World Scientific News

An International Scientific Journal

Structural and Optical Properties of Sol-Gel Derived Dip-Coated CdO Thin Film

Renu Kumari and **Vipin Kumar***

Department of Applied Sciences, KIET Group of Institutions, Ghaziabad, India

*E-mail address: vipin.kumar.as@kiet.edu

ABSTRACT

In this paper CdO thin film has been prepared by sol-gel dip-coating method on glass substrate. The film was characterized by X-Ray diffraction, UV-Visible spectroscopy and photoluminescence spectroscopy for structural and optical properties of CdO thin film. The XRD pattern shows that film is polycrystalline in nature and has a cubical structure with orientation along (111) plane. The diffuse reflectance spectra for the film is studied in wavelength range 400-800 nm. The direct energy band gap of 2.50 eV is found for the film using modified Kubelka-Munk function. Photoluminescence spectra shows one sharp peak at 540 nm due to oxygen vacancy of cadmium oxide.

Keywords: Sol-gel dip coating, Thin film, Band gap, CdO

1. INTRODUCTION

In the last few years, CdO thin films have gained considerable attention because of its unique structural, optical and electrical properties. CdO is a II - VI group n-type semiconductor [1]. It is a semiconductor with a rock salt crystal structure and having a large energy band gap ranging from 2.2 to 2.8 eV. Cadmium oxide has high electrical conductivity and high transmission coefficient in the visible region along with the average refractive index. Its unique properties make it useful for various applications like solar cells, phototransistors, transparent electrodes, photodiodes, photovoltaic cell, IR detectors and anti-reflection coatings, and many more [2-7].

CdO thin film have been prepared by many techniques like spray pyrolysis [8], pulsed laser deposition [9], sol-gel [10-11], DC magnetron sputtering [12-13], chemical bath deposition [14], SILAR [15], thermal evaporation [16], chemical vapour deposition [17], RF magnetron [18], screen printing [19] etc. Some of these methods are very expensive and need extra attention. Sol-gel dip-coating method has been used in this paper because it has many advantages like low cost, easy fabrication of large area films, good homogeneity, easy to control the composition, easy coating process on large shaped substrates.

In the present work CdO thin film is prepared by sol-gel dip-coating method and investigated for its structural and optical properties for using them in practical applications.

2. EXPERIMENTAL DETAILS

2. 1. Synthesis

Sol-gel dip coating method has been used for the preparation of the CdO thin film. 20 ml ethylene glycol was used to dissolve Cadmium acetate (AR-grade) with constant stirring for 45 minutes and monoethylamine (MEA) (10 ml) is added drop wise to the solution. Here, ethylene glycol is used as a solvent and monoethylamine is used as a stabilizer. The solution is prepared at room temperature. The final solution was stirred with magnetic stirrer at a constant temperature of 80 ºC for 2 hours to yield a homogeneous and clean solution. The pH of the solution was maintained at 7.5 during gel formation. Glass substrate was cleaned with soap solution and then by distilled water and then finally cleaned with acetone before dip coating.

The clean glass substrate was dipped into the solution vertically at a speed of 120 mm/min. After dip coating the film was dried at 100 ºC for 20 minutes in the oven and this procedure was repeated for 9 to 10 times, and finally the coated glass substrate was subjected to the annealing process at 500 ºC temperature for 10 minutes to combust the undesired organic materials and to stabilize the film.

2. 2. Characterization

For the study of XRD pattern of thin film, Rigaku (ULTIMA-IV) diffractometer was used in the 2θ range of 25º – 60º. Diffuse reflectance spectra for CdO thin film was recorded by UV-Visible Spectrophotometer (U-3900, Model No. 2116-010) in the wavelength range 400-800 nm. The energy band gap of the CdO thin film was calculated by using modified Kubelka-Munk function. PL spectra was used to analyze the emission characteristics of CdO thin film. The thickness of the film was measured by using a gavimetric weight difference method, and it is found to be of the order of 10^{-8} meter.

3. RESULTS AND DISCUSSION

3. 1. Structural analysis

The XRD pattern for dip-coated CdO thin film is shown in Figure 1. Three peaks are obtained corresponding to (111), (200), (220) planes as shown in Figure 1. The d-values for CdO calculated using Bragg's equation were compared with JCPDS card no. 75-0594 for the confirmation of the structure of film material. This comparison confirms the cubic structure for prepared CdO film. It is also observed that the prepared film is strongly oriented in the (111)

direction. Average crystalline size for the film was calculated using Debye – Scherrer formula as [20]:

$$D = 0.94\lambda/\beta\cos\theta$$

where: D = Average crystalline size of the particle.
$\quad$ λ = Wavelength of the X-Ray diffraction.
$\quad$ β = Full width half maxima (FWHM).
$\quad$ θ = Diffraction angle.

