



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

Muthanna K. Mahmood¹, Hanan R. A. Ali¹, Khudheir A. Mishjil²

¹ Department of Physics, College of Education for Pure Sciences, University of Tikrit, Tikrit, Iraq

² Department of Physics, College of Education, University of Al-Mostansiriyah, Baghdad, Iraq

DOI: <http://dx.doi.org/10.25130/tjps.24.2019.051>

ARTICLE INFO.

Article history:

-Received: 6 / 8 / 2018

-Accepted: 2 / 10 / 2018

-Available online: / / 2019

Keywords: CdO, thin films, Spray pyrolysis, XRD, AFM, SEM.

Corresponding Author:

Name: Muthanna K. Mahmood

E-mail: mmfq2023@gmail.com

Tel:

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 $Cd(CH_3COO)_2 \cdot H_2O$ (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

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 determined optical energy gap were found to lie between (2.47-2.84)eV.

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/cm². X ray diffraction (XRD) easurements were recorded by XRD diffractometer type Philips pw 1850, Cu-K α 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.

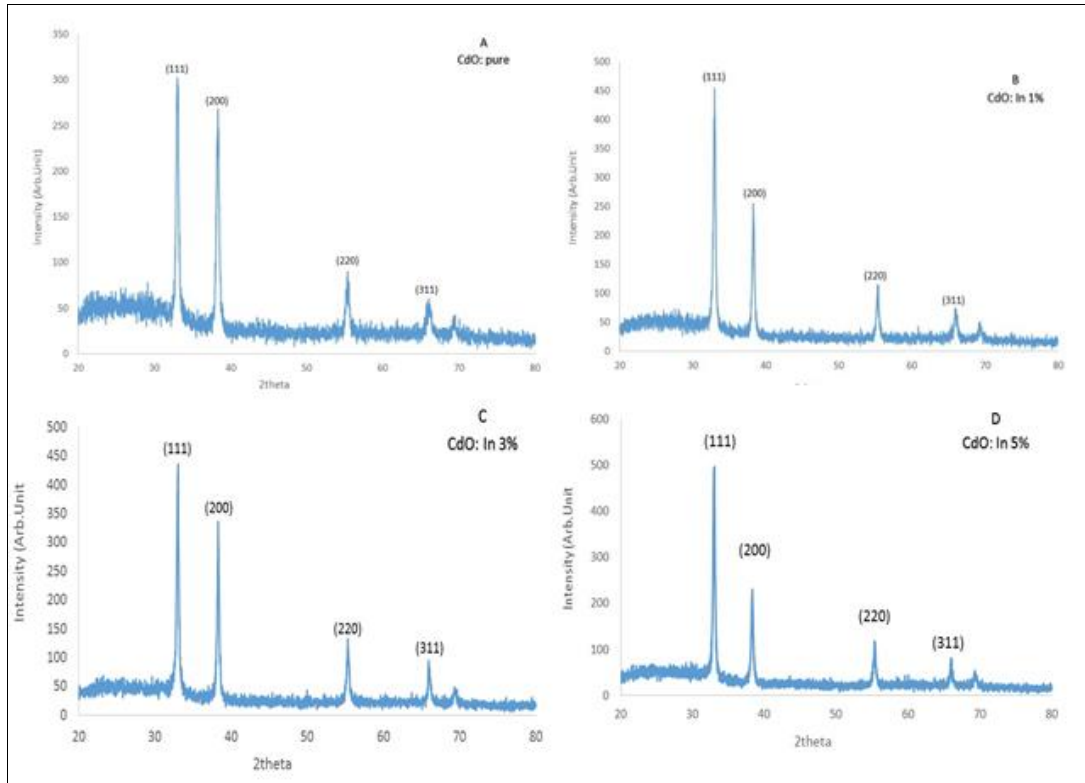


Fig.1. XRD of CdO and CdO:In thin films at different In concentrations

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].

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

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].

