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ARTICLE

Depending the Structural and Optical Properties of ZnTe Thin Films on Cd Doping by Thermal Evaporation

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Abstract

In this paper, pure ZnTe films doped with Cd were prepared by the thermal evaporation method in a vacuum and deposited on glass bases at a temperature (300°k) and thickness (300 ± 20) nm. Then annealing was performed at different temperatures (250 and 350) °C for 1 h. The effects of thickness and annealing temperature on the prepared films were studied. The X-ray measurements XRD results showed that all the films, whether they were pure or doped, had polycrystalline and cubic crystal structures and appeared to include some Te in their hexagonal phase, with growth in the direction (111) predominating in all the films made. The optical UV results showed that as the doping ratio went up, the energy gap values went down from 2.58 eV to 2.12 eV, while the transmittance spectrum went up as the annealing temperature went up.

Keywords: ZnTe:Cd thin films, XRD, SEM, Thermal evaporation, Optical properties

1. Introduction

Semiconductors are used in the manufacture of transistors and terminal devices such as rectifiers, photovoltaic cells, integrated circuits, and optical applications such as entering the field of optical communications, light-emitting diodes, detectors, and optical filters as they are used in solar cells [1,2]. ZnTe is a semiconductor material of the transition group (II-IV) and is used in most research. It is a p-type material with an energy gap (2.26−2.3 eV) characterized by a high absorption coefficient used in photovoltaic cells and electrochemical cells and with high conductivity and efficiency in solar cells [3] ZnTe is a polycrystalline zinc blende compound that is difficult to prepare due to its small crystalline size. The high sedimentation temperature works to evaporate the film, break it up or dissolve it, and make a line between the crystals. This line determines the Hall Mobility and raises the resistance of the film … [4]. It has an electronic affinity (3.53 eV) and is used to manufacture lasers and light-emitting diodes in the green and blue regions of wavelengths. The manufacture of such bipolar devices requires that the optical characteristics of the two sides of the installation be good, and that ZnTe is one of the most important composite semiconductors used for this purpose [5]. So, a number of researchers have looked into the structural, optical, and electrical properties of ZnTe films that have been doped with In, Cu, Cr, and Gd [6,7]. There have not been any studies on the structural or optical characteristics of thermal evaporated Cd-doped ZnTe (ZnTe: cd) thin films, though. So, in this work, we present the results of our investigation into the optical and structural characteristics of thermally vacuum-evaporated ZnTe thin films produced on glass substrates. These films have the potential to be used in defense and medical hardware.

2. Experimental work

The amount of powdered material that achieves the desired thickness (300 25 nm) in a molybdenum boat, which has a cover made of the same material

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to prevent the membrane from volatilizing during the sedimentation process, and the process will be according to the following law:

$$t = \frac{m}{\pi \rho r^2} \quad (1)$$

where, In this equation, m is the amount of material that has to be put into the boat (g), t: is the film's thickness (cm), r: represents the distance between the base and the boat (in centimeters), and ρ: is the material's density (g/cm^3). When the pressure reaches its maximum value (4 × 10-5) mbar, the process of the deposition begins by passing an electric current through the boat. It is known that the increases in flow must be slow and gradual for thermal equilibrium to happen inside the bell while the pressure gauge is being read. This is because a rapid rise in temperature causes a large rise in pressure inside the vacuum chamber. The material is deposited on the surface of the substrate at a temperature (300 K) fixed at a distance of (9 cm) from the boat and at a rate (2 nm.s-1) thus obtaining pure ZnTe films. After completing the deposition process, the samples are left in the deposition chamber until their temperature reaches room temperature in order to ensure the completion of the crystallization process and prevent the samples from oxidizing or cracking. After that, we doped the films with cadmium using another molybdenum boat, where the cadmium material is placed, which achieves one of the weight ratios required for doping (5,7 %) of the weight of ZnTe. The samples are kept in the evaporation chamber after the doping procedure is finished until their temperature approaches room temperature. After that, the samples of pure and cd-doped films are annealed by being heated to temperatures between 250 and 350 °C for an hour to assure the diffusion process, after which the samples are removed from the oven.

