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Influence of Tin Doped Cadmium Oxide on Structural and Optical Properties by Laser Induced Plasma

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Abstract:

In this research, the structural and optical properties of pure cadmium oxide films (CdO) prepared by pulsed laser sedimentation technique (PLD) in the vacuum were studied. Also, the effect of tin inoculations with tin ratios (0.1, 0.3, 0.5) was studied on the structural and optical properties of cadmium oxide films. Crystallization of the prepared membranes through X-ray diffraction technology (XRD), which showed that the synthesis of the prepared membranes is polycrystalline, and AFM images also showed that increased tin vaccination resulted increased the grain size and decreased surface roughness, as well as the absorption coefficient and the optical energy gap. For prepared films, It was found that both the absorption coefficient and the energy gap increase with the increase in the percentage of vaccination .

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(CdO) ҒNJTƽƵŭ ʒDŽNJƺəÙƱƵŭ ΘNJЬƱ!ŭ ҒNJcʊϧə ҒǉǂāŽŭ! ҒNJŇNJƱǂĶƵŭ ĐŭDŽƏƵŭ Ғбŭə ҜЧŽŭ ŭ؟ǁ ǈƧ ƸϿҫ ǂǉΘāTƵÙ ƸNJηlĶƵŭ ǂNJкÖϿҫ Ғбŭə Җǉ-γŭ ƮƵؚƱ Θŭ-ƨƵŭ ǈƧ (PLD) ǈҒšƵŭ ƀNJƶƵÙ ŇNJб-ĶƵŭ ҒNJƽTĶ ǂҒЧʒƵŭ ҒηNJĞ ĎЧƧ ƸϿҫ , ʒDŽNJƺəÙƱƵŭ ΘNJЬƱ!ĭ ҒNJcʊϧə ҒǉǂāŽŭ! ҒNJŇNJƱǂĶƵŭ ĐŭDŽƏƵŭ džƶN (0.5 , 0.3 ,0.1)ƂƽƵÙ ҒNJcʊϧəŭ ŇNJƱ-ϿҫƧӦҖƽNJǈĶƵŭ! (XRD) ҒNJƽNJЬƵŭ ҒηCəŭ əDŽNJϰ ҒNJƽTϿҫ Yāh ƼƸ ǂҒЧʒƵŭ ҒNJcʊĀƵ ĎŽƶĶƵŭ YΘηƸ əÙǉ⅏ džƵŭ Džəŭ ǂǉΘāTƵÙ ƸNJηlĶƵŭ əÙǉ⅏ ƻŭ (AFM) ĎŽƋ ҖƽNJ ƮƵؚƱ! ¤ ĎŽƶĶƵŭ əΘηĶƸ DŽǁ ǂҒЧʒƵŭ ҒNJcʊĀƵ ҒǉǂāŽŭ ҒƫÙlƵŭ ĎŽ¥Ƨ! ĐÙāĶƸĀŭ γƸÙηƸ ùÙЬϰ ƸϿҫ ƮƵؚƱ ¤ ҲlЬƵŭ ҒƽDŽCħ ϱÙƶƏƽŭ! ǈŇNJЧƵŭ Ƹ¥ЧƵŭ .ƸNJηlĶƵŭ ҒЬƽ əÙǉ⅏ ШƸ ƻŭəŭəbǉ ҒƫÙlƵŭ ĎŽ¥Ƨ! ĐÙāĶƸĀŭ γƸÙηƸ ƼƸ γƱ ƻĭ Θγ! ĶNJϰ , ǂҒЧʒƵŭ

***Keywords**: Cadmium oxide, Pulse laser deposition , Sn-doped CdO , thin films*

Introduction

The study of materials in the form of thin membranes is one of the appropriate means to know many of the physical and chemical properties of these substances, which make the harvest stake in its natural properties**.** **(1) (2)** Thin films are of industrial and technological importance as they interfere with many electronic applications, where it has been used for the processing of magnetic memory and in transistors and in the Integrated circles. solar cells and Detectors. **(3)** Cadmium oxide (CdO) is a semiconductor as it possesses a presence in nature in two synthetic forms, random and crystalline, and its random synthetic body is characterized as colorless, while its crystalline synthetic form is characterized by brown or red color**.** **(4)** It can be obtained (industrially) from intense heating. For pure cadmium in the air and for a specific temperature,

