International Journal of Nanomaterials and Chemistry

http://dx.doi.org/10.18576/ijnc/020104

Synthesis and Study the Structure and Optical Properties of CdO Polycrystalline Thin Film Using Electrochemical Depositing Method

Wasna'a M. Abdulridha*

Basic Science Department, University of Al- Kufa, Najaf, Iraq.

Received: 19 Nov. 2015, Revised: 9 Dec. 2015, Accepted: 14 Dec. 2015.
Published online: 1 Jan. 2016.

Abstract: CdO thin film synthesis by electrochemical deposition method at 15 min deposition time was investigated in this paper. The result of the optical transmittance of CdO thin film which formed at room temperature was 20% at wavelength ≈ 350 nm then increases to 60% at wavelength ≈1100 nm for thin film of CdO. The band-gap was also calculated from the equation relating absorption coefficient with the wavelength. The energy band gap changes from 2.3eV (Bulk CdO) to 2.45eV (CdO thin film). The plotted graphs show the optical characteristics of the film which varied with the wavelength and the photon energy. The optical conductance and band-gap indicated that the film is transmitting within the visible range. The dielectric constant and optical conductance of the film initially decreases slowly with increase in photon energy. The extinction coefficient and refractive index of the films also evaluated, which affected with the change in transmittance. The structure of synthesized CdO thin film was analyzed by X-ray diffraction XRD which revealed that the CdO thin film are polycrystalline and have several peaks of cubic face structure. The crystallite size, dislocation density, microstrain and number of dislocations of the thin film were calculated and listed.

Keywords: CdO, electrochemical deposition, thin films, and optical properties.

1 Introduction

Cadmium oxide (CdO) is transparent conducting oxides (TCOs) materials that possess both high electrical conductivity and high optical transparency (>80%) in the visible light region of the electromagnetic spectrum [1]. CdO is a n-type semiconductor with nearly metallic conductivity [2]. It has a direct energy band gap (E_g) of ~2.3 eV and two indirect transitions at lower energies [3]. It has extensive of applications as solar cells, windows, flat panel display, photo transistors etc. It was experimentally confirmed that structural, electrical and optical properties are very sensitive to the film structure and deposition conditions [4, 5]. Such transparent conductors are being used comprehensive in thin film solar cells [6] and optoelectronic devices [7]. CdO films can be synthesized by many techniques such as sputtering [8], chemical vapor deposition (CVD) [9], spray pyrolysis [10], thermal evaporation [11] sol gel [12], and electrochemical [13]. The electrochemical deposition presents a simple, cost, and quick method for the synthesis of CdO nanostructure.

2 Experimental Work

Teflon container homemade and cylindrical shape, length 9.5cm, internal radius: 2.5cm, external radius: 3.6cm,

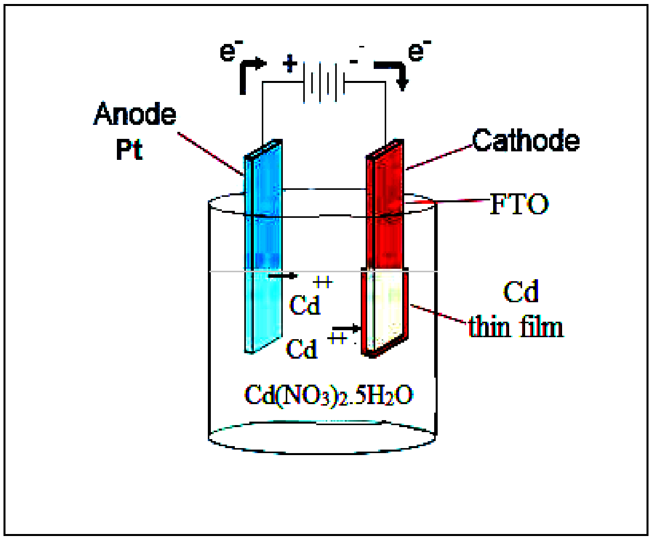

Fig.1: Schematic diagram of electrochemical deposition system.

distance between electrodes: 3cm, Anode material: Pt foil, Cathode material: Fluorine Tin Oxide (FTO) glass. The deposition of the films was carried out in cell containing 1mM $Cd(NO_3)_2.5H_2O$ with the a temperature about 35°C .