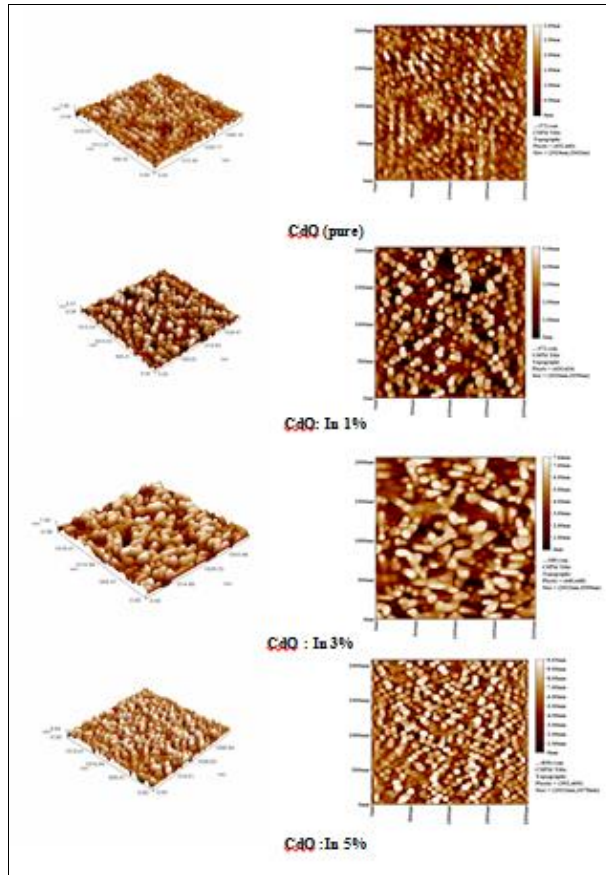


Fig.2. AFM images for CdO and CdO:In thin films at different In concentrations

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).

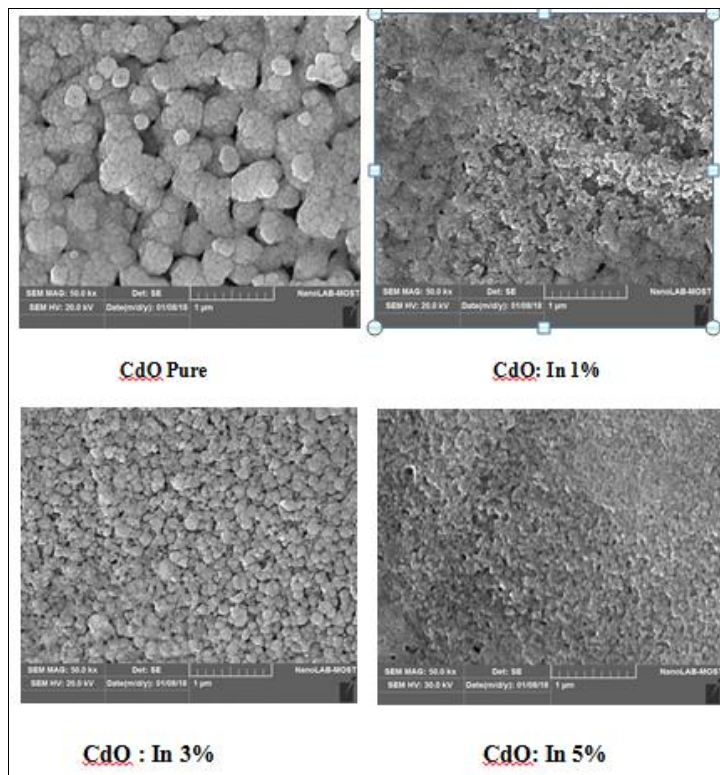


Fig.3. SEM images for CdO and CdO:In thin films at different In concentrations

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.