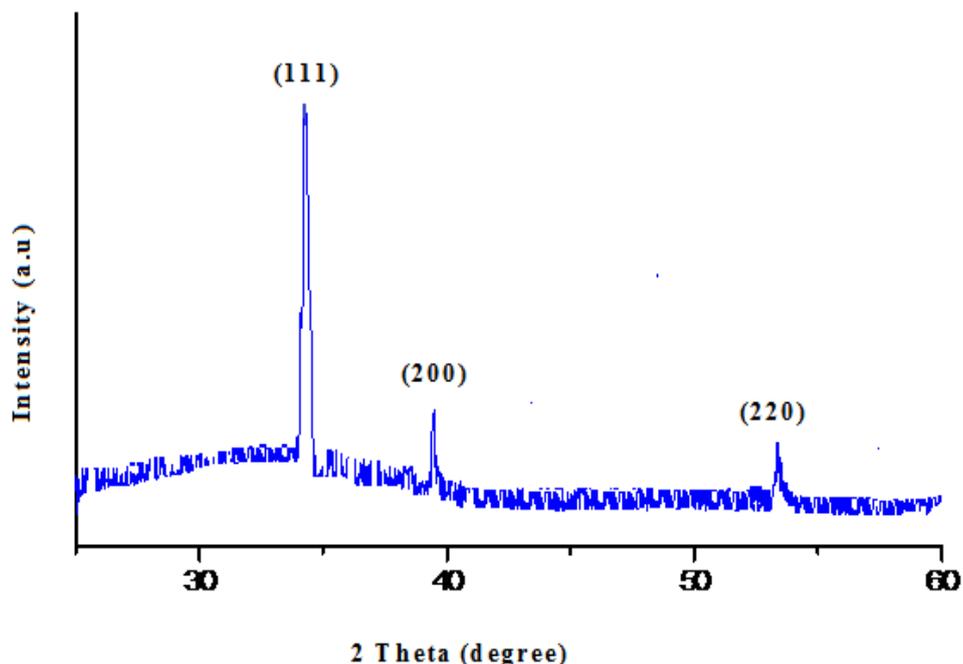In present study the estimated crystallite size of CdO film was 28nm.

Figure 1. X-Ray diffraction (XRD) spectra of CdO thin film.

3. 2. Optical analysis

Energy band gap of CdO thin film was studied through the diffuse reflectance spectra in 400-800 nm wavelength range. Figure 2. Shows the diffuse reflectance spectra of CdO thin film. Diffuse relectance spectra is an useful tool for studying energy band gap of the materials. To calculate the energy band gap for the film, a graph between modified Kubelka-Munk function $[F(R)h\upsilon]^2$ versus photon energy ($h\upsilon$) is plotted. The extraplotation of linear part of this graph gives the value of energy band gap for the film. The modified Kubelka-Munk function can be expressed as:

$$[F(R)h\upsilon] = A(\ h\upsilon - E_g\ )^{1/2}$$

where: $F(R) = (1-R)^2 / 2R$ is the Kubelka – Munk function [21], R is the absolute reflectance and A is constant. Figure 3. Shows the graph between modified Kubelka function $[F(R)hv]^2$ versus photon energy (hv). The value of energy band gap estimated from this graph is found to be 2.50 eV for CdO film, which agrees well with the reported values [22].
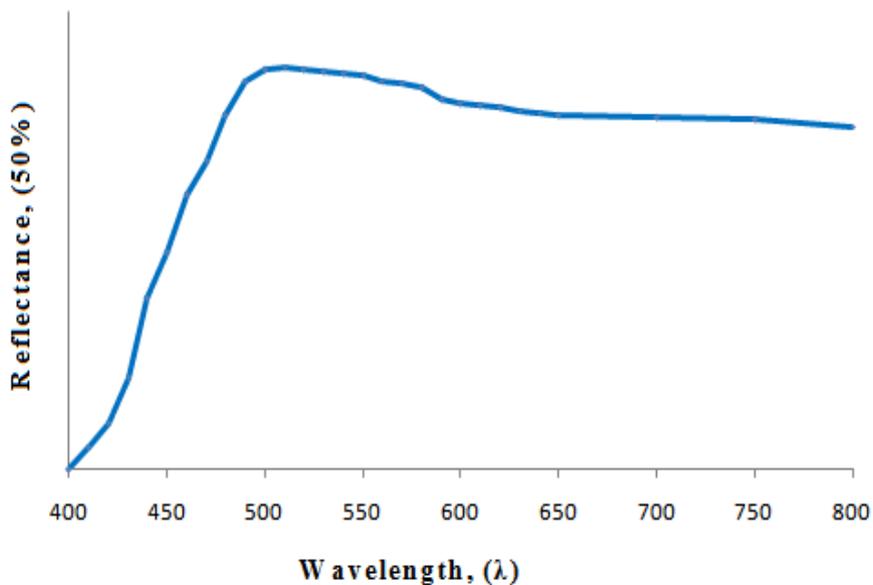