* Corresponding author E-mail: sonadody30@yahoo.com

The electrolyte pH used in this deposition was fixed at 7.5. Deposition of the films was carried out cathodically by using a power supply (Farnell type) with a standard two electrode system. FTO (TEC8) glasses of approximately $2cm^2$ area and resistance 8Ω/square from Dye Sol. FTO is used here as transparent conductor. In all experimentally we fixed the voltage at -0.5volt and the time deposition is 15 min. The electrolyte precursors $Cd(NO_3)_2.5H_2O$ was used in all deposition as shown in figure(1). After finally deposition the thin films annealing in air ambient at 300 ^{c}C to obtaining oxidation and best adhesion.

3 Resultants and Dissection

The Transmittance spectrum is taken by Cary 100 Conc plus UV-Vis Spectro-photometer 350 nm to 1100 nm. The UV –Vis spectra is very important because it is provide the details related with the optical band. The optical transmittance of the CdO thin film at 15 min deposit time was around 20% at wavelength 350 nm then increases sharply to 60% at wavelength 1100 nm as shown in figure (2). Also it is observed that the optical transmittance spectra shift towards shorter wavelength as particle size decrease due to increase in optical energy band gap.

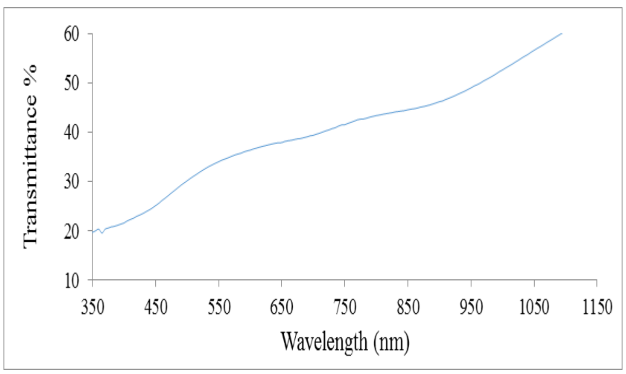

Fig.2: Transmittance Spectra of CdO thin film

The absorbance spectrum shown in figure (3) a sharp increase in absorption at wavelength near to the absorption edge (510 nm) of the threshold wavelength for onset of absorption, the energy corresponding to this determines the band gap of the semiconductor material .The inset of figure (3) shows the CdO thin film absorption coefficient α of around 4× 10^4 cm^{-1} near to the absorption edge (510 nm). This result is agree with [14]. Figure (4) shows that graph between $(\alpha h\nu)^2$ versus photon energy (hν) gives the value of direct band gap .The extrapolation of the straight line to $(\alpha h\nu)^2$ =0 , gives the value of band gap . From the UVspectra shows the absorbance decreases with increasing wavelength and the energy gap increase from 2.3 eV to 2.45 eV from bulk to the thin film via quantum size effect.

The reflectance of CdO thin film increases from 0.1 to 0.2 when the wavelength increases from 350 nm to greater than 500 nm as shown in figure (5) and the refractive index (*n*)

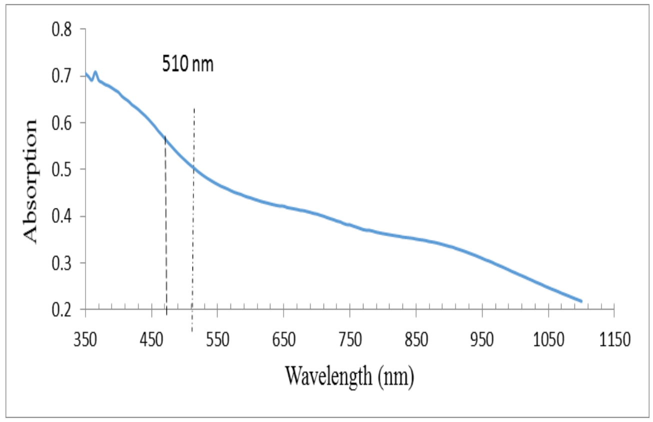

Fig.3: Absorption Spectra of CdO thin film

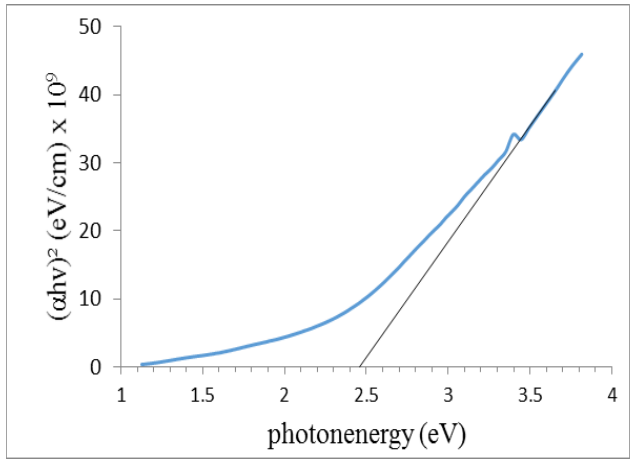

Fig.4: $(\alpha h\nu)^2$ versus photon energy gap of CdO thin film.

