**Indonesian Journal of Electrical Engineering and Computer Science**
Vol. 5, No. 1, January 2017, pp. 81 ~ 84
DOI: 10.11591/ijeecs.v5.i1.pp 81-84 

# Optical Properties of Cadmium Oxide (CdO) Thin Films

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***Abstract***

*Cadmium (Cd) is a soft, silver-white or blue lustrous metal typically found in mineral deposits with lead, zinc and copper. Cadmium Oxide thin films have been prepared on a glass substrate at 350$^0$C temperature by implementing the Spray Pyrolysis method. The direct and indirect band gap energies are determined using spectral data. The direct and indirect band gap energies decrease with the increasing film thickness. It is noted that for the same film thickness the direct band gap energy is greater than indirect band gap energy. The transmittance increases with the increasing wavelength for annealed and deposited films. It is also noted that for the same wavelength the transmittance for deposited films is greater than the transmittance for annealed films.*

***Keywords***: *Cadmium Oxide, Optical Properties, Annealed Film, Deposited Film, Spray Pyrolysis etc*



## 1. Introduction

As an alternative of Transparent Conducting Oxide (TCO) that possesses transparent conducting property, oxides of many metals such as Tin, Indium, Zinc, Cadmium and their alloys can be used. Most of the experimented transparent conducting metal oxides are anion deficient (i.e., Oxygen deficient) and for this reason they are always denoted as n-type conductors [1]. Besides, they are also expressed as oxide semiconductors. Metal oxide thin films have a great importance in the field of science and technology. With the improvement of electrical and optical properties, these films can exhibit different characteristics of metals, semiconductors and insulators. The CdO compound has a color of reddish brown and is built by the process of burning of Cd in the air. It has a good characteristic of being insoluble in water, power of absorbing the $CO_2$ from the air and can be decreased to the conducting oxides. Although it is one of the hopeful postulants for the optoelectronic field, it has been appreciated very little [2-4]. Cadmium oxide (CdO) gets an eminent popularity because of its electrical and optical characteristics. In the application of electronic device, thin films of Transparent Conducting Oxide (TCO) have great acceptance. Among all of these TCOs, cadmium oxide (CdO) is an n-type semiconductor which has a direct band gap at almost 2.2-2.7 eV [5-9]. CdO has many properties which attracts the researchers most such as large energy band gap, high transmission coefficient in visible spectral domain, exceptional luminescence characteristics etc. These properties have shaped it adequate in the preparation of photodiodes [10], phototransistors [11], photovoltaic cell [12], diaphanous electrodes [13], liquid crystal displays, IR detectors and anti-reflection coatings [14] and Transparent Conducting Oxides (TCO) [15]. Besides, it can be applicable in IR heat mirror, gas sensors [16], low-ejective windows, thin-film resistors etc. [17-18]. The n-type CdO thin films show rock salt structure having a band gap of 2.2eV. It also captures good optical conductivity and transmission in the range of visible light [19].

It is known very well that there should be a stroll not only of interstitial cadmium atoms but also of oxygen vacancies to improvise the electrical characteristics of CdO films. According to the report of Flores-Mendoza et al. [20], the behaviour, amount, atomic layouts of metal captions, scientific study of form and structure and the existence of intrinsic or idiosyncratically produced lapses are the reliable parameters of the electrical conductivity and optical transparency of CdO thin films. DC magnetron sputtering [21], spray pyrolysis [22], chemical bath deposition [23], SILAR [24], Activated reactive evaporation [25], Metal Organic Chemical

*Received August 3, 2016; Revised December 2, 2016; Accepted December 21, 2016*

Vapour Deposition (MOCVD) [26], Pulsed laser deposition [27-29] and Sol-gel dip coating [30] etc. are the methods which have been used to deposit CdO thin films. According to the comparison of all of these methods, spray pyrolysis is more beneficial than all other methods. The ultrasonic spray pyrolysis has many benefits like as: (a) it is altogether facile in structure (b) the necessary arrangement cost is less valuable and ductile for the procedure of alternations (c) capability of large area coatings.

Though, there are so many earlier informations on the electrical and optical characteristics of CdO thin films depending on the temperature of substrate, researches on the luminescent characteristics of the films are so much rare in the erudition. The temperature of Substrate also effect to dig up the excellence of CdO films unto the applications of optical devices which are less explicit in the study. For this reason, luminescent exercises were executed on the CdO films and the praiseworthiness of them on the application of optical device was also clinched in the present study.

