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Effect of Indium Doping on the Structural and Optical Properties of CdO thin films

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ABSTRACT

The aim of this study is to investigate the effect of indium doping on structural and optical characteristics of CdO thin films prepared by spray pyrolysis. According to x-ray diffraction analysis, the studied samples are polycrystalline with preferred orientation along (111) orientation. The surface topography determined by AFM and SEM indicates that the surface roughness and root mean square (RMS) values were increased as the indium doping concentration increased. The determinedoptical energy gap were found to lie between (2.47-2.84)eV.

Introduction

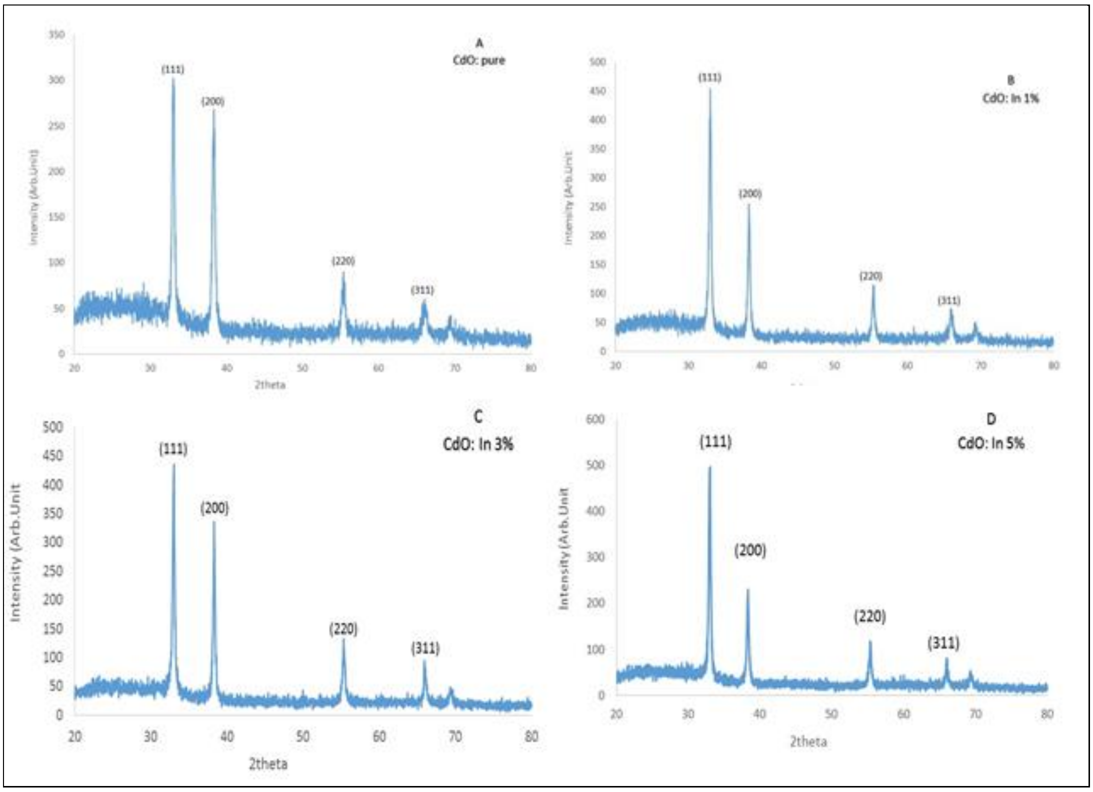
Metal -doped cadmium oxide (CdO) has been widely used in many optoelectronic applications like solar cells [1], solid state gas sensors[2], transparent electrodes [3], and diodes[4]. CdO thin films showed transmission in the UV and visible regions with high ohmic conductivity as well. It has n-type semiconducting and optical band gap between (2.2 – 2.7) eV relying on the technique and the preparation conditions of the method used [5-7]. CdO thin films have been prepared by several ways such as, SILAR method [8], Spray pyrolysis [9], Vacuum evaporation [10], magnetron sputtering [11], pulsed laser deposition [12], sol-gel[13], solid state reaction (SSR) [14], Bath Chemical technique[15].