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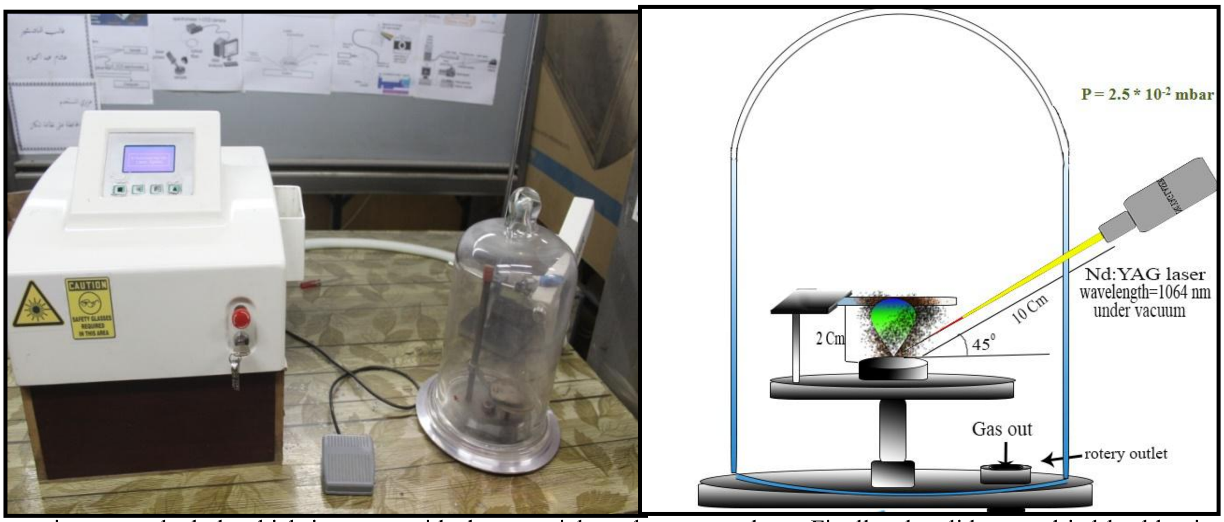
it is prepared laboratory with oxidation of cadmium vapor deposited in the presence of air and in special ovens (5) and has the ability to melt in acids and ammonia salts, while its solubility is lacking in water or bases.

Experimental

The pure cadmium oxide material Supplied or provided from the German company (FLUKA) was used with a purity (99.9%) to prepare the pure cadmium oxide films, as well as a cadmium oxide tainted with tin was prepared by adding the pure tin (Sn) prepared from the company (Alfa Aesar) and purity (99.8%) And with vaccination ratios (0.1, 0.3, 0.5), then the mixture mixes well and then the material powder is placed under the hydraulic piston, where a pressure of (8 Ton) is applied, so that the target will be in diameter (2.4 cm) and thickness (0.5 cm). After that, glass slides with dimensions **(2.6 * 7.6) cm** were used and cleaned using distilled water placed in the ultrasonic device, then the same step was repeated



using pure alcohol, which interacts with the materials and removes them. Finally, the slides are dried by blowing them with air and then Wipe it with a soft texture.

Figure (1) parts of the PLD system

After the preparation of the targets and the glass slides begin the sedimentation phase by pulse laser (PLD) as the value of the pressure inside the room is ($2.5\times \mathbf{10^{-2}}$ **mbar**) for the purpose of contributing to the ionization of the material. Where the laser beam falls on the surface of the target at an angle $(\mathbf{45})^{\circ}$and the base is placed in front of the target and parallel to its surface, as shown in figure (1), bearing in mind that the distance between the target and the base is sufficient so that the base holder does not obstruct the falling laser beam.

