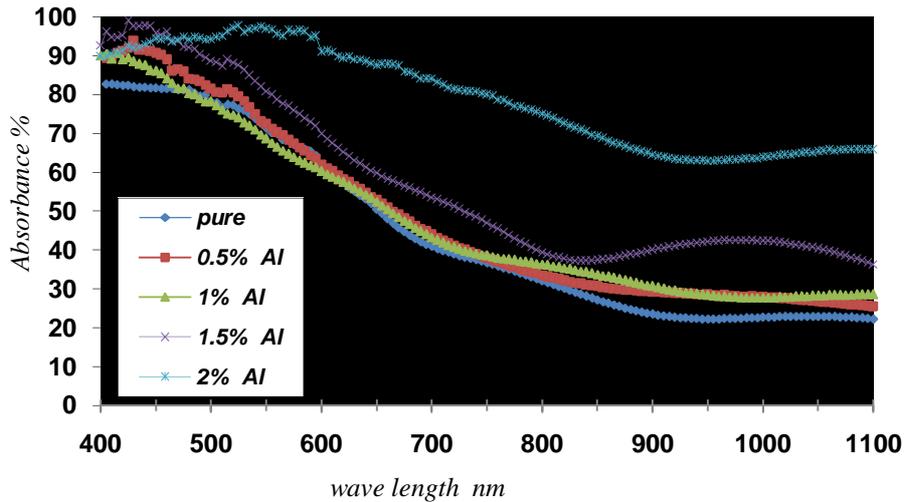


Figure (2): Absorption spectra of Pure and Al doped ZnTe thin films

The free carrier absorption of the photons` may also contribute to the observed reduction in the optical transmission of heavily doped films [10, 12]. The absorption coefficient (α) of a film of thickness (t) can be calculated from the transmittance spectrum using the relation [13]:

$$\alpha = (2.303) \frac{A}{t} \dots\dots\dots (1)$$

Where, A: is the absorbance, which is calculated from the relation $\{A = \log (1/T)\}$, (T) is the transparence. The calculated values of absorption coefficient are in the order of 10^4 cm^{-1} . The absorption coefficients as a function of photon energy ($h\nu$) are shown in Fig (3). From this figure can see higher absorption coefficient α with higher photon energies, the absorption coefficient α indicates a long band tail in the absorption curves, which may cause due to defects and impurities of the samples [14].

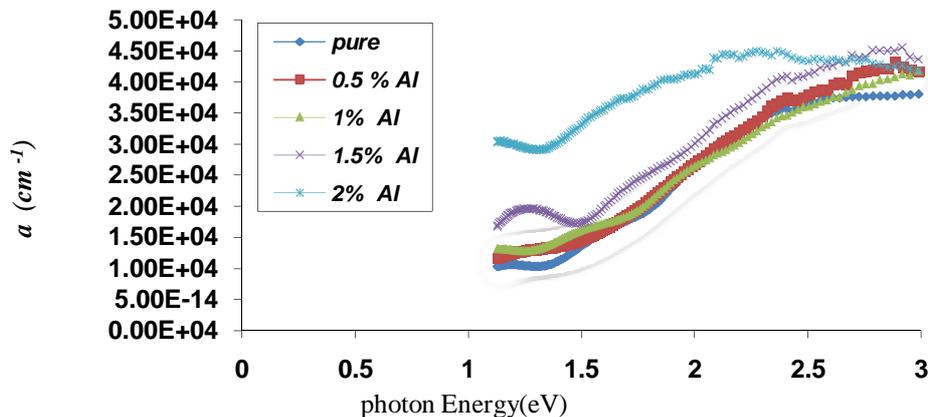


Figure (3): Variation of absorption coefficient as a function of photon energy of pure and Al doped ZnTe thin films

International Journal of Innovative Research in Science, Engineering and Technology