Experimental Procedure

CdO and CdO:indium(In) thin films were prepared by chemical spray pyrolysis technique. A homogeneous solution was prepared by dissolving cadmium acetate $Cd(CH_3COO)_2$-H_2O (0.1 mol/L) in 100 mol re-distilled water and Indium chloride $Incl_3$ with (1,3,5% V/V) with CH_3COOH as aiding solvent. CdO and CdO : In thin films were deposited by spraying an aqueous solutions onto glass substrates at 425°C . The optimized deposition parameters like spray nozzle- substrate distance (29± 1 cm), spray time (8 s) and the spray interval (60 s) were kept constant . The carrier gas (N_2) pressure was 10^5 N/cm^2. X ray diffraction (XRD) easurements were recorded by XRD diffractometer type Philips pw 1850, Cu-Kα target . Atomic force microscopy was carried out by using Spm AA 3000 Å , Advanced Inc., USA. Optical measurements were performed by Shimadzu double beam UV-V spectrophotometer at (300-900) nm.

Results and discussion

Fig. 1 shows the XRD patterns of the CdO and CdO: In films prepared at different indium concentrations (1,3,5)% respectively. All patterns show polycrystalline of cubic CdO structure and the CdO: In, films are composed of crystallites of CdO (JCPDS card NO: (ICDD 36 - 1451), International Center For Diffraction Data CdO) and have preferred orientation along (111) orientation.



Fiq.1. XRD of CdO and CdO:In thin films at different In concentrations

The width and intensity of the peak were found depending on the concentration. Peak shifts towards lower angles Compared to un doped CdO value may be due to the lower ionic radius of In when compared to Cd ionic radius. From the full width at maximum (β) the average crystallite size (D_{av}) was estimated according to Scherrer formula [16].

Average crystallite size (D_{av}) $= \frac{0.9\lambda}{\beta \cos\theta}$ (1)

Where λ is the X-ray wavelength, β should be in radian and θ Corresponds to the position peak . The results are shown in Table (1) .

Table 1. Crystallite Size , Surface roughness Average and RMS value of the deposited films of CdO

Thin Films	Surface Roughness Average (nm)	Root Mean Square RMS (nm)	D_{av} (nm)
CdO pure	0.459	0.569	39.444
CdO :In 1%	1.28	1.48	41.1955
CdO :In 3%	1.69	1.98	47.9237
CdO :In 5%	1.91	2.31	51.9655

AFM images of the prepared films under varied In concentrations are shown in Fig.2. For all the prepared films, an area of (99.13-64.78) nm has been used for evaluation. As seen from Table 1, the surface roughness average and root mean square RMS values were increased as In concentrations increased, due to the crystalline structure of the films [17].

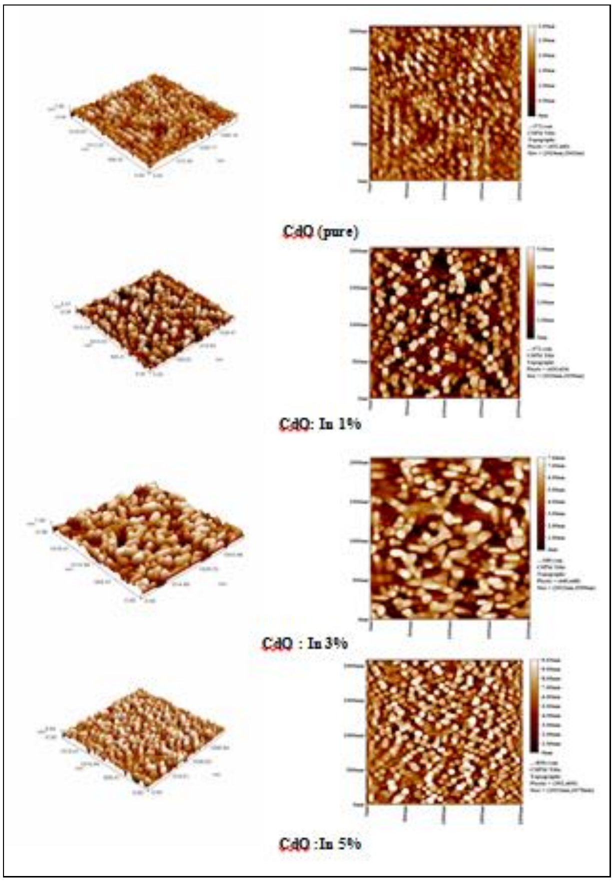


Fig.2. AFM images for CdO and CdO:In thin films at different In concentrations

SEM images of un-doped and In doped CdO thin films showed that all prepared thin films have a uniform and homogeneous coverage of spherical grains (Fig.3).