3. Results and discussion

3.1. Structural properties

Figure 1 shows the X-ray results (XRD) before and after annealing for (300 nm) thickness of ZnTe films prepared by the thermal evaporation technique in a vacuum, which showed that these films have a polycrystalline structure and cubic type with the

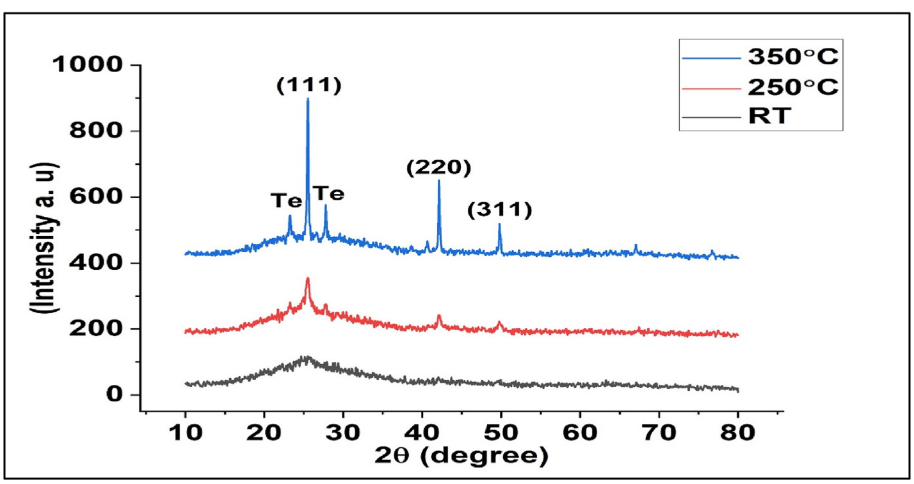

Fig. 1. X-ray diffraction pattern of ZnTe before annealing and after.

Table 1. Shows the structural parameters (crystal size, lattice constant).

Sample	Annealing temperature	2 (θ) d	θ (d)	Cos θ	a (Å) EXP.	a (Å) Sat.	β (rad)	G.S	hkl
ZnTe	RT	25.40	12.701	0.9755	6.07	6.04	0.01148	11.774	(111)
	250	25.53	12.766	0.9753	6.04	6.04	0.00753	17.929	(111)
	350	25.45	12.725	0.9754	6.05	6.04	0.00329	40.988	(111)
ZnTe: Cd 5 %	RT	25.35	12.676	0.9756	6.08	6.04	0.01055	12.807	(111)
	250	25.40	12.701	0.9755	6.07	6.04	0.01209	11.179	(111)
	350	25.24	12.623	0.9758	6.10	6.04	0.00411	32.839	(111)
ZnTe: Cd 7 %	RT	25.33	12.668	0.9756	6.08	6.04	0.00928	14.565	(111)
	250	25.43	12.718	0.9754	6.06	6.04	0.00895	15.101	(111)
	350	25.21	12.609	0.9755	6.11	6.04	0.00513	32.840	(111)

appearance of some hexagonal phase of Te. The X-ray spectrum showed the presence of three peaks at the apparent angles (25.55, 42, 12, & 49.79°) of the levels (111), (220) and (311) respectively, as it is clear that there is a dominant peak (111) before and after annealing and it increased significantly when the annealing temperature was increased. When comparing the results with the card, we find that there is a great agreement with the results as shown in Table 1 [8].