Results and discussion

The results of the examination with The X-ray Diffraction Technology (=λ 1.5406 Å) showed that the pure prepared cadmium oxide films had a polycrystalline structure (Cubic type) with atomic growth with three crystal line trends [111], [200], [101] and the angles of the diffraction correspond (33º) (30.6º) (32º) , respectively, which was distinctive and prevalent (depending on the method of precipitation) in the direction [111] and the pure membranes as in the figure (2) correspond to the According to published research (6) (7) films inlaid with different combinations of (CdO:Sn) showed preferential growth towards the crystal line (200) with increased concentration of (Sn). This increase in peak density suggests that there may be an improvement in the crystalline composition of the film due to increased concentration of steroids. This is consistent with the research published (8) (9) (10) where the peak position (111) was converted slightly towards the peak (200) when the concentration of steroids increased, which is due to the shrinking of the (CdO) crystalline network due to the replacement of (Sn) ions with(Cd) ions.

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It was calculated the rate of grain size (C. S) of membranes prepared (Table 1) using the equation of (Formula Scherer s) **(11)**

$$D = \frac{0.94\,\lambda}{B_{FWHM}\cos\theta} \quad \ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

D is average particle size and (θ) Brag angle

It was shown that the granular volume increased by increasing the ratios of the vaccination used to (56.6 nm) at the vaccination ratio (0.5) and this is consistent with the results of the research **(12)**

Table No. (1) Synthetic parameters of (CdO: Sn) films obtained from (XRD)examination.