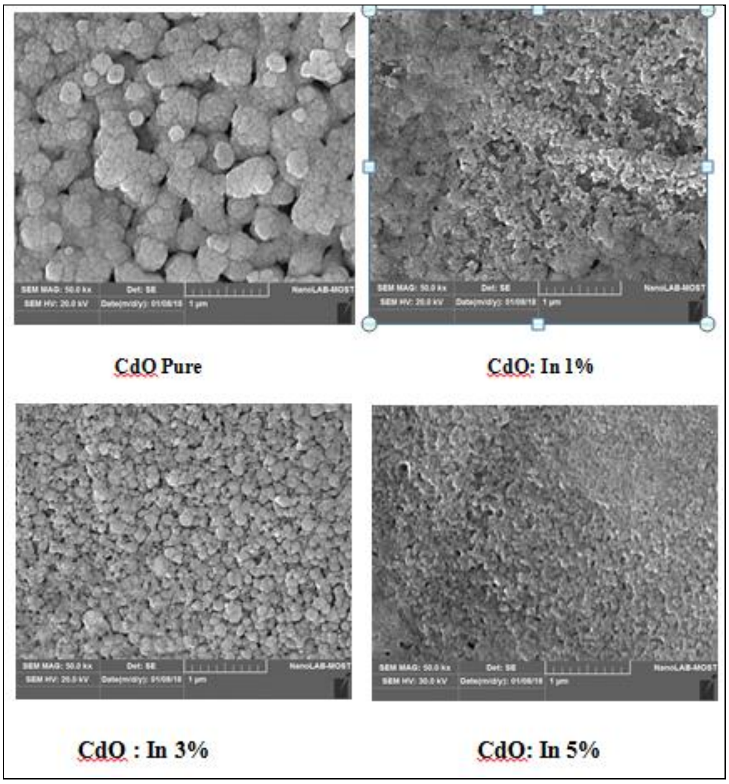


Fig.3. SEM images for CdO and CdO:In thin films at different In concentrations

Optical transmittance spectra of the CdO and CdO: In at different In concentrations in the range of (380-900) nm are shown in Fig.4. As seen from this Figure, the transmittance of all prepared films was increased with the increase of In concentration. Transmittance increased up to 85% (900nm) and this was due to the decreased absorbance of the film within this region.