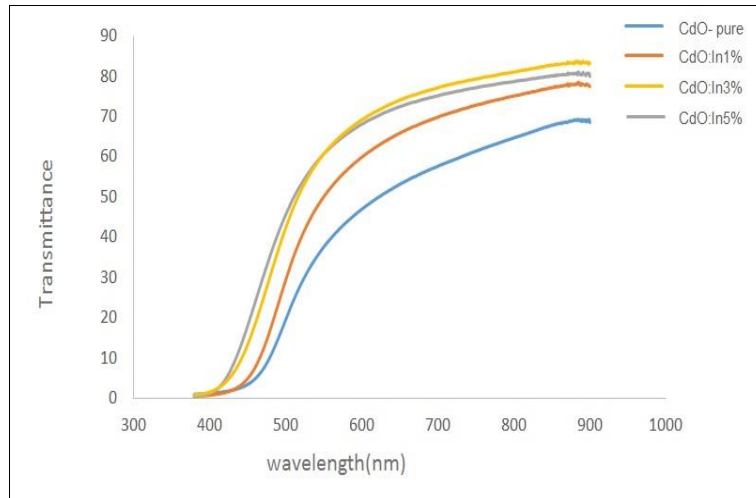


Fig.4. Optical transmittance versus wave length at different In concentrations

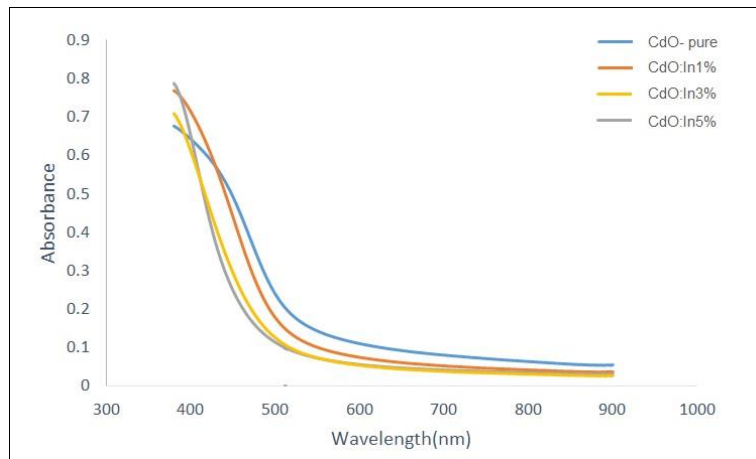


Fig.5. Absorbance versus wave length at different In concentrations

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 homogeneity 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 kumaravel [19]. The absorption coefficient (α) is calculated from the transmittance spectrum using the following relation [20].

$$\alpha = \ln (1/T)/t \dots\dots (2)$$

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

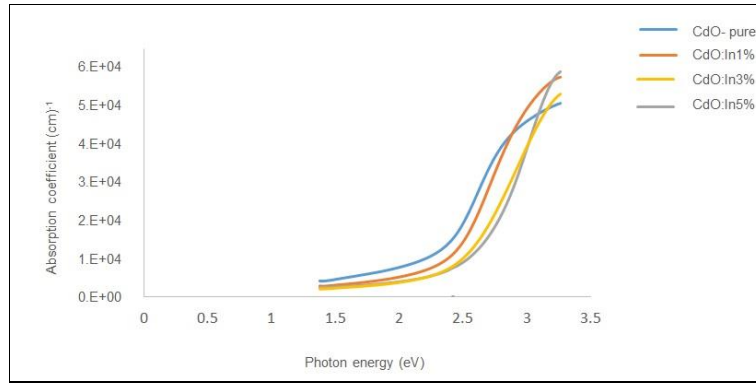


Fig.6. Variation of optical absorption coefficient with photon energy for different In concentrations

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

$$\alpha h\nu = K(h\nu - E_g)^{1/2} \dots \dots (3)$$

Where K is constant, $h\nu$ the incident photon energy, E_g is determined by extrapolating the straight line position seen in fig.6 to $\alpha h\nu=0$, 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.