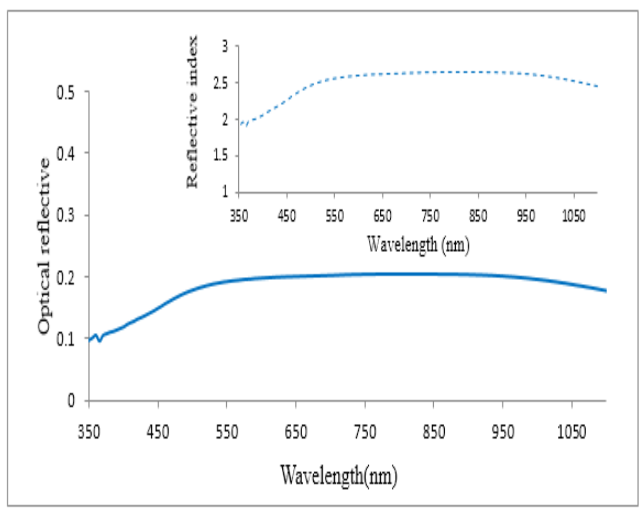

Fig.5: reflection spectra of CdO thin film a function of wavelength

has been calculated by formula [14]:

$$n = \frac{1+\sqrt{R}}{1-\sqrt{R}} \qquad (1)$$

Figure (6) shows the plot between photon energy versus extinction coefficient (k) .The extinction coefficient decrease from 1.5 eV to 2.3 eV then increase with the absorption edge 510 nm (≈ 2.45 eV) indicated increases with photon energy from 2.3 eV to 2.7 eV. The dielectric constant and absorption coefficient are related and can be obtained theoretically with the relation given by the following: [Ugwu, 2006; Okujagu, 1992; Parachiniet etal., 1980; Chalkwski, 1980; Born et al., 1970; and Jenkins et al., 1976].

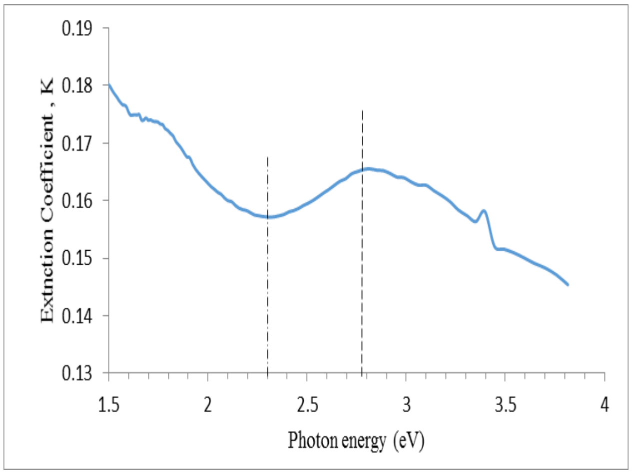

Fig. 6: extinction coefficient versus photon energy of CdO thin film.

$$\epsilon_r = n^2 - k^2 \qquad (2)$$

$$\epsilon_i = 2nk \qquad (3)$$

Where ϵ_r is the real part of the dielectric constant and ϵ_i is the imaginary part of the dielectric constant .The real part as shown in figure 7(a) almost decreases slowly with increasing photon energy .Also the figure indicate the absorption edge is the point which decreases the real part of the dielectric constant. The imaginary part of dielectric represents the absorption associated of radiation by free carriers and imaginary part is always positive and represented loss factor or energy absorbed. Also the figure 7(b) relieve that the imaginary part of CdO thin film decreases with increases the photon energy.

The imaginary part of dielectric constant is related to the optical conductivity (σ) which calculated from the following relation [14]:

$$\sigma = \alpha nc \ \epsilon_\circ = \frac{\alpha nc}{4\pi} \qquad (4)$$

Where *c* is the velocity of the radiation in the space, n is the refractive index and α is the absorption coefficient.

Figure (8) shows the relation of optical conductivity with the incident photon energy. The increased optical conductivity at high photon energy is due to high absorbance of CdO film in that region. The optical conductance and band gap indicated that the film is transmittance within the visible range then it is suitable as a window in solar cell application. The XRD pattern for films deposited at Fluorine Tin Oxide (FTO) glass showed that they are polycrystalline .The XRD patterns for CdO film are presented in Figure (9). Several peaks of cubic face-centered CdO corresponding to (111), (200) , (220) , (311) and (222) planes with = 4.6953 A° can be seen in the figure and have been compared with standard X-ray diffraction data file (JCPDS file No. 75-0594) [15].

