Fabrication and Optical Characterization of CdO Thin Films Deposited by Chemical Bath Method

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Abstract

Cadmium oxide (CdO) thin films have been deposited by chemical bath method onto glass substrate at 300K. The optical properties of the fabricated films are studied in details. The absorbance spectra of the fabricated films were obtained with a Janway 6405 UV/ Visible spectrophotometer in the range of wavelength 300nm - 1100nm. The films were found to have high transmittance of 100 % for the film with the lowest thickness and lowest deposition time and average transmittance of 50% for the film with highest film thickness with the highest deposition time. The optical absorption study reveals that CdO thin film have a bandgap range of 3.85eV- 4.00eV and a refractive index of 2.50. The reflectance of the deposited film was found to be generally low. Our results also revealed that the thickness of the films were dependent on the time of growth.

KEYWORDS Cadmium Oxide; Chemical Bath Deposition; Optical characterization.

INTRODUCTION

Cadmium oxide is an important II–VI semiconductor [1,2]. Such semiconductors are now widely used as transparent conductive oxides in many physical applications, specifically in optoelectronic devices such as solar cells, smart windows, optical communication, flat panel display, phototransistor etc [3,4], diodes and transparent electrodes [5-7]. CdO has high transparency in the visible region of the solar spectrum [8]. Cadmium oxide (CdO) has a narrow direct band gap of 2.2 eV to 2.5eV [9,10]. [11] Also reported a band gap of (2.32eV).

Various techniques such as thermal evaporation [12], sputtering [13], solution growth [14], pulsed laser sputtering[15], activated reactive evaporation [16], spray pyrolysis deposition [17], chemical bath deposition [18], metal organic vapor phase epitaxy [19], vacuum evaporation [20], electrochemical deposition [21], Sol - gel method [22], electron beam evaporation [23], solid vapour deposition [24], RF magnetron sputtering [25], and successive ionic layer adsorption and reaction [26], were employed to prepare thin films of CdO.

In this paper, we have deposited CdO thin films onto glass substrate by chemical bath deposition technique because of it's simplicity, cheapness, low cost of starting material and capability of large area deposition. Detailed optical properties of the fabricated CdO thin films have been investigated for various film thicknesses. The influence of annealing temperature on the films characteristics have also been investigated. We have compared the results of our as-deposited CdO thin films with the results of other researchers.

MATERIALS AND METHODS

We synthesized all the films for this experiment using chemical bath deposition (CBD).

The preparations were done under normal atmospheric pressure in a controlled temperature water bath. The deposition of CdO thin film by CBD was based on the reaction between aqueous solutions of cadmium nitrate and 0.5M solution of kOH (Potassium hydroxide) using H_2O_2 (hydrogen peroxide) as a complexing. 0.2M solution of Cadmium nitrate was prepared by dissolving 11.82g of $Cd(NO_3)_2$ in 250ml of distilled water. 0.5M solution of kOH was prepared by dissolving 7.01g of kOH in 250ml of distilled water. Prior to the deposition, the substrates were degreased, by dipping them in concentrated (HNO_3). They were brought out after 42hrs, washed with detergent, rinsed in distilled water and dried in air. The degreased and cleansed surface has the advantage of providing nucleation centre for the growth of the films, hence yielding highly adhesive and uniformly deposited films. Potassium hydroxide acted as a pH stabilizer in the alkaline medium, and it represented a source of (OH^-) ions. While the role of H_2O_2 is to avoid the spontaneous precipitation of any solid phase in the reaction. The deposition of CdO film is achieved by slowly mixing 20ml solution of cadmium nitrate, 20ml of potassium hydroxide and 10ml of 6% hydrogen peroxide solution. The mixing was done at room temperature in five beakers. The pH of the mixtures was 10.5. The beakers containing the mixture were placed in a water bath maintained at a temperature of 343k and were allowed to stay 1hr, 2hrs, 3hrs, 4hrs and 5hrs. Each beaker contains a substrate vertically introduced in it. Each substrate was washed with distilled water after removal and dried in air. Whitish films due to the $Cd(OH)_2$ were formed on the glass substrates. An attempt to heat treat the films was made in an oven at temperature of 473k so that the $Cd(OH)_2$ films could be converted to CdO films. However, the temperature of 473k is not enough to convert $Cd(OH)_2$ to CdO as will be shown by the results.