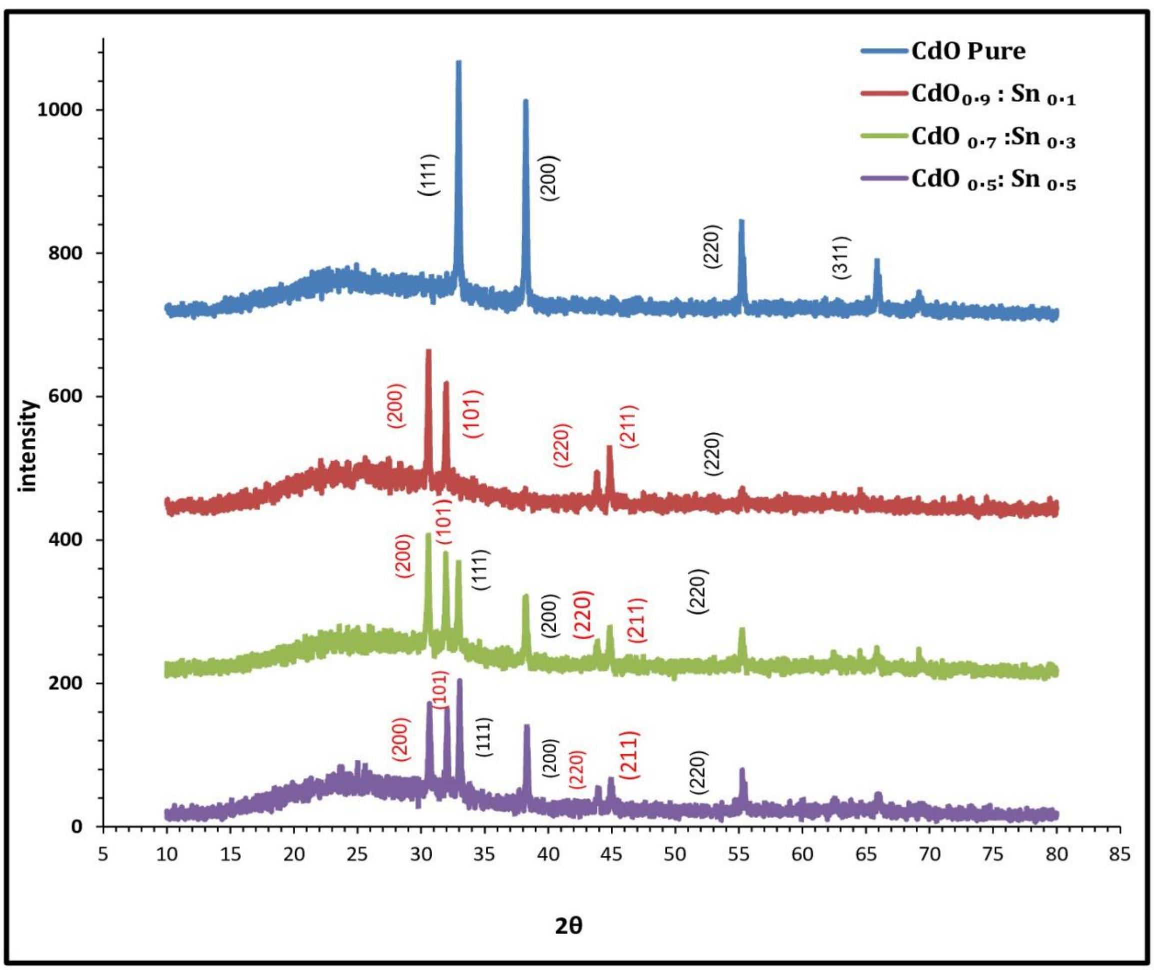


Figure (2) X-ray diffraction pattern for membranes (CdO:Sn)

material	2θ (Deg.)	FWHM(Deg.)	C.S (nm)	d_{hkl} Exp.(Å)	d_{hkl} Std.(Å)	hkl
CdO Pure	32.9681	0.17010	48.52	2.71473	2.7120	1 1 1
	38.2562	015650	52.73	2.35076	2.3490	2 0 0
	55.2349	0.16050	51.42	1.66168	1.6610	2 2 0
$CdO_{0.9}:Sn_{0.1}$	30.5995	0.15790	52.27	2.91925	2.9150	2 0 0
	31.9861	0.15680	52.63	2.79580	2.7930	1 0 1
	44.8717	0.13650	60.46	2.01835	2.0170	2 1 1
$CdO_{0.7}:Sn_{0.3}$	30.5941	0.16450	50.17	2.91976	2.9150	2 0 0
	32.9596	0.16350	50.48	2.71541	2.7120	1 1 1
	31.9770	0.17550	47.02	2.79657	2.7930	1 0 1
$CdO_{0.5}:Sn_{0.5}$	33.0513	0.14580	56.60	2.70808	2.7120	1 1 1
	38.3397	0.16930	48.75	2.34583	2.3490	2 2 0
	30.6792	0.16350	50.48	2.91185	2.9150	2 0 0