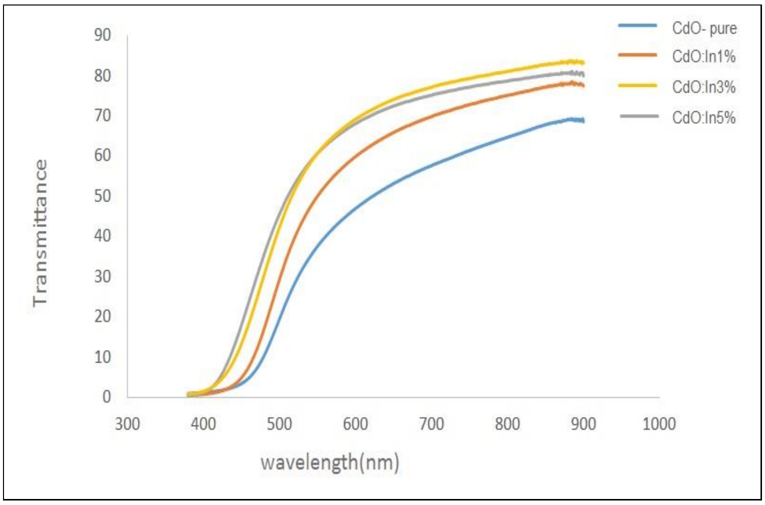


Fig.4.Optical transmittance versus wave length at different In concentrations

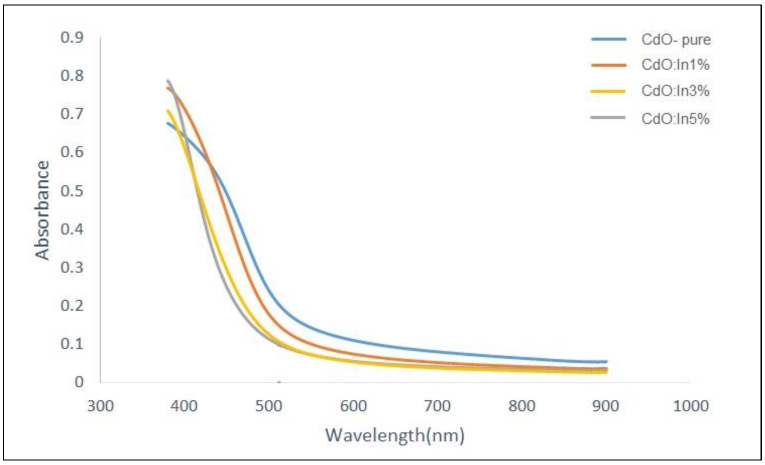


Fig.5. Absorbance versus wave length at different In concentrations

The deposited films at lower In concentration have less transmittance in the visible region in comparison with the films at higher In concentration. The increase in transmittance may be attributed to the increase in structural homogenity and crystallinity of the film with the increase of In concentration [18] . Fig.5 shows the optical absorbance spectra of CdO and CdO: In thin films at different In concentration. Results from the figure revealed that the maximum absorption occurs near 400nm, and starts to decay exponentially in the visible region. The spectra showed that the absorbance was decreased by the increase in In concentration.

The ability of a material to absorb light is measured by its absorption coefficient. Variation of optical absorption coefficient with photon energy for various In concentrations is shown in Fig.6, which reveals that the absorption coefficient is in the order of 10^4 cm^{-1} and this agrees with kumarovel [19]. The absorption coefficient (α) is calculated from the transmittance spectrum using the following relation [20].

$\alpha = \ln (1/T)/t$ ……. (2)

Where T is the transmittance and t is the thickness of the film.

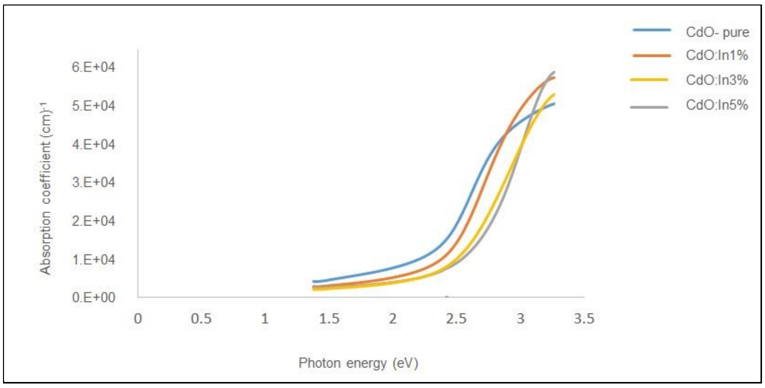


Fig.6. Variation of optical absorption coefficient with photon energy for different In concentrations

The optical energy gap (Eg) was estimated by assuming a direct transition between valance and conduction bands and by applying Tauc's relation Eg can be obtained following this relation [21].

$\alpha h\nu = K(h\nu - Eg)^{1/2}$…….. (3)

Where K is constant, hν the incident photon energy , Eg is determined by extrapolating the straight line position seen in fig.6 to α hν=0 , it can be observed from this figure that the value of the optical band gap increased by doping from (2.47 to 2.84) eV .When doping concentration was increased, The Fermi level was shifted to higher energy states due to the electron populated states in the conduction band , which could cause band broadening [22] . This band gap widening is important for TCO application such as solar cells. This increment may be due to the enhancement of crystallite order which can be clearly seen from XRD and AFM results.