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The electronic transition between valence and the conduction bands, is given by the expression [15]

$$(\alpha h\nu) = B(h\nu - E_g)^r \dots\dots\dots(2)$$

Where, B is constant, α [cm^{-1}] is the absorption coefficient, $h\nu$ is the photon energy and E_g [eV] is the optical band gap. The parameter (r) is an index related to the nature of the material which is determined by the optical transition involved in the absorption process, it specifies the allowed direct ($r = 1/2$) and indirect transition ($r = 2$) in the electronic band structure. The optical band gap energy E_g was obtained from the intercept on the photon energy axis after extrapolating of the straight line section of the curve of $(\alpha h\nu)^2$ versus $(h\nu)$ plot. Fig (4) shows $(\alpha h\nu)^2$ against the photon energy ($h\nu$), when compared the band gap value of pure ZnTe films with Al doped films, it decreased in band gap value due to the segregation of impurities at the grain boundaries. The optical band gap value decreased from (1.92) eV to (1.54) eV, associated with the introduction of the Al impurity level between the valence and conduction bands [16]. similar observation have been made for In doped ZnTe films [17], and for Cu doped ZnTe films [18].

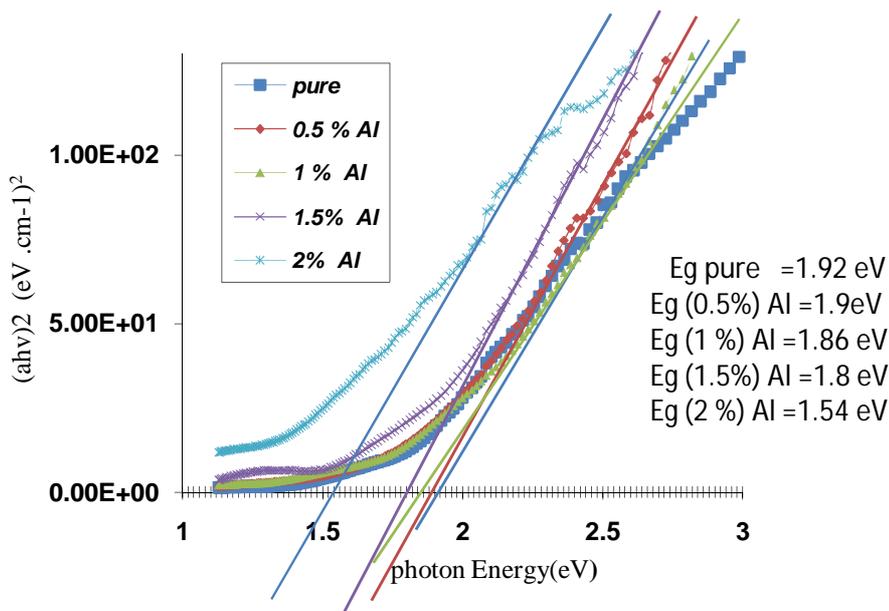


Figure (4): Variation of $(\alpha h\nu)^2$ with photon energy of pure and Al doped ZnTe thin films

Optical constants included refractive index (n), extinction coefficient (k), real part (ϵ_1) and imaginary parts (ϵ_2) of dielectric constant. The refractive index (n) can be calculated using following equation [19]:

$$n = \{ [4R / (R-1)] - K^2 \}^{1/2} - [(R+1) / (R-1)] \dots\dots\dots(3)$$

Where R is the reflectance which calculated by using equation ($R = 1 - T - A$).

From the absorption coefficient (α) can be calculated extinction coefficient (k) by [20]:

$$\alpha = 4\pi k / \lambda \dots\dots\dots(4)$$

Where λ : is the wavelength of the incident radiation. The fundamental electron excitation spectrum of the films was described by means of a frequency dependent of the complex electronic dielectric constant (ϵ), where can be introduced by [20]:

$$\epsilon = \epsilon_1 - i \epsilon_2 \dots\dots\dots(5)$$

Where $\epsilon_1 = n^2 - k^2 \dots\dots\dots(6)$

$$\epsilon_2 = 2nk \dots\dots\dots(7)$$

Where ϵ_1 = real part of dielectric constant, ϵ_2 = imaginary part of dielectric constant.

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It is obvious from Fig (5), the refractive index values increase with the increase photon energy, than at higher photon energy the refractive index values decreases reaching the lowest value, and decreases with the increase of Al dopants.