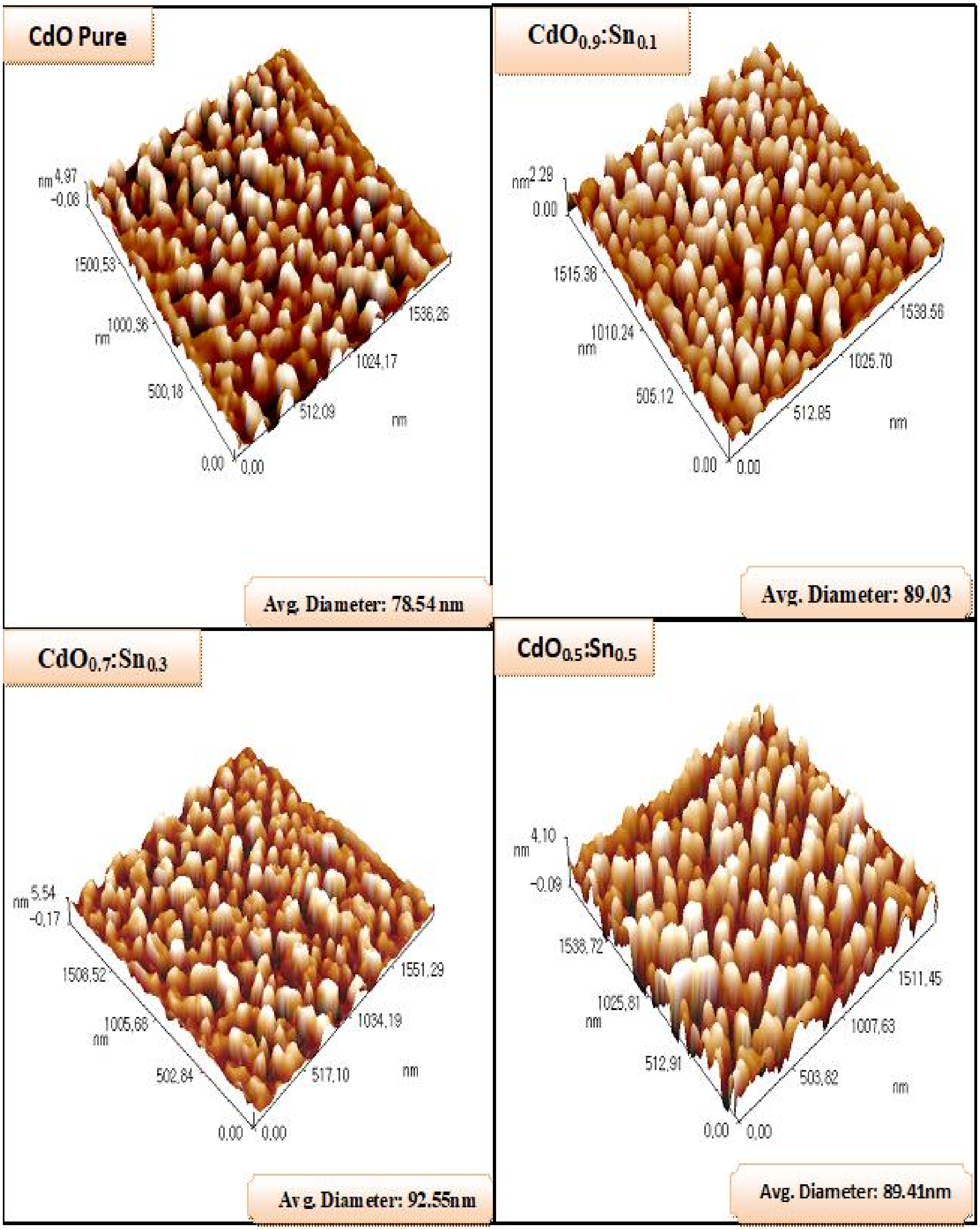


Figure (3) three-dimensional images of (CdO: Sn) films and of various vaccination ratios

Figure (3) shows the variation in surface morphology of the thin films (CdO: Sn) prepared using different tin vaccination ratios (Sn). The sediments were uniform pyramidal granules, and they were well bonded to the substrate. The highest roughness for grafted films was (1.24 nm) at the rate of vaccination (0.3), and this indicates that the surface is homogeneous. Also shown is an increase in the average diameter of the particles and a decrease in the surface roughness of the films with an increase in doping. Table No. (2) This result indicated that the grain size and surface roughness of the(CdO) membranes can be controlled by vaccination, and the increase in grain size indicates an increase in crystallization with a decrease in grain boundaries (13)

Table (2): Synthetic parameters of CdO:Sn membranes obtained from the (AFM) examination.

Sample	Average diameter (nm)	Average roughness (nm)	Root mean square (nm)
CdO Pure	78.54	1.26	1.46
$CdO_{0.9}$: $Sn_{0.1}$	89.03	0.5	0.593
$CdO_{0.7}$: $Sn_{0.3}$	92.55	1.24	1.47
$CdO_{0.5}$: $Sn_{0.5}$	89.41	1.04	1.2

After examining the (UV-Visible) membranes and drawing the relationship between the wavelength (λ) and the Transmittance of each of the prepared films, we notice from Figure (4) an increase in Transmittance with an increase in the wavelength of all the prepared films and that the vaccination process did not show any change in The general form of the Transmittance curve, and that the highest Transmittance obtained was for pure cadmium oxide films (72%) at the wavelength (500 nm). The Transmittance decreases by increasing the vaccination ratios to about (10%) due to impurities atoms and the accompanying composition of local levels within the energy gap between the valence and conduction beams, and this decrease in permeability Its visible range makes it suitable for optical applications.

