

# Effect of Zinc Content on Optical Characteristics of $Zn_{1-x}Cd_xO$ Thin Films

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## Abstract

Reactive co-sputtering technique was used to deposit thin films of  $Zn_{1-x}Cd_xO$  on glass substrates in presence of oxygen inside vacuum chamber. A geometrical approach was considered to determine the fractional amount of both zinc and cadmium in the final product. The effect of Zn dopant concentrations on the morphological, structural and optical properties was introduced. The prepared thin films contain cluster structures of  $Zn_{1-x}Cd_xO$  particles. These films are polycrystalline and their band gap values were increasing with increasing Zn dopant concentration.

**Keywords:** Zinc oxide; Cadmium oxide; Co-sputtering; Thin films; Structural characteristics

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## 1. Introduction

The technology of thin films playing an important period especially in the scope of integrated optics, optical coating, microelectronics and super conductors etc. [1]. ZnO is an II-VI wide band gap (3.3 eV) which is commercially abundant with accrued such as relatively low cost, peristalsis – friendly non-venomous nature, high thermal and chemical stability and high resistance to radiation damage [2]. This type of semiconductor material has an ability to modulate the band to lower level by alloying with CdO [3] in order to increase more electronic carriers, then the conductivity can be improved. As doping concentration heavily, the amount of electronic carriers are also increased in general [4]. These materials have been extensively studied due to its intrinsic properties and potential applications to optoelectronic devices [5]. Recently, compound  $Zn_{1-x}Cd_xO$  semiconductors have been more used to tailor the ZnO band gap to visible spectral range from ultraviolet because of the small band gap of CdO about 2.30 eV [6,7]. Also, cadmium oxide have special features such as high conductivity and high transmission which made it applicable in photodiodes [8], gas-sensing devices [9], thin film resistors [10], solar cell [11] and flat panel display

[12]. Various growth techniques have been employed to obtain ZnO and CdO thin films on a different substrates including sol-gel [13], pulse laser deposition [4], molecular beam epitaxy [6], spray pyrolysis [14], successive ionic layer adsorption and reaction (SILAR) [8] and thermal evaporation technique [12]. Among these methods spray pyrolysis which is astonishing technique for thin films deposition [15]. Comparison to another techniques spray pyrolysis process has many benefits: it is facile, tawdry [14], safety, inexpensive in equipment and the crude materials, no evaluative tools like systems of vacuum etc., the fabrication of mass have been well adopted these leads to maximum coating of area for thin films [16]. Spray method include sprayed the solution on the substrate direct with carrier gas which assisting the working of nozzle. Physical properties and specificity of thin films relies on the different factors of method similar to the temperature of substrate, the rating of spray, the carrier gas pressure, the molarity concentration of solution, and the geometric properties of the spray regime [17].

The present study, deals with civilizing the thin film of  $Zn_{1-x}Cd_xO$  by spray pyrolysis method. The dopant films have been characterized by various technique such as

(XRD) X-ray diffraction, (SEM) scanning electron microscopy, and UV-Vis spectroscopy.

## 2. Experimental Part

Spray pyrolysis method has been used to deposit  $Zn_{1-x}Cd_xO$  onto glass pillar. The solution of spraying has been presented by deliquesces cadmium acetate dehydrate in distilled water to investigate the doping effect of Zinc on CdO films, we have used zinc acetate dehydrate as a source of material for zinc which was added in different weight percentage such as 25, 50, 75%. The substrate temperature was  $250 \pm 10$  °C and controlled by a thermocouple connected to a temperature controller. The spray rate was maintained at 3 ml/min and the air compressor has been used as carrier gas.

Films thickness was determined by optical interferometer method using the relation [18]:

$$d = \frac{\Delta x}{x} \cdot \frac{\lambda}{2} \quad (1)$$

where  $\Delta x$  is the distance between two fringes,  $x$  is fringe width, and  $\lambda$  is the wavelength of He-Ne laser (632.8 nm)

The surface morphology by using scanning electron microscopy SEM (TEScan–Vega II SBH). An optical transmission spectrum was recorded using UV-1650 UV-visible recording spectrophotometer to measure optical transmittance films in the range 300-900nm.

## 3. Results and Discussion

The scanning electron microscope image illustrates the surface topography of  $Zn_{1-x}Cd_xO$  thin film in Fig. (1) for undoped and Zn doped CdO thin films. The film shows homogenous distribution with polycrystalline nature and has uniform spherical grains. The film dopant with 25% Zn concentration has small grains in compared with film Zn dopant concentration of 75% which show large grains clustered together within the surface. SEM images suggest that the films are showing crystalline nature for lower zinc doping and the films become amorphous for higher concentration of Zn doping.