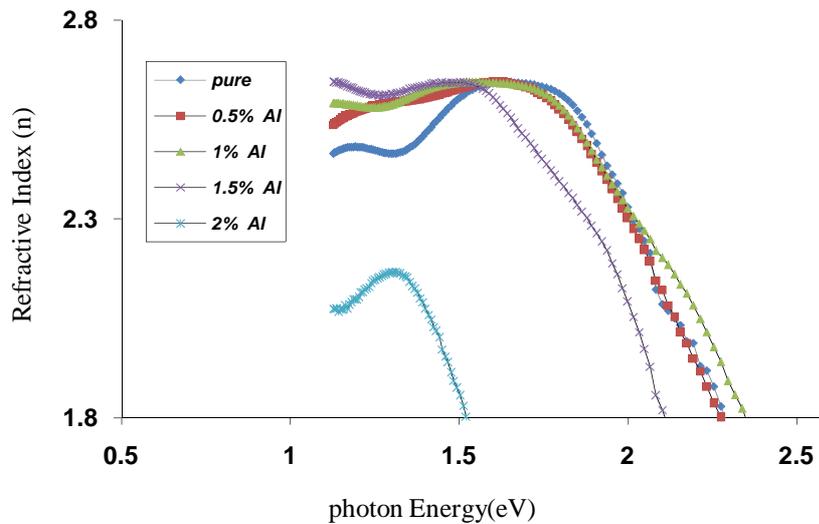


Figure (5): Variation of refractive index a function of photon energy of pure and Al doped ZnTe thin films

Fig (6) show the extinction coefficient increases with the increase of Al dopants, this behavior of refractive index and extinction coefficient may be due to the density of the localized states increases with increasing Al dopants. This behavior of the extinction coefficient values similar for all the range of the wavelength spectrum to that of the absorption coefficients for the same reasons as mentioned before.

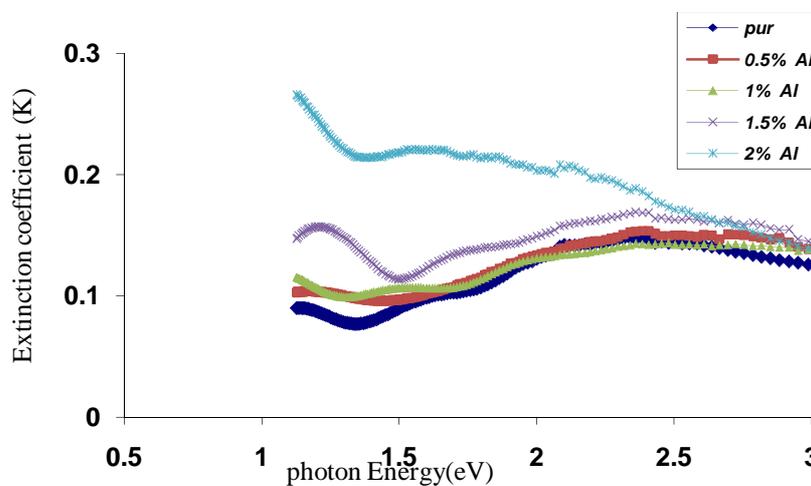


Figure (6): Variation of extinction coefficient as a function of photon energy of pure and Al doped ZnTe thin films

Fig (7) and (8) shows effect of Al dopants on the values of the real (ϵ_1) and imaginary (ϵ_2) parts of the dielectric constant. From this figure we can notice that the real part of the dielectric constant (ϵ_1) decrease with the increase of Al dopants in all the range of the spectrum while the imaginary part of the dielectric constant (ϵ_2) showed an reverse trend

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because the variation of (ϵ_1) mainly depend on the value of the refractive index while the (ϵ_2) value mainly depend on the extinction coefficient values which are related to the variation of absorption coefficient.