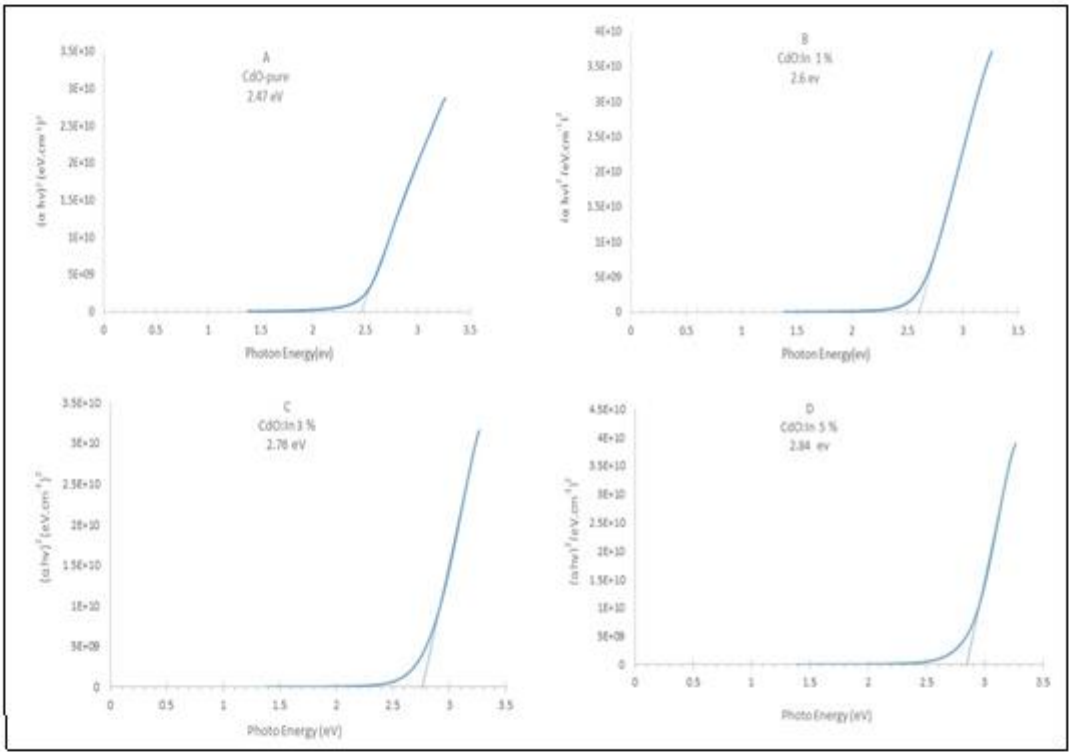


Fig.7. $(\alpha h\nu)^2$ versus wave length at different In concentrations.

Fig.8 shows the variation in the refractive index with wavelength. This Fig. shows. that the refractive index of the films decrease with the increase in In concentration. This decrease may be due to the larger grain size and lower strain in the film deposited at different In concentrations.

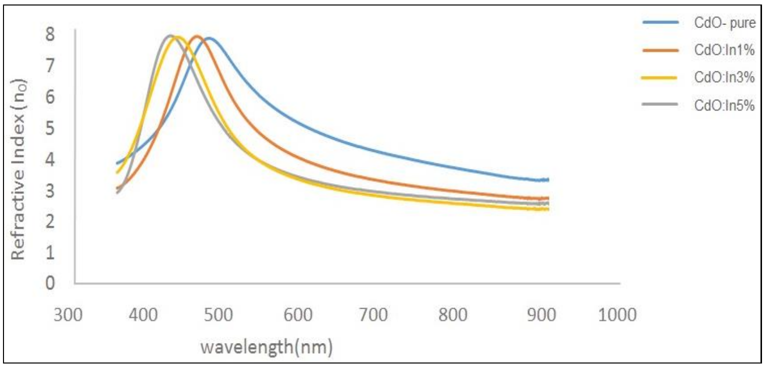


Fig.8. Refractive index versus wave length at different In concentrations.

Conclusion

CdO and CdO:In thin films have been successfully prepared by spray pyrolysis method .The effect of In doping had been studied. The structure and optical properties were determined. XRD, AFM and SEM results were in coincidence, where the grain size increased with the In doping increase and by the increase in In doping the energy gap was increased as well.

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تأثير التطعيم بالانديوم في الخصائص التركيبية والبصرية لأغشية CdO

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الملخص

الهدف من البحث هو دراسة تاثير التطعيم بالانديوم في الخصائص التركيبية والبصرية لغشاء CdO المحضر بطريقة التحلل الكيميائي الحراري. تبعا لتحليل حيود الاشعة السينية بينت النتائج ان جميع الاغشية ذات تركيب متعدد التبلور وان الاتجاه السائد هو (111). وجدت الطوبوغرافية السطحية من خلال مجهر القوة الذرية والمجهر الالكتروني الماسح وتبين ان معدل الخشونة السطحية وقيم مربع الجذر يزداد بزيادة نسب التطعيم بالانديوم. كما وجد ان فجوة الطاقة البصرية بحدود eV (2.47-2.84).