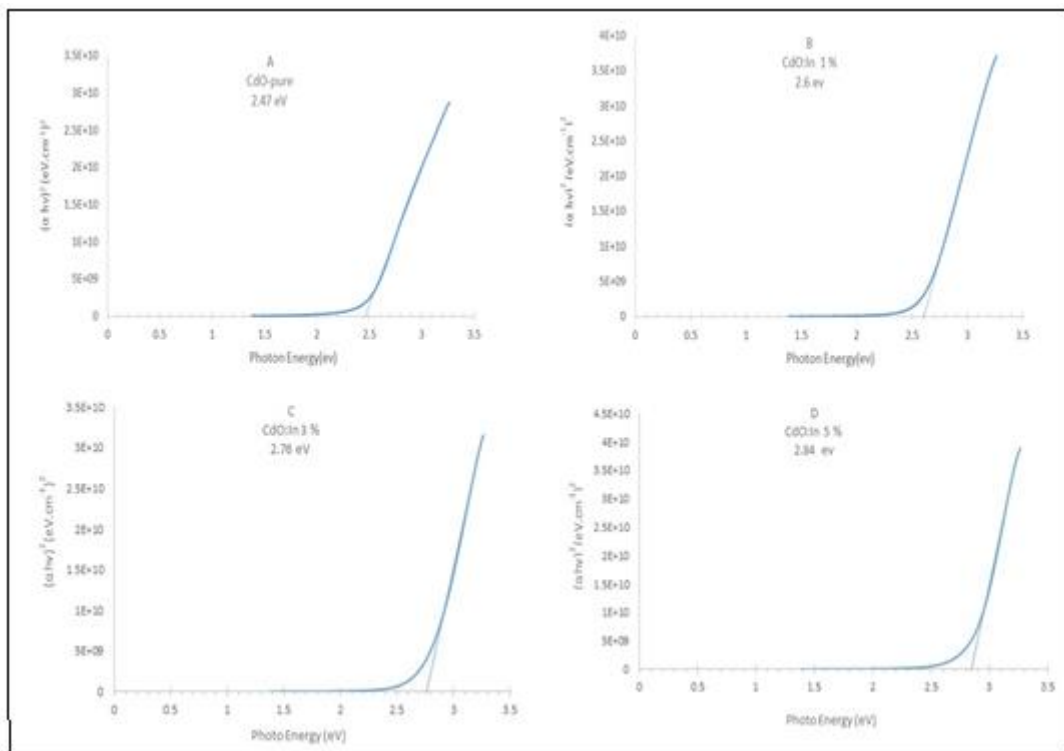


Fig.7. $(\alpha h\nu)^2$ versus wave length at different In concentrations.

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.

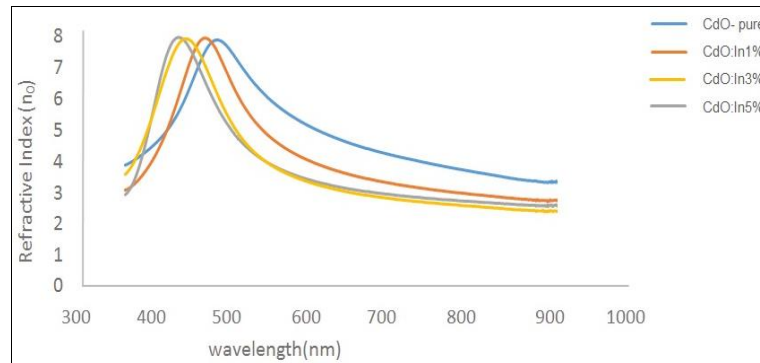


Fig.8. Refractive index versus wave length at different In concentrations.