Fig (1) SEM micrographs for the prepared samples (a) CdO, (b)  $Zn_{0.1}Cd_{0.9}O$ , (c)  $Zn_{0.8}Cd_{0.2}O$

Figure (2) illustrates the optical absorbance with the range of wavelength 300-900 nm for CdO films doped with different concentration of Zn for 250°C substrate temperature. It seems from figure the films have a hefty absorbance in the absorption spectra of ultraviolet region which increased with increasing the zinc dopant while low absorbance in the visible region.

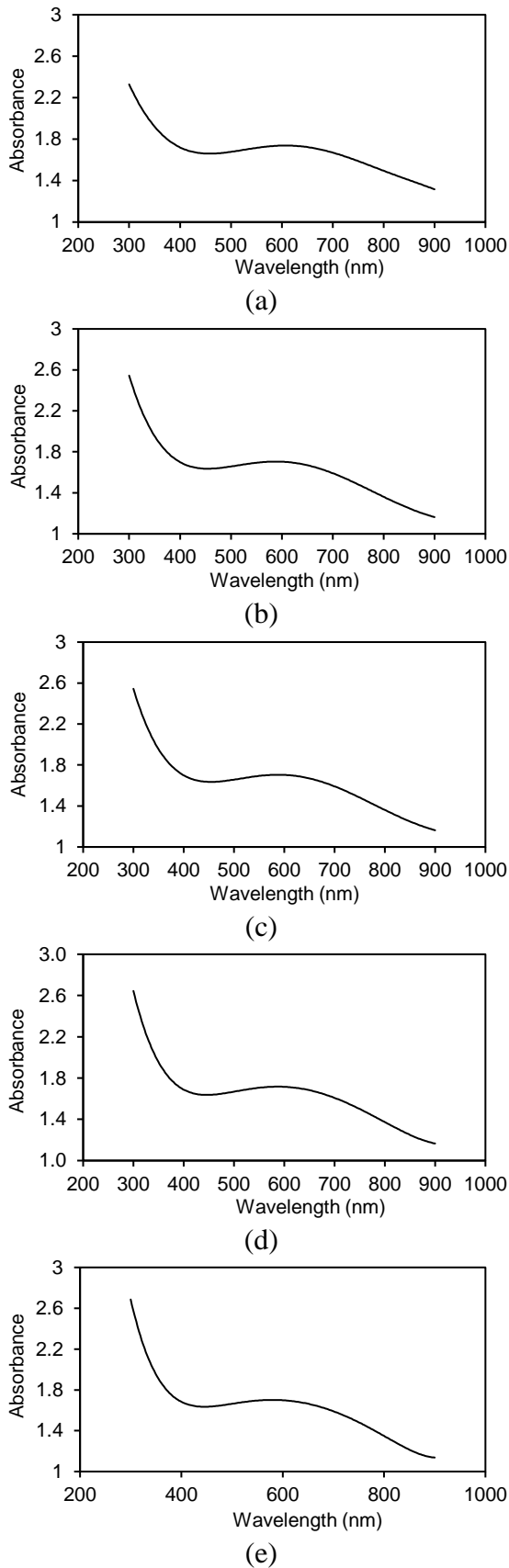


Fig. (2) Absorption spectra of (a) CdO, (b) Zn<sub>0.1</sub>Cd<sub>0.9</sub>O, (c) Zn<sub>0.3</sub>Cd<sub>0.7</sub>O, (d) Zn<sub>0.5</sub>Cd<sub>0.5</sub>O and (e) Zn<sub>0.8</sub>Cd<sub>0.2</sub>O thin films

The band gap as function to concentrations of Zn shows in Fig. (3). To

determine the band gap of Zn<sub>1-x</sub>Cd<sub>x</sub>O film, the absorption coefficient ( $\alpha$ ) was used by using the expression [18,19]:

$$\alpha h\nu = B (h\nu - E_g)^r \quad (2)$$

where  $B$  is a constant,  $E_g$  is energy band gap of film,  $h\nu$  is the incident photon energy, and ( $r=2$ ) for the indirect allowed transition and ( $r=0.5$ ) for direct allowed transitions

After calculating the band gap we found it's equal to 2.49eV for cadmium oxide films without zinc dopant and increased with increasing the Zn dopant concentration to 2.9eV.

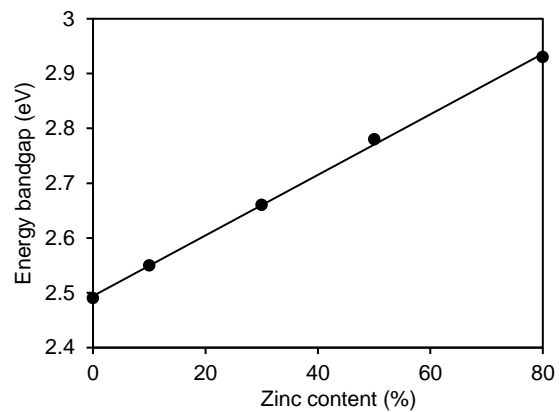


Fig (3) Optical band gap of Zn<sub>1-x</sub>Cd<sub>x</sub>O films with different concentration of Zn dopant

#### 4. Conclusions

In concluding remarks, the effect of Zn dopant concentrations were cleared on morphological, optical and structural properties of Zn<sub>1-x</sub>Cd<sub>x</sub>O thin films. These films have polycrystalline structure and the preferred orientation in the direction of the  $a$ -axis. Optical results illustrate that the optical band gap of Zn<sub>1-x</sub>Cd<sub>x</sub>O films increase from 2.49 to 2.9 eV with increasing the Zn dopant concentration.