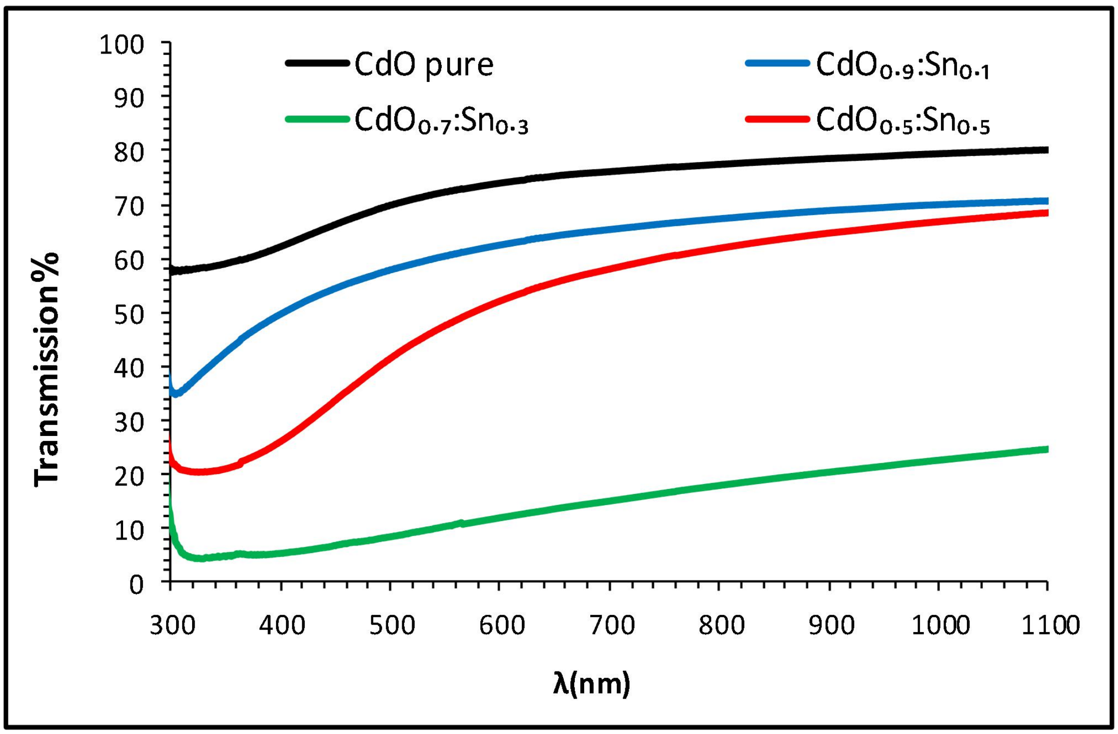
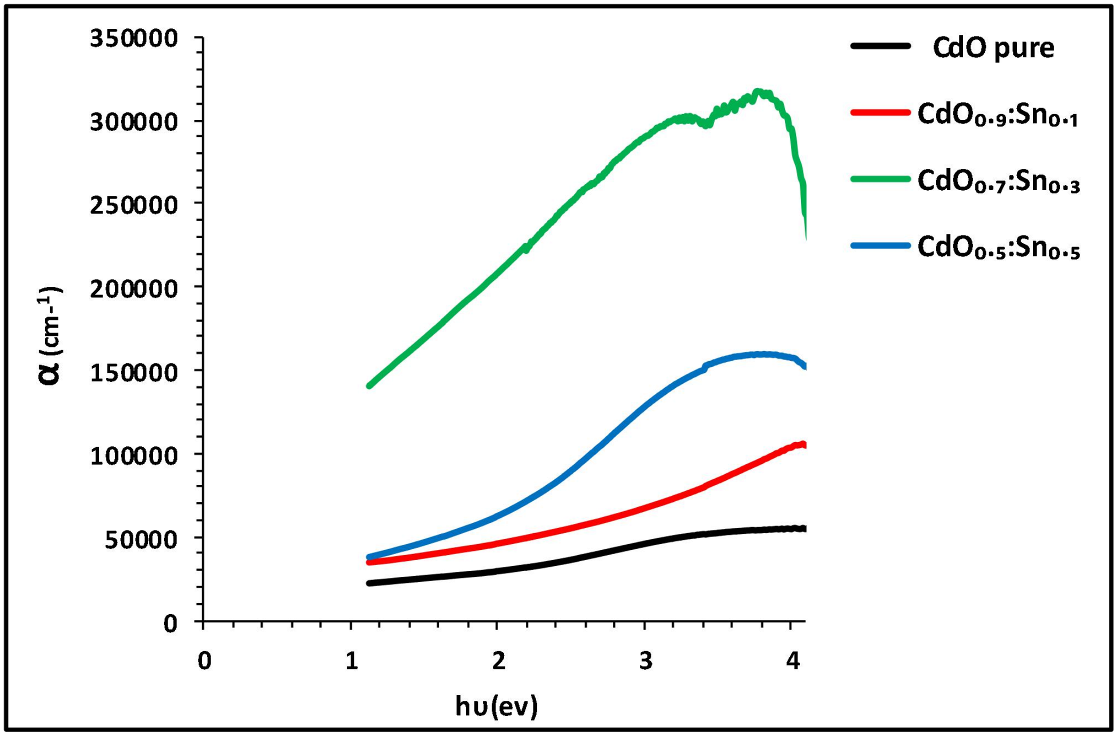