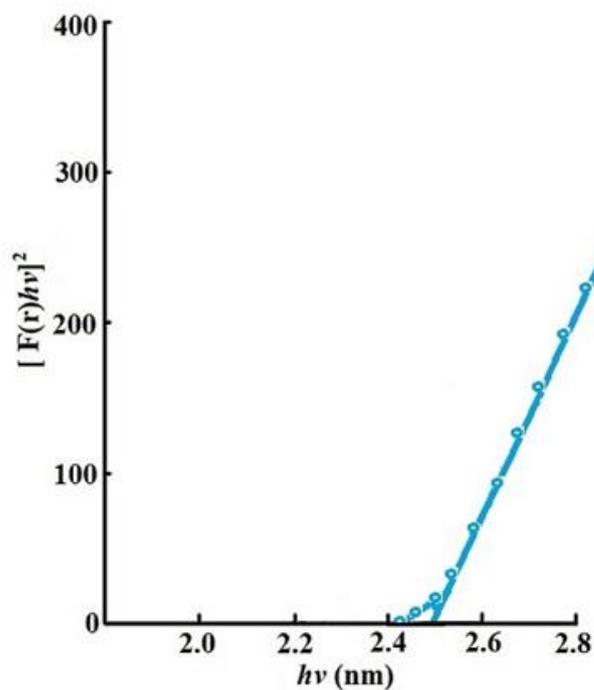**Figure 2.** Diffuse reflectance spectra of CdO thin film.

Figure 3. Plot of $[F(R)hv]^2$ versus photon energy (hv) for CdO thin film.

Refractive index is an important parameter for the fabrication of devices. Figure 4. Shows the variation of refractive index with photon energy ($h\upsilon$). The refractive index initially increases with photon energy up to 2.12 eV and then decreases. This result is consistent with the result reported earlier [23]. The refractive index for the prepared CdO film is calculated by the relation [24]:

$$n = [(1+ R^{1/2}) / (1- R^{1/2})]$$
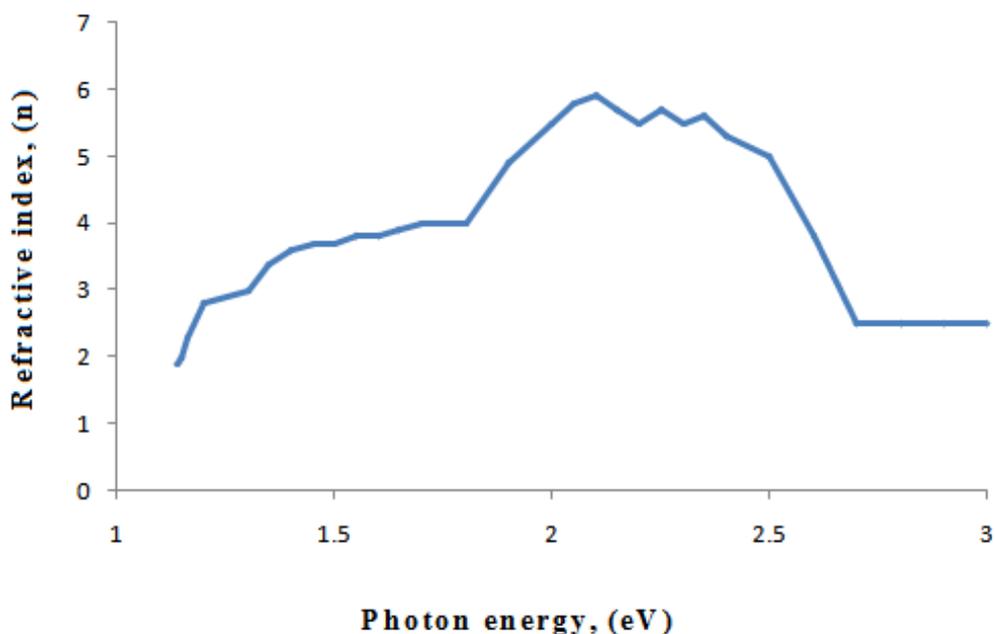
where: R is reflectance.