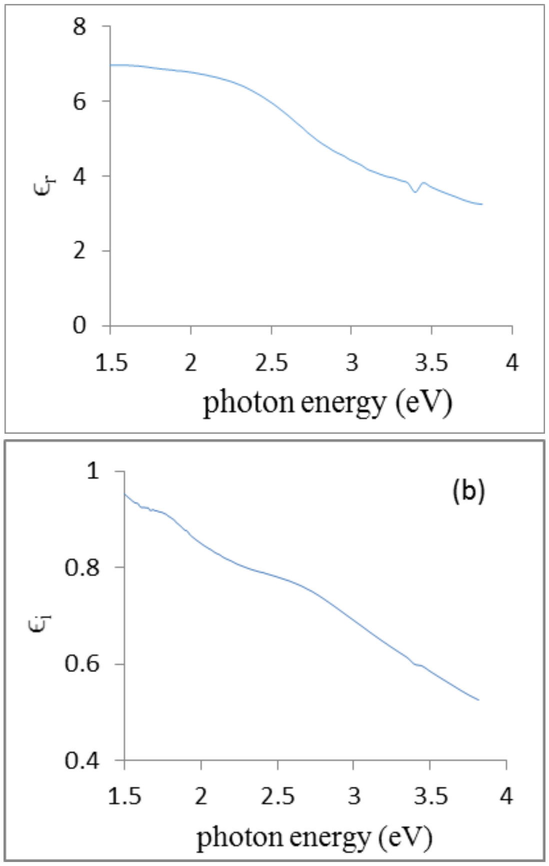

Fig.7: plot between photon energy with a: real part of the dielectric constant and b: the imaginary part of the dielectric constant

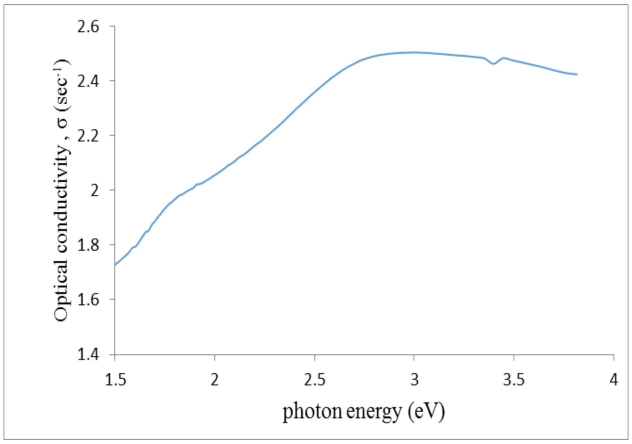

Fig. 8: Optical Conductivity of CdO thin film.

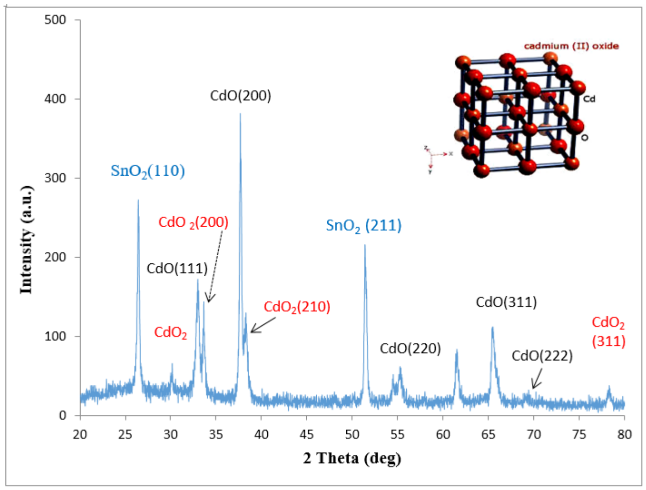

Fig. 9: XRD for CdO thin film.