Table 1: Bath constituents for the deposition of cadmium oxide Thin Film

Slide No.	**Vol. of** H_2O_2 **(mls)**	**Vol. of** $Cd(BO_3)_2$ **(mls)**	**Vol. of** kOH **(mls)**	**Time (hrs)**	**Thickness (µm)**
H_1	10.00	20.00	20.00	1.0 0	0.37
H_2	10.00	20.00	20.00	2.0 0	0.43
H_3	10.00	20.00	20.00	3.0 0	0.60
H_4	10.00	20.00	20.00	4.0 0	0.65
H_5	10.00	20.00	20.00	5.00	0.70

Optical absorption and transmission of the prepared films were recorded over the wavelength range from 300-1100 nm using a Janway 6405 UV/ Visible spectrophotometer. Other optical properties which include reflectance, refractive index, extinction coefficient where calculated using theory.

Result and Discussion

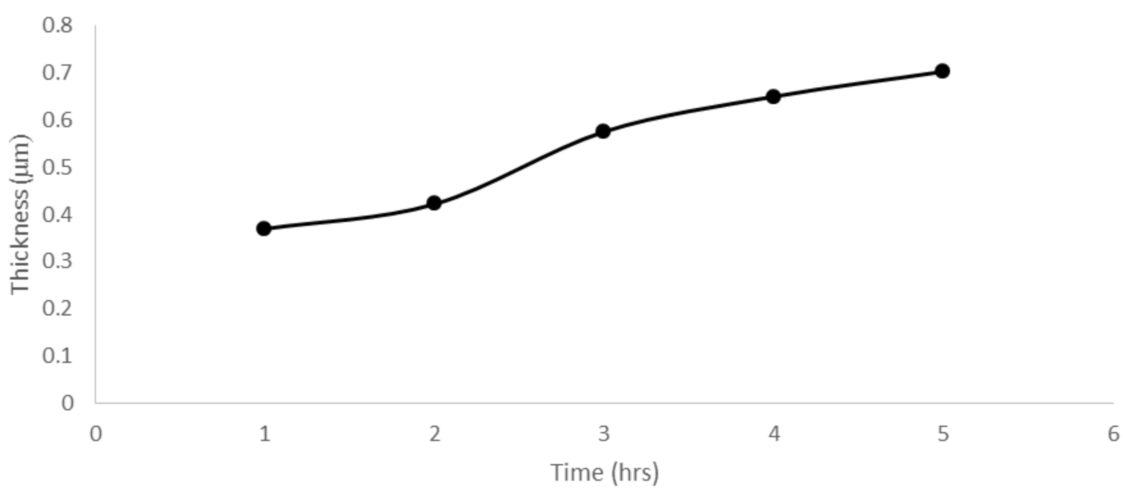

Fig. 1: Plot of thickness of as-grown films against time