Figure 4. Variation of refractive index with photon energy of CdO thin film.

3. 3. Photoluminescence analysis

Optical quality of CdO thin film was determined by using photoluminescence spectroscopy. Figure 5 shows the PL spectra of prepared CdO thin film at room temperature. This spectra shows a sharp peak in the visible range at 540 nm which may be due to oxygen vacancy of CdO as recombination of photogenerated hole occurs with an electron in conduction band.Similar peaks in PL spectrum of CdO have been reported earlier [25]. A rough estimation of energy band gap can also be made from photoluminescence spectra of the CdO film given in Figure 5, by employing the formula:

$$E_g = 1240 / \lambda$$

The energy band gap estimated from PL spectra corresponding to wavelength 540 nm is found to be 2.29 eV, which is slightly lower than the band gap calculated using Kubelka-Munk function.
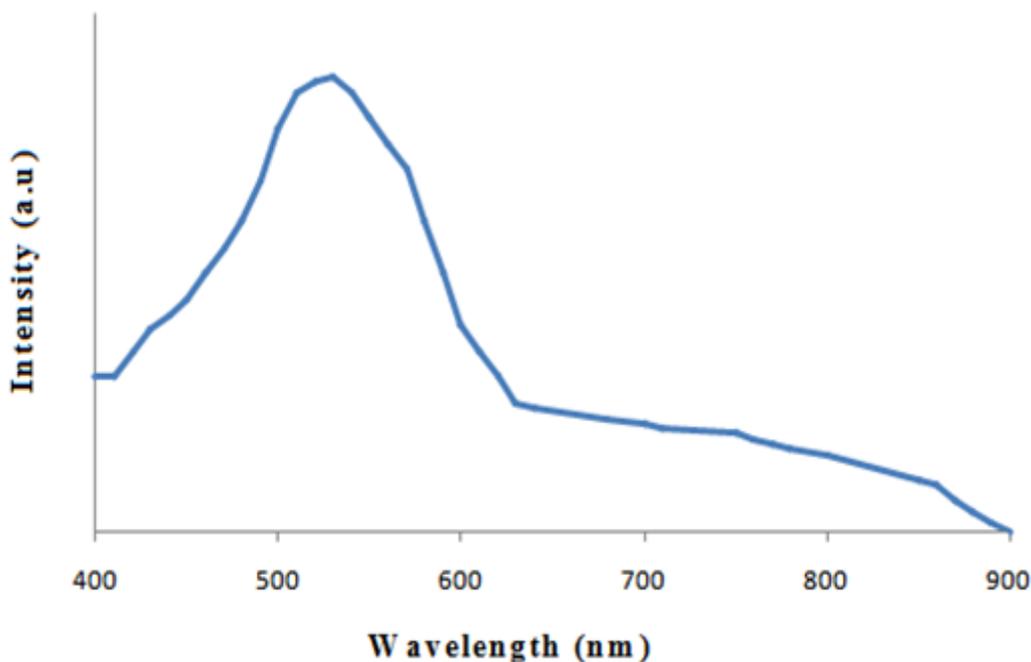
Figure 5. Potoluminescence spectra of CdO thin film.

4. CONCLUSION

A simple and low cost sol-gel derived dip – coating method was used for synthesis of CdO thin film. XRD pattern confirm that CdO thin film was polycrystalline in nature. The energy band of CdO thin film was found to be 2.50 eV. PL measurement shows that CdO thin film has strong luminescence character. The results obtained in this work are suitable for device application.

References

[1]   Roy B. II-VI compounds. Pergamon Press. Oxford 1969.

[2]   Daza OG, Readigos A-C, Campos J, Nair MTS, Nair PK. Formation of conductive CdO thin films on photoconductive CdS thin films for window layer applications in solar cells. *Modern Physics Letters B* 2001; 15(17-19): 609-612.

[3]   Champness CH, Chan CH. Optimization of CdO layer in Se-CdO photovoltaic cell. *Solar Energy Materials and Solar Cells* 1995; 37(1): 75-92.

[4]   Lewis BJ, Paine DC. Applications and processing of transparent conducting oxides. *Materials Research Society Bulletin* 2000; 25(8): 22-27.

[5]   Kondo R, Okhimura H, Sakai Y. Electrical properties of semiconductor photodiodes with semitransparent films. *Japanese Journal of Applied Physics* 1971; 10(11): 1547.

[6]   Zhao Z, Morel DL, Ferekides CS. Electrical and optical properties of tin-doped CdO films deposited by atmosphereic metalorganic chemical vapour deposition. *Thin Solid Films* 2002; 413(1-2): 203-211.