Figure (4) the spectrum of transmittance as a function of wavelength membranes (CdO) pure and with (Sn).

The optical absorption coefficient (α) from the absorbance spectrum of thin films (CdO: Sn) at room temperature was calculated using the following relationship (14)

$$= \alpha \quad \frac{2.303A}{t} \text{……………(2)}$$

Where (A) is the absorbance of the film.



Figure(5) Change of absorption coefficient with photon energy for a pure and tinged CdO film

Figure (5) shows that the absorption coefficient generally begins with a gradual increase with the increase of the energy of photons that fall, until its value becomes greater than (10^4 cm^{-1}). This is consistent with what the study reached **(15)** and then the value of the absorption coefficient continues to increase with increasing energy ranges That exceeds the value of the optical energy gap for all prepared membranes, which indicates the possibility of direct electronic transitions between the valence and conduction beams at these energies. Also, it is observed from Figure (5) that the absorption coefficient increases significantly with increased vaccination rates taken at low photon energies, Which means that atoms are a Impurities have helped spot levels have created an increase absorbance and thus increasing the absorption coefficient according to the equation (2) , and this is consistent with the findings of the studies.

Calculating the optical energy gap is of great importance, as it gives us a clear idea of optical absorption and is a basic measure of spectral selectivity. The energy gap was calculated based on the following formula **(16)**