Figure 2 shows the X-ray diffraction spectrum of Cd-doped ZnTe films before and after annealing, with percentages of (5,7 %), respectively, as we notice an increase in the intensity of the diffraction peaks appearing at levels (111), (220), and (311) with the increase in doping ratios. One of the transitional metallic elements with bivalent Cd+2 is where the cadmium ion of ionic radius (0.97 Å) can contribute to balance charges with the host ion Zn^{+2} with ionic radius (0.74 Å) and takes a substitution position. The increase begins in crystallization by increasing the intensity of the peaks of the crystal levels as the annealing temperature increases as the atoms are arranged and aligned, and the intergranular boundaries decrease [9,10].

Figure 3 shows that the surfaces of the prepared films are evenly distributed, that their crystallization increases as the annealing temperature goes up, and that the size of the granules increases as the annealing temperature goes up, as the surface structure becomes more uniform [8,11].

In the case of films doped with Cd, the images in Figs. 4 and 5 show that the surfaces are smoother and the homogeneity increases. When crystal

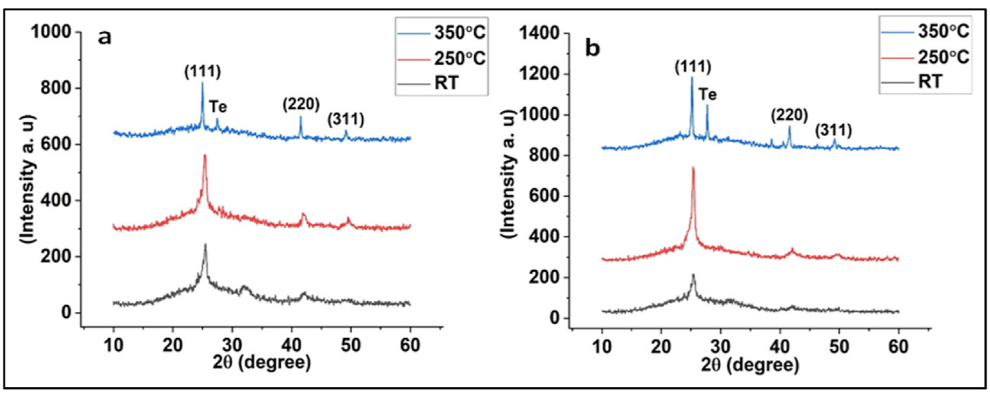

Fig. 2. Pattern X-ray diffraction for (Cd: ZnTe) thin films with two impurity ratios. (a) 5 %. (b) 7 %.

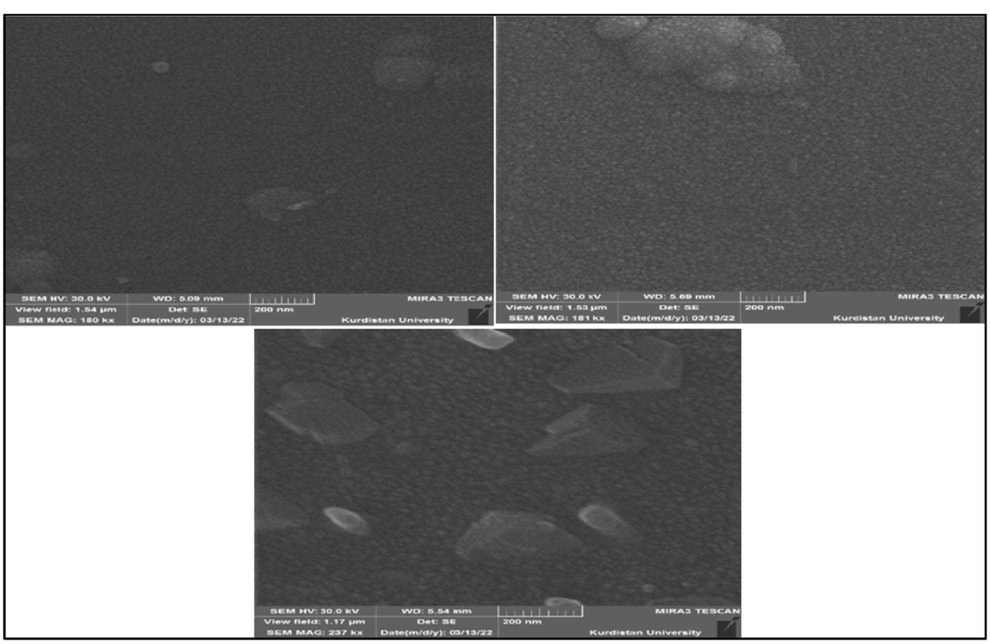

Fig. 3. SEM images of ZnTe thin films before and after annealing.