Table (1): X-Ray characterization for CdO thin film

2 Theta (deg)	**(hkl) planes**	**β (deg)**	**D (nm)**	**σ × 10^{14} ($1/m^2$)**	**η × 10^{-4} ($lines^{-2}.m^{-4}$)**	**N× 10^{19} $lines.m^{-2}$**
26.42	SnO_2 (110)	**0.12**	32.99	2.19	5.13	9.80
30.09	CdO_2 (111)	**0.25**	32.73	9.33	10.58	86.09
32.92	CdO (111)	**0.40**	20.60	23.55	16.81	345.25
33.62	CdO (210)	**0.28**	20.64	23.46	16.78	343.37
37.67	CdO (200) CdO_2 (210)	**0.25**	33.40	8.95	10.37	80.99
51.42	SnO_2 (211)	**0.24**	36.12	7.66	9.59	64.07
55.25	CdO (220)	**0.36**	24.93	16.80	14.20	208.13
65.94	CdO (311)	**0.24**	39.31	6.47	8.81	49.70
69.44	CdO (222)	**0.13**	76.44	1.71	4.53	6.75

In the present investigation, the films exhibit a preferential orientation along the (200) diffraction plane which were grown CdO thin films on (FTO) glass substrate by the electrode deposition technique as 15 min, they show another peaks corresponding to (110) and (2 11) planes for Fluorine Tin Oxide (FTO) glass and (200), (211), (210) and (311) planes for CdO_2 as shown in figure (9). The information on the grain size (D), dislocations density (σ), microstrain (η) and density of dislocations of the deposited film has been obtained using Scherer's formula have been listed as shown in Table 1.

In general, by increasing annealing temperature about 300 ºC. The grain size (D) variation between 24 nm and 76 nm was observed.

4 Conclusion

This work has clearly presented how CdO thin film was grown by electrochemical deposition method (simple, cost, and quick method for the synthesis of CdO nanostructure).The behavior of the film as illustrated in the figures shows that the film is a visible transmitting thin film with a good crystallize.

References

[1] Y. Hames and S. E. San, "CdO/Cu_2O solar cells by chemical d eposition," Solar Energy, 77 (2004) 291-294.

[2] F. P. Koffyberg, "Diffusion of donors in semiconducting CdO," Solid State Common., 9, (1971) 2187-2189.

[3] F. A. Benko and F. P. Koffyberg, " Quantum efficiency and optical transitions of CdO photoanodes , " Solid State Commun., 57, (1986) 901 - 903.

[4] R.L.Mishra, A.K.Sharma, S.G.Prakash, "Gas sensitivity and characterization of cadmium oxide semiconducting thin film deposited by spray pyrolysis technique," Digest Journal of Nanomaterials and Biostructures, 4, (2009) 511-518.

[5] K.Gurumurugan, D.Mangalraj and S.K.Narayanandas, "Correlations between the optical and electrical properties of CdO thin films deposited by spray pyrolysis," Thin Solid Films, 251, (19947-9.

[6] O. Gomezdaza, A. Arias-Carbajal Readigos, J. Campos, M. T. S. Nair, P. K. Nair, "Substrate spacing and thin - film yield in chemical bath deposition of semiconductor thin films," Semicond. Sci. Technol.15 (11), (2000). 1022-1029.

[7] D. C. Renolds, D. C. Look, B. Jogai, "Optically pumped ultraviolet lasing from ZnO," Solid State Comm.99, (1996) 873-875.

[8] L. I. Popova, S. K. Andreev, V. K. Gurorguev, E. B. Manolov, "Resistance changes of SnO_2 thin films suitable for microelectronic gas sensors," Proceedings of the 20th international IEEE Conference on Microelectronics, 2, (1995) 581-583.

[9] K. B. Sundaram, G. K. Bhagara, "Chemical vapor deposition of tin oxide films and their electrical properties," J. Phys.D: Appl.Phys. 14, (1981)333-338.

[10] C. H. Bhosale, A. V. Kambale, A. V. Kokate and K. Y. Rajpure, "Structural, optical and electrical properties of chemically sprayed CdO thin films," Mater. Science Eng. B, 122, (2005) 67-71.

[11] A.Salehi, M. Gholizade, "Gas-sensing properties of indium-doped SnO_2 thin films with variations in indium concentration," Sensors and Actuators B: Chemical, 89, (2003) 173-179.

[12] L. Znaidi, G. J. A. A. Soler Illia, S. Beyahia, C. Sanchez and A.V. Kanaev, "Oriented ZnO thin films synthesis by sol–gel process for laser application," Thin Solid Films, 428, (2003). 257-262.

[13] M. Santamaria, P. Bocchetta, F. D. Quarto, "Room temperature electrodeposition of photoactive $Cd(OH)_2$ nanowires," Electrochem. Commun. 11(2009) 580–584.

[14] Ruby Das and Suman Pandey, Comparison of Optical Properties of Bulk and Nano Crystalline Thin Films of CdS Using Different Precursors, International Journal of Material Science , 1 (2011) 35-40 JCPDS "powder diffraction file" No. 96-101-1052".