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

References

- [1] Rusu, R.S. and Rusu, G.I. (2005). *Journal Optoelectronics and Advanced Materials*, **7**:p1511.
- [2] Dakhel, A.A. (2004). *Journal Material Science*, **(46)**:p6925.
- [3] Dakhel, A.A. and Ali-Mohamed, A.Y. (2007). *Journal Sol. Gel Sci. Tehmol*, **44**:p241.
- [4] Maity, R. and Chattopadhy, K.K. (2006). Synthesis and characterization of aluminum-doped CdO thin films by sol-gel process. *Sol. Energy Mater. Sol. Cells*, **90**:p597.
- [5] Lokhande, B.J.; patil, P.S. and Uplane, M.D. (2004). Studies on cadmium oxide sprayed thin films deposited through non-aqueous medium. *Mater. Chem. Phys.*, **84**:p238.
- [6] Matsubara, K. et al. (2008). *Thin Solid Films*, **341**:p369.
- [7] Henori, F.Z. and Dakhel, A.A. (2008). Linear and Nonlinear Optical Properties of Hydrogenated CdO Thin Films. *Laser Phys.*, **18**:p1557.
- [8] Yildirim, M.A. and Ates, A. (2009). Structural, Optical and electrical properties of CdO/Cd(OH)₂ thin films grown by the SILAR method. *Sens. Actuators Phys.*, **155**:272-277.
- [9] Usharani, K. and Balu, A.R. (2016). Properties of spray deposited Zn,Mg incorporated CdO thin films. *Journal Mater. Sci. Mater. Electron*, **27**:2071-2075.
- [10] Dakhel, A.A. (2011). Effect of thermal annealing in different gas electrical properties of Li-doped CdO nanocrystalline films. *Solid State Sci.*, **13**:1000-1005.
- [11] John, R.; Shanmugaral, S.F. and Rajaram, T.E. (2010). Synthesis and characterization of nano Zn and CdO. *Journal Cera. Soc. Jpn.*, **118**:329-332.
- [12] Subramanyam, T.; Uthanna, S. and Srniuasulu, B. (1998). Preparation and charecterization of CdO films deposited by dc magnetron reactive sputtering. *Mater. Lett*, **35**:214-220
- [13] Yan, M.; Lane, M.; Kannewurf, C.R. and chang, R.P.H. (2001). Highly conductive epitaxial CdO thin films prepared by pulsed laser deposition. *Appl. Phys. Let.*, **78**:p2342.
- [14] Yahia, I.S.; Salem, G.F.; Abd-Elsadek, M.S. and Yakuphanoglu, F.Y. (2013). Optical properties of AL-CdO nano-clusters thin films, superlattice. *Microstruct*, **64**:p178-184
- [15] AL-Jawad, S.M.; Kadhim, H. and Alogili, J. (2011). Investigation of optical and electrical properties of chemically deposited nano-crystalline CdO thin films. *The College of Basic Education Journal*, **17**:p68.
- [16] Cullity, B.D. and Rstok, S. (2001). Elements of X-ray Diffraction. Prentice Hall. Upper saddle River, NJ, USA.
- [17] Ali, H.M.; Mohamed, H.A., Wakkad, M.M. and Hasanen, M.F. (2009). Optical and electrical preparation of Tin-Doped Cadmium oxide films prepared by electron Beam Technique. *Japanese Journal of Applied Phys.*, **48**:p041101.
- [18] Sudjaatmoko; Wirijoadi, B. and Siswanto, (2009). *Atom Indonesia*, **35**:p115.
- [19] Kumaravel, R.; Ramamuthi, K. and Krishnakumar, V. (2010). Effect of indium doping in CdO thin films prepared by spray pyrolysis technique. *Journal of Physics and Chemistry of solid*, **71**:p1545.
- [20] Miao, W. et al. (2006). *Thin Solid Films*, **500**:p70
- [21] Brodsky, M.H. (1978). Amorphous Semiconductors. Cambridge University Press, N.Y., USA.
- [22] Kathalingam, A.; Kesavan, K. and Rana, A.H.S. (2018). Analysis of Sn concentration effect on Morphological, Optical, Electrical, and photonic properties of Spray-coated Sn-doped Cdo Thin Films. *Coating*, **8(5)**:p167.

تأثير التطعيم بالانديوم في الخصائص التركيبية والبصرية لأغشية CdO

مثنى خلف محمود خليفة¹، حنان رضا عبد¹، خضير عباس مشجل²

¹قسم الفيزياء، كلية التربية للعلوم الصرفة، جامعة تكريت، تكريت، العراق

²قسم الفيزياء، كلية التربية للعلوم الصرفة، الجامعة المستنصرية، بغداد، العراق

الملخص

الهدف من البحث هو دراسة تأثير 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 (2.47-2.84) eV.