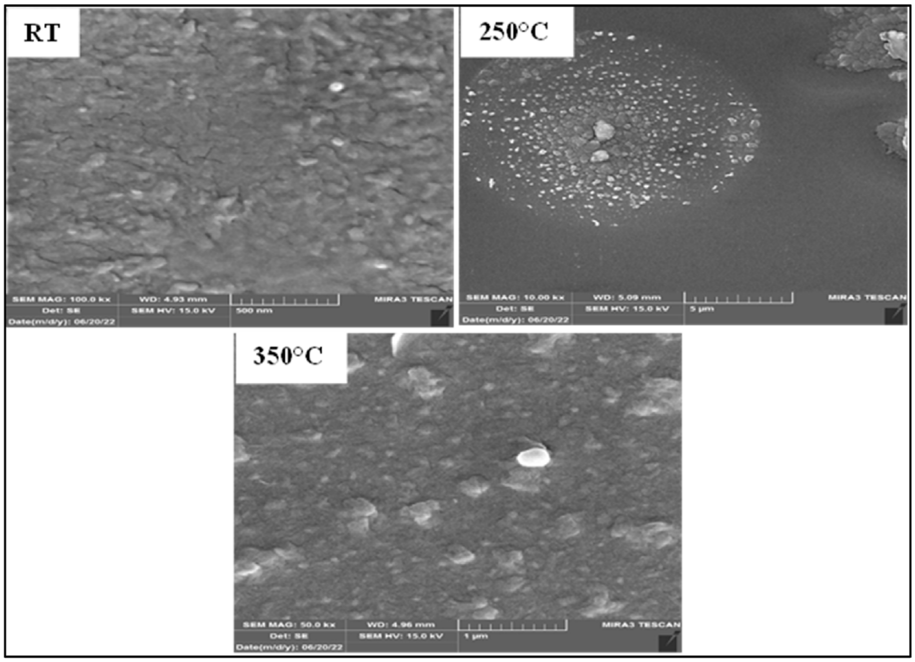

Fig. 4. SEM images of ZnTe thin films before and after annealing at x = 5 %.