[7]   Yan M, Lane M, Kannewurf CR, Chang RPH, Highly conductive epitaxial CdO thin films prepared by pulsed laser deposition. *Applied Physics Letters* 2001; 78(16): 2342-2344.

[8]   Gandarilla F, Morales-AA, Vigil O, Hasiquio-GV, Vaillant L, Contreras-PV. Micro-structural characterization of annealed cadmium zinc oxide thin films obtained by spray pyrolysis. *Materials Chemistry and Physics* 2003; 78(3): 840-846.

[9]   Ismail RA, Rasheed BG, Salm ET, Al-HM. High transmittance – low resistivity cadmium oxide films grown by reactive pulsed laser deposition. *Jouranal of Materials Science: Materials in Electronics* 2007; 18(10): 1027-1030.

[10]   Ghosh PK, Das S, Chattopadhyay KK. Temperature dependent structural and optical properties of nanocrystalline CdO thin films deposited by sol-gel process. *Journal of Nanoparticle Research* 2005; 7(2-3): 219-2215.

[11]   Santos-CJ, Torres-DG, Castanedo-PR, Jimenez-SS, Jimenez-SO, Zuniga-RCI, Marquez MJ, Zelaya-AO. Dependence of electrical and optical properties of sol-gel prepared undoped cadmium oxide thin films on annealing temperature. *Thin Solid Films* 2005; 493(1-2): 83-87.

[12]   Zhou Q, Ji Z, Hu BB, Chen C, Zhao L, Wang C. Low resistivity transparent conducting CdO thin films deposited by DC reactive magnetron sputtering at room temperature. *Materials Letters* 2007; 61(2): 531-534.

[13]   Ma D, Ye Z, Wang L, Huang J, Zhao B. Deposition and characteristics of CdO films with absolutely (200) – preferred orientation. *Materials Letters* 2003; 58(12): 128-131.

[14]   Khallaf H, Chen CT, Chang LB, Lupan O, Dutta A, Heinrich H, Shenouda A, Chow L. Investigation of chemical bath deposition of CdO thin films using three different complexing agents. *Applied Surface Science* 2011; 257(22): 9237-9242.

[15]   Gokul B, Matheswaran P, Satyamoorthy R. Influence of annealimg on physical properties of CdO thin films prepared by SILAR method. *Journal of Materials Science and Technology* 2013; 29(1): 17-21.

[16]   Dakhel AA, Henari FZ. Optical characterization of thermally evaporated thin CdO films. *Crystal Research and Technology* 2003; 38(11): 979-985.

[17]   Ellis DM, Irvine JC. MOCVD of highly conductive CdO thin films. *Journal of Materials Science: Materials in Electronics* 2004; 15(6): 369-372.

[18] Cheemadan S, Rafiudeen A, Santosh Kumar MC. Highly transparent conducting CdO thin films by radio frequency magnetron sputtering for optoelectronic applications. *Journal of Nano Photonics* 2016; 10(3): 033007.

[19] Kumar V, Sharma DK, Sharma KK, Agrawal S, Bansal MK, Dwivedi DK. Structural, optical and electrical characterization of nano crystalline CdO films for device applications. *Optik* 2016; 127(10): 4254-4257.

[20] Cullity BD. Elements of X-ray diffractions. Addision-Wesley, Reading 1978.

[21] Kumari R, Singh P, Kumar V. Study on structural, optical and electrical properties of CdO and Cd0.98Al0.02O films prepared by innovative sol-gel screen printing method. *Journal of Materials Science: Materials in Electronics* 2018; 29(11): 8989-8994.

[22] Saha S, Das S, Chattopadhyay KK. Electrical and optical properties of Al doped cadmium oxide thin films deposited by radio frequency magnetron sputtering. *Solar Energy Materials and Solar Cells* 2007; 91(18): 1692-1697.

[23] Khan MKR, Rahman MA, Shahjahan M, Rahmann MM, Hakim MA, Saha DK, Khan JU. Effect of Al doping on optical and electrical properties of spray pyrolytic nano-crystalline CdO thin films. *Current Applied Physics* 2010; 10(3): 790-796.

[24] Zargar RA, Arora M, Bhat RA. Study of nanosized copper-doped ZnO dilute magnetic semiconductor thick films for spintronic device applications. *Applied Physics A* 2018; 124(1): 36.

[25] Lange AS, Ningthoujam RS, Sharma SJ, Pode RB. Luminescence and electrical resistivity properties of cadmium oxide nanoparticles. *Indian Journal of Pure and Applied Physics* 2011; 49(4): 234-238.