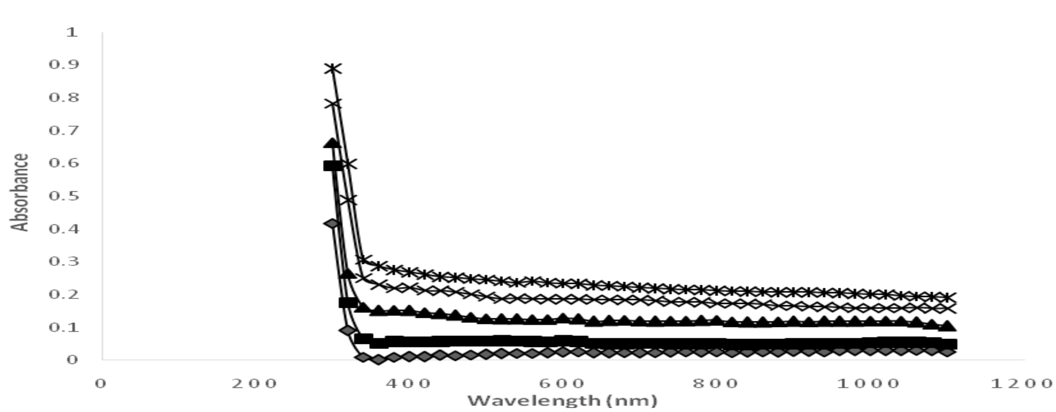

Fig. 2 Plot of absorbance of as-grown films against wavelength

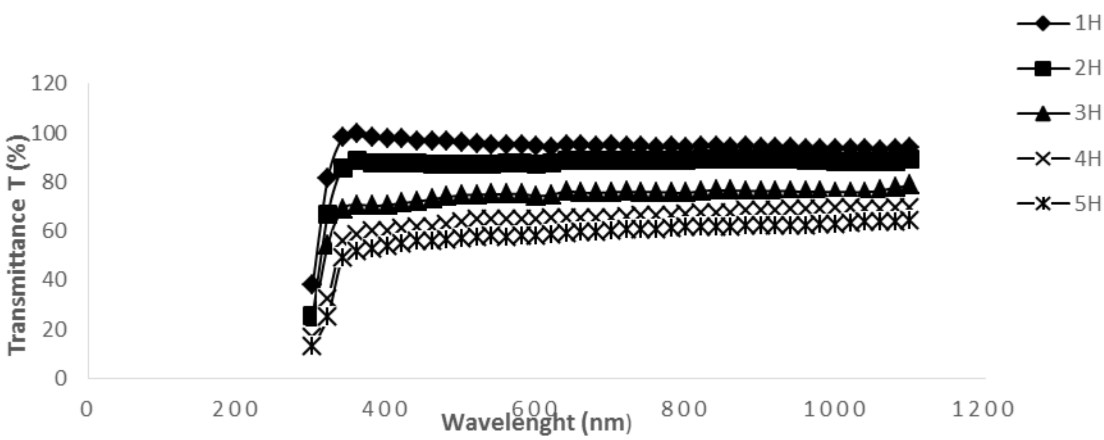

Fig. 3 Plot of Transmittance of as-grown films against wavelength

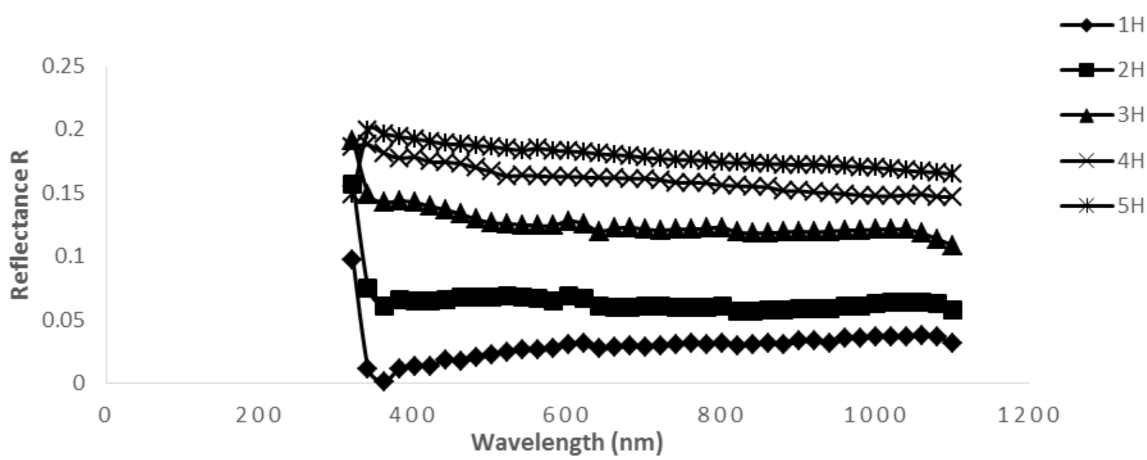

Fig. 4 Plot of reflectance of as-grown films against wavelength

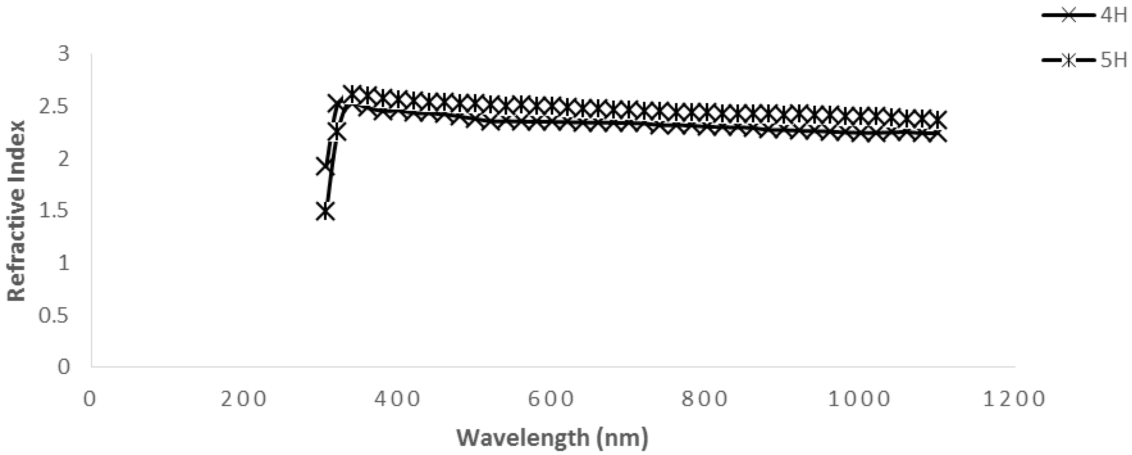

Fig. 5 Plot of refractive index of as-grown film against wavelength

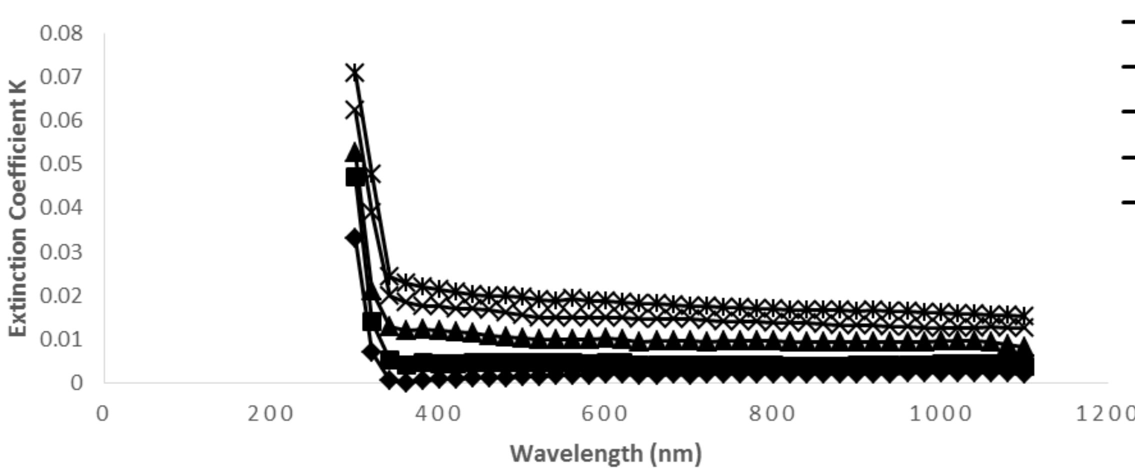

Fig. 6 Plot of extinction coefficient of as-grown film against wavelength

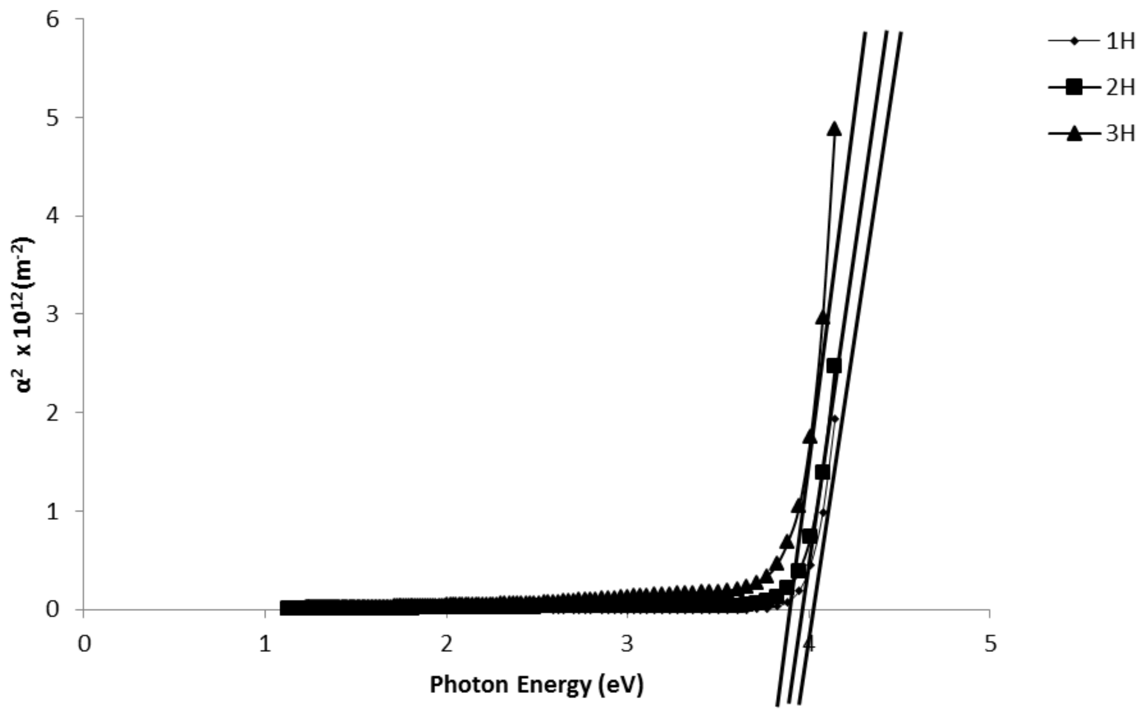

Fig. 7 Plot of absorption coefficient square (α^2) of as-grown films against photon energy

Fig. 1 is a plot of thickness versus time. The thickness of the film increased almost linearly with deposition time. The lowest