$$\alpha h\upsilon = \beta(h\upsilon - E_g^{OPt})^r \text{................}(3)$$

(α) is Optical absorption and (hυ) is incident photon energy

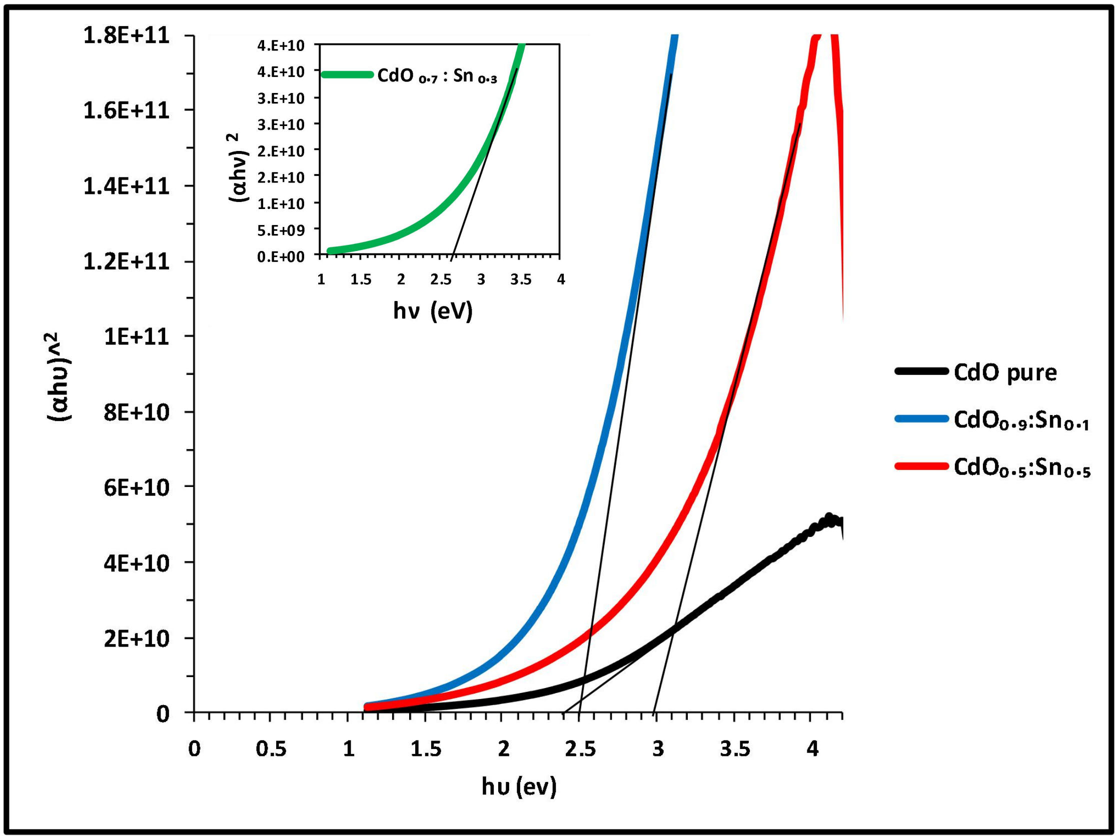


Figure (6) represents the optical energy gap of pure and doping film

From Figure (6) it becomes clear that the values of the film's optical energy gap (pure) is (Eg =2.4eV), at which time the value of the absorption coefficient ($\alpha \geq 10^4$) indicates that the energy gap of all the prepared films was a direct gap ، and this is consistent With published research result (17). The preparation is within different preparation techniques. With increase concentration of (Sn) the optical band gap of (CdO) was found to increase in all the samples. The aliovalent (Sn) doping increases the free carrier (electron) concentration in the material which shifts the Fermi level into the conduction band. This phenomenon is widely known as Moss–Burstein shift . The band gap of the nanocrystals increases from (2.4ev) to (3 ev) with increasing Sn concentration . and this is consistent with the findings of the studie (18).

Table (3) shows the values of the optical energy gap of pure and doped CdO films

Sample	Eg (ev)
CdO Pure	**2.4**
$CdO_{0.9}$: $Sn_{0.1}$	**2.5**
$CdO_{0.7}$: $Sn_{0.3}$	**2.6**

$CdO_{0.5}$: $Sn_{0.5}$	**3**

Conclusions

The cadmium oxide film and tin-impregnated films had Polycrystalline structure and the addition of impurities led to a peak shift from [111] to [200] and also increased the granular size, by studying the results of visual tests showing that the transfer of electrons from the valence beam to the conduction beam It was permissible direct electronic transmission, and that increased vaccination led to an increase in the absorption factor and a increase in the forbidden energy gap.

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