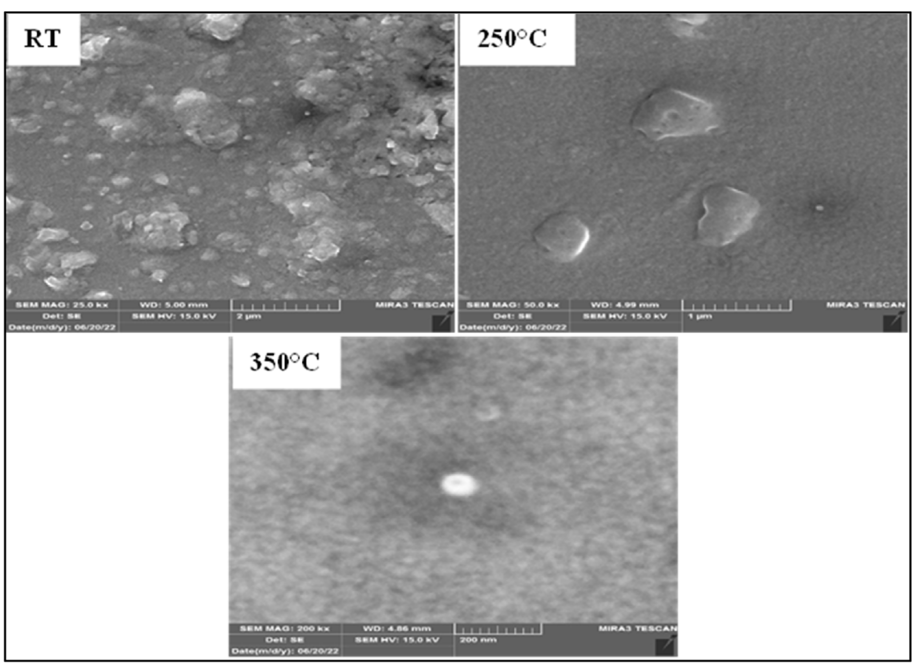

Fig. 5. SEM images of ZnTe thin films before and after annealing at x = 7 %.

growth is completed, the voids and crystal defects decrease when annealing [12].

3.2. Optical studies

The transmittance spectrum was calculated as a function of the wavelength in the spectral region (600−1000) nm with the thickness (300 nm) of ZnTe films at room temperature and annealing value (350 °C). According to Fig. 6, the annealing procedure results in a little rise in the transmittance value [13]. From Fig. 7, we notice that the transmittance spectrum of ZnTe films doped with Cd and annealed also increases with increasing wavelength

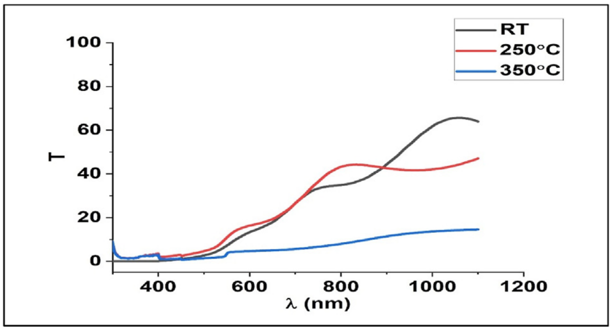

Fig. 6. Transmittance spectra of ZnTe at room temperature and the annealing (250, 350)°C.

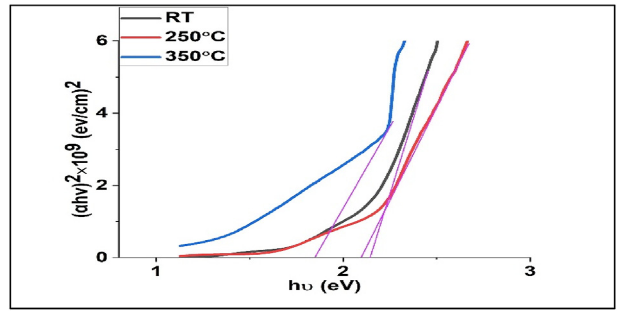

Fig. 8. Energy gap values of ZnTe at room temperature and the annealing (250,350)°C.

within the visible region of the electromagnetic spectrum (800-100) nm for all annealing temperatures to reach its peak and stability in the near infrared region (800 nm). There is higher radiation transmittance and good stability there [14].

The equation was used to figure out the difference in energy between pure and doped films that allowed direct electronic transitions:

$$\alpha h\upsilon = B_{\circ}\left(h\upsilon - E_g\right)^r \qquad (2)$$

where $B_{\circ}$ is a variable constant depending on the substance, h is photon energy (eV), Eg is energy gap (eV), and r is the exponential coefficient. Where $r = 1/2$, a graphic relationship is drawn between the energy of the photon (hυ) and (αhυ)2 and then a tangent to the high absorption region is drawn to cut the photon patency at ($y = 0$), where the point of intersection of the tangent on the axis (x) is the optical energy gap [9]. Figure 8 demonstrates that the energy gap peaks in the (ASTM) card were close to the theoretical values of ZnTe, which were roughly equal to (2.07 eV). During annealing, we observe that the energy gap peaks decrease with increasing temperature, and during the doping process, we observe that the gap decreases with increasing impurity concentration and with increasing annealing temperature [14] (see Fig. 9).