#### References

- [1] R.L. Mishra, A.K. Sharma and S.G. Prakash, "Gas Sensitivity and Characterization of Cadmium Oxide (CdO) Semi Conducting Thin Film Deposited by Spray Pyrolysis Technique", Digest J. Nanomater. Biostruct., 4(3) (2009) 511-518.
- [2] A. Singh and P. Kumar, "Structural, morphological and optical properties of sol gel processed CdZnO nanostructured films: effect of precursor solvents", Int. Nano Lett., 3 (2013) 57.
- [3] A. Fouzri et al., "Structural, morphology and optical properties of Zn<sub>(1-x)</sub>Cd<sub>x</sub>O solid solution grown

- on c-plane sapphire substrate”, EPJ Web Conf., 29 (2012) 00019.
- [4] A.A. Ali, K.T. Al-Rasoul and I.M. Ibrahim, “Influence of Doping and Annealing on Structural, Optical and Electrical properties Amorphous ZnO Thin Films Prepared by PLD”, Indonesian J. Electr. Eng. Informat., 3(1) (2015) 21-29.
- [5] X. Tang et al., "Study on interactions between Cadmium and defects in Cd-doped ZnO by first-principle calculations", Solid State Sci., 13 (2011) 384-387.
- [6] K.F. Chien et al., "Thermal-activated carrier transfer in ZnCdO thin film grown by plasma-assisted molecular beam epitaxy", J. Cryst. Growth, 378 (2013) 208–211.
- [7] H.W. Lei et al., "Temperature dependence of surface and structure properties of ZnCdO film", Chinese Phys. B, 23(12) (2014) 126104.
- [8] A.R. Balu et al., "Effect of the Solution Concentration on the Structural, Optical and Electrical Properties of SILAR Deposited CdO Thin Films", J. Electron Dev., 12 (2012) 739-749.
- [9] A. Alemi et al., "Sol-gel synthesis, characterization, and optical properties of Gd<sup>3+</sup>-doped CdO sub-micron materials", Int. Nano Lett., 3 (2013) 41.
- [10] A.N. Naje et al., “Current -Voltage Characteristics of CdO Nanostructures Ultraviolet Photoconductive Detector”, Int. J. Sci. Enviro. Technol., 3(2) (2014) 684-691.
- [11] H.S. Kang et al., "Optical property and Stokes' shift of Zn<sub>1-x</sub>Cd<sub>x</sub>O thin films depending on Cd content", J. Appl. Phys., 99 (2006) 066113.
- [12] M.H. Suhail, I.M. Ibrahim and G. Mohan Rao "Characterization and Gas Sensitivity of Cadmium Oxide Thin Films Prepared by Thermal Evaporation Technique", J. Electron Dev., 13 (2012) 965-974.
- [13] J. Zhang et al., "A study of photoluminescence properties and performance improvement of Cd-doped ZnO quantum dots prepared by the sol-gel method", Nanoscale Res. Lett., 7 (2012) 405.
- [14] N.S. Kumar, K.V. Bangera and G.K. Shivakumar, "Effect of annealing on the properties of zinc oxide nanofiber thin films grown by spray pyrolysis technique", Appl. Nanosci., 4 (2014) 209–216.
- [15] C. Rameshkumar and R. Subalakshmi, “Optical and electrical properties of ZnO:Al thin films synthesized by low cost spray pyrolysis”, Int. J. Chem. Tech. Res., 7(5) (2014-2015) 2532-2536.
- [16] P. Kandasamy and A. Loudusamy, "Studies on Zinc Oxide Thin Films by Chemical Spray Pyrolysis Technique", Int. J. Phys. Sci., 9(11) (2014) 261-266.
- [17] G.Y. Nasser, "Effect of Heat Treatment on the Optical Properties of ZnO Thin Films Prepared by Chemical Spray Method", Iraqi J. Appl. Phys., 9(1) (2013) 23-26.
- [18] J.S. Carter, “Characterization of Zn-doped Cadmium Oxide Thin Films Prepared by Low-Pressure Plasma Sputtering Technique”, Thin Films Sci. Technol., 15(8) (2013) 199-206.
- [19] M.R. Leissner, “Dynamic Analysis of Energy Band Gap of Zn<sub>1-x</sub>Cd<sub>x</sub>O Nanostructures Synthesized by Chemical Vapor Deposition”, Rev. Mater. Sci. Eng., 22(1) (2021) 355-380.