## 2. Experimental Descriptions

### 2.1. Sample Preparation

The light films of cadmium oxide were reposed on to Pyrex reflector that are synthetically washed substrates. A technique of spray was built indoors an actinic exhaust cowl to overcome disclosure to pernicious pour. When a jet of fine aerosol of initial solution is driven the deposition of the layer is gained by the carrier gas to the warmth substrate where pyrolysis reaction takes place. 2.5 psi air was used as the carrier gas. The substance nozzle distance and rate of gas flow was adjusted in like a way that sprays to 10 to 30 minutes generate $1800A^0$ to $6500A^0$ heavy rigid CdO films. Deionized water was used as the solution where 0.1M cadmium acetate diffused. It is observed that for producing good quality films $350^0$C temperature is more appropriate where $250^0$C to $380^0$C Substrate temperature taken as a reference temperature. By using copper-constantan thermocouple Substrate temperature was measured. The temperature of Substrate varies from +50C to -50C. The desired chemical reaction is following:

$$Cd\ (COOCH_3)_2.2H_2O \longrightarrow CdO + CO_2 + CH_4 + \text{steam}$$

### 2.2. Film Characterization

We use Fizeaufringes method along with Newton’s ring method for measuring the thickness of CdO films.Using PW 3040 X’Pert PRO XRD (X-ray Diffraction) System the diffraction was measured.using UV-1601 PC SHIMADZU scanning double beam spectrophotometer optical transmission measurements were carried out between the range of wavelength from 400 to 700 nm. By using transmittance spectra Absorption coefficient (α) optical band gap energy (Eg) were calculated.

## 3. Results and Analysis

A deposited film of the optical transmission spectra shown in Figure 1, reposed at $350^0$C temperature, and after the film was annealed at $400^0$C in air for two hours. The decreasing absorption edge shows the band gap at the time of annealing represented by hitch shift at the highest wavelength. The films are prepared by activation reactive evaporation method [31] and thermal evaporation method [32], shift on CdO was also observed. During annealing a reduction in band gap has also been observed for electrodeposited ZnO films from an aqueous bath [33]. The decrease in band gap might be happened for conduction of gathering free electrons (the Burstein-Moss shift) as CdO is a good material for optical coatings due to its high conductivity and transmittance. By employing Tauc’s plot along with the transmittance spectra, the optical band gaps of the films are measured. Implementing the equation, [34] the absorption coefficient (α) is determined:

$$\alpha = \ln (1/T)/d \quad (1)$$

Where, d and T represents film thickness and transmittance.

The optical band gap of the semiconductor dominates the optical absorption in the UV region. There is a relation between optical band gap (Eg) of a semiconductor, the optical absorption coefficient (α) and the incident photon energy (hv) by [35, 36]:

$$\alpha (v)\, hv = A\,(hv - Eg)^{n} \quad (2)$$

Where, A denotes a constant, Eg represents band gap of the material and the exponential term n relay on the type of electronic transition in k-space.

Cosidering a parabolic density of states in crystalline semiconductors, the variable may take values ½, 2, 3/2, and 3 for allowed direct, allowed indirect, forbidden direct and forbidden indirect transition gradually [37]. Let, n = ½, the direct band gap from (αhv)1/n vs. hv has been enumerated by anticipating the linear portion of the graph to hv axis at α = 0 and the value of absorption coefficient is found to be of the order of 104 cm−1 that supports the direct band gap nature of the semiconductor. The value of optical band gap energy is represented by the Extrapolation of the linear portion i.e. straight line portion up to the hv axis. The optical transition indicates that the fundamental region is due to the direct interring band transition. For films of various thickness is plotted in Figure 1 where optical band gap obtained for direct and indirect transition. The value of band gap determined here definitely homologues with the number found by Dakhel [38] for Zn-incorporated CdO thin films made by sol-gel method. A strong red shift in the optical spectra due to the reducion in band gap observed and this is implied to the rise of thickness of localized conditions in the energy gap. The accuracy found by experimental absorbance is ± 0.005 and the wavelength is ±0.05nm. The practical absorbance data were accurated relatively to optically identical uncoated glass substrate. With various substrate temperature the variation of optical band with the CdO films with various substrate temperatures are obsereved. Due to the decrease in Fermi energy in the degenerated semiconductor, this optical band gap happened which agree with the results of Vigil et al. [39], and has been assigned to local mechanical stress yield by impurities and defects [40].

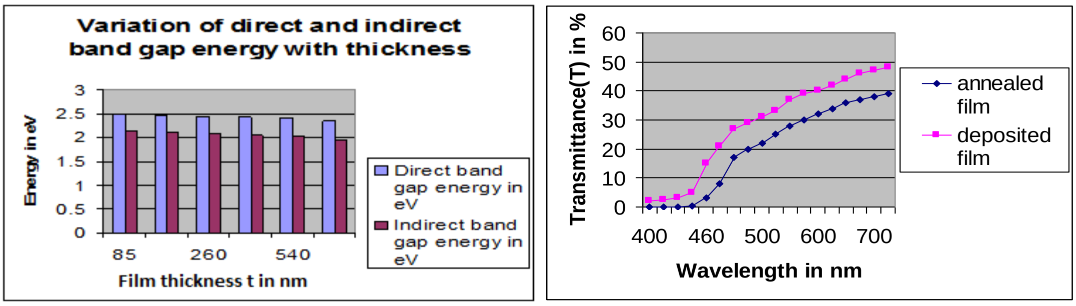


Figure 1. Plot of the Optical Transmittance (T) with Wavelength (nm) of an as Deposited and Annealed Film

## 4. Conclusion

CdO thin films of different thickness have been prepared by spray pyrolysis method at $350^{0}$C substrate temperature. The direct and indirect band gap energies were determined from optical transmission and reflection spectra and the values are obtained for samples that we have prepared. Obtained results are in good agreement with the results of others. From Figure 1, we can see that the transmittance increases nonlinearly with the increasing wavelength.

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