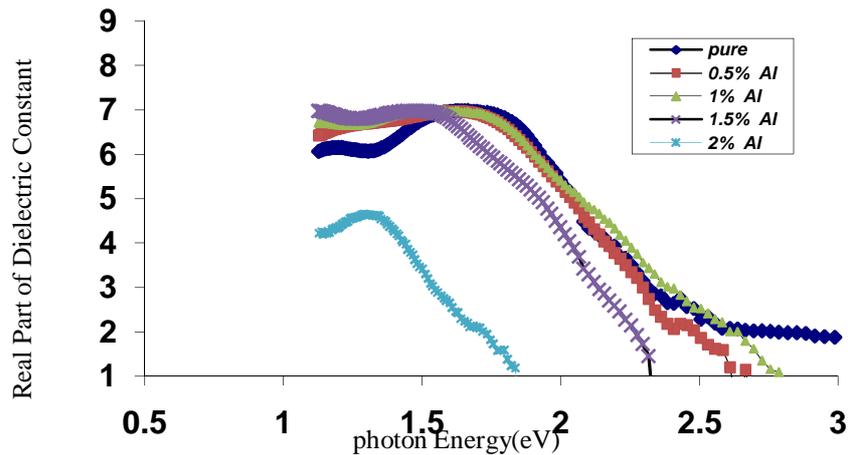


Figure (7): Real part of dielectric constant as a function of photon energy of pure and Al doped ZnTe thin films

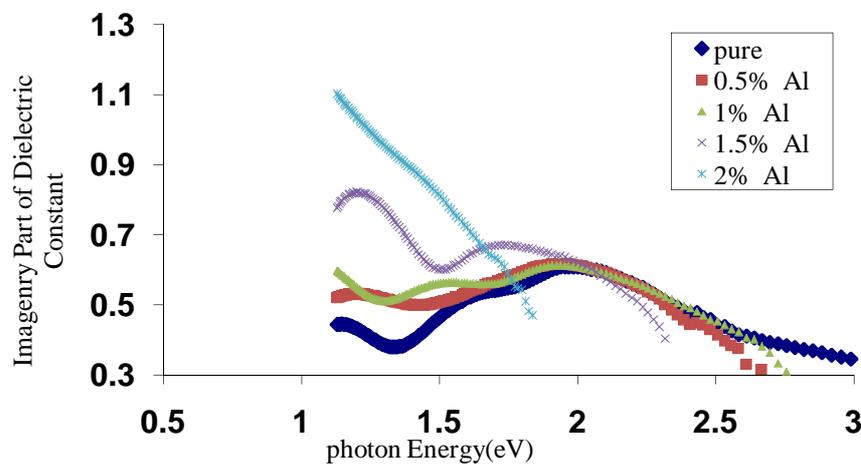


Figure (8): Imaginary part of dielectric constant as a function of photon energy of pure and Al doped ZnTe thin films

At last, table 1 shows the evaluated some of the optical constants values.

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Table (1): The optical constant of (ZnTe) films at different Al doping concentration

Al doping concentration	E_g^{opt} (eV)	Optical constant at $\lambda = 680$ nm				
		$\alpha \times 10^4$ cm^{-1}	n	k	ϵ_1	ϵ_2
0 % (pure)	1.92	2.01	2.59	0.102	6.73	0.567
0.5 %	1.9	2.14	2.55	0.117	6.48	0.599
1 %	1.86	2.17	2.54	0.12	6.46	0.601
1.5 %	1.8	2.5	2.36	0.139	5.57	0.633
2 %	1.54	3.9	1.12	0.213	1.224	0.661

IV. CONCLUSION

In conclusion, study in detail the optical properties of the ZnTe films were influenced by Al doping, the films deposited by Physical Vapor Deposition in vacuum technique. It was observed that the Al doping concentration has a strong effect on optical properties, where the transmittance value decreases with the increase of Al doping concentration and the absorption edge shifts to higher wavelength for higher Al percentage. The absorption coefficients increase with higher photon energies due to attributed to the introduction of impurity level. The optical energy gap values decrease when Al doping concentration increases and the variation in Al doping concentration decreases values of refractive index and real part of the dielectric constant while increases the values of the absorption coefficient, extinction coefficient, and the imaginary part of the dielectric constant when Al doping concentration increases.

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