4. Conclusions

When X-ray diffraction XRD was studied, it was found that the pure and doped ZnTe films are all polycrystalline of the cubic type with a preferred growth direction of (111) before and after annealing, with the appearance of some hexagonal phase of Te. When studying the surface morphology with the device SEM, it was found that the films have homogeneity and uniform distribution. By studying the transmittance spectrum, it was found that the transmittance increases with increasing wavelength, its value decreases when doped, and its value increases after annealing for all films. It was found that as the doping ratio goes up, the energy gap goes

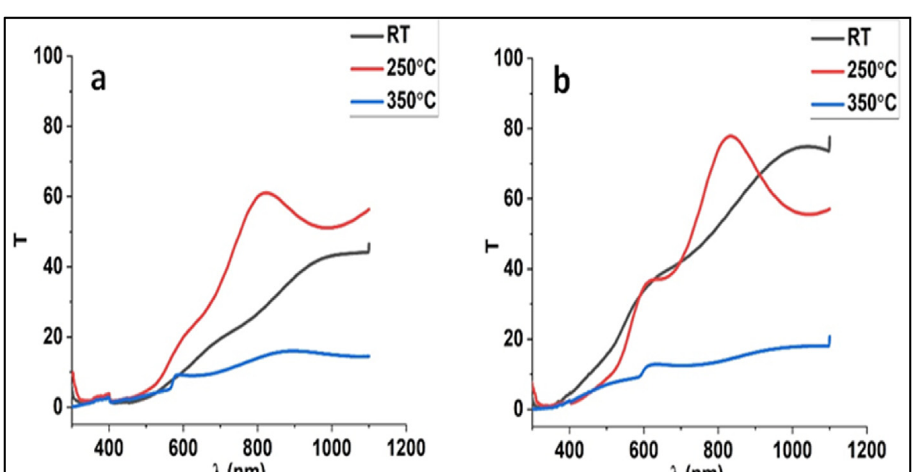

Fig. 7. Transmittance spectra of ZnTe: Cd at room temperature and the annealing temperatures (250, 350)°C, at (a) x = 5 %, (b) x = 7 %.

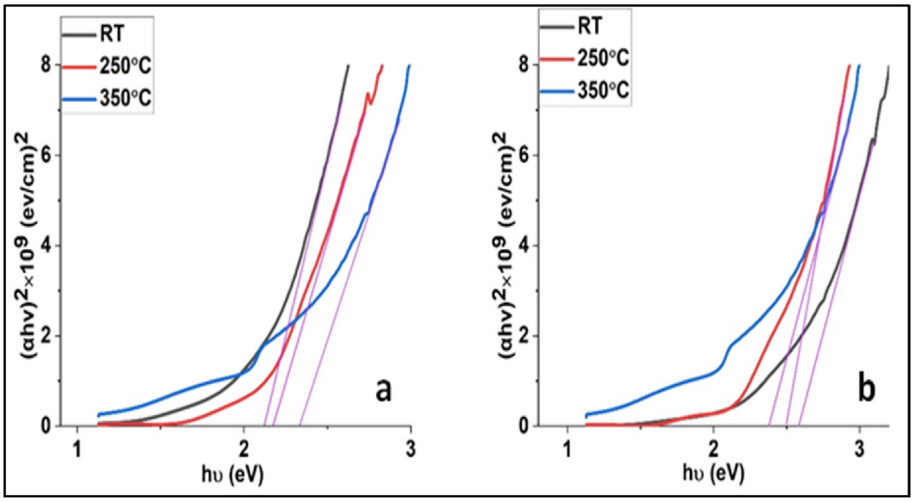

Fig. 9. Energy gap values of ZnTe at room temperature and the annealing (250, 350)°C, at (a) x = 5 %, (b) x = 7 %.

down, and after annealing, the energy gap goes up for all films.

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