film thickness of 0.37µ at 1hr deposition time and highest film thickness of 0.70 µ at 5hrs deposition time was obtained.

Fig. 2 shows the variation of absorbance with wavelength. The film grown at 5hrs deposition time with the highest film thickness has the highest absorbance of approximately 0.300 in the Vis/Nir region of the electromagnetic spectrum, while that with the lowest film thickness grown at 1hr deposition time has the lowest absorbance of approximately 0.000 in the Vis /Nir region of the electromagnetic spectrum. The absorbance is generally high in the UV region for all the samples. Slide 5H has approximately 0.900, while slide 1H has approximately 0.440.

Fig. 3 shows the variation of transmittance with wavelength. Slide 5H grown at 5hrs deposition time with the highest film thickness has the lowest transmittance of approximately 50% in the Vis/Nir region of the electromagnetic spectrum, while that with the lowest film thickness grown at 1hr deposition time has the highest transmittance of approximately 100% in the Vis /Nir region of the electromagnetic spectrum, this is in agreement with the finding of [27]. Generally the transmittance increased with decrease in the film deposition time which conversely indicates that the lower the film thickness the higher the transmittance. The very high optical transmittance exhibited by these films makes them potential candidates for application as low-cost large-area transparent conductors.

Fig. 4 shows the variation of reflectance with wavelength. All the samples reveal very low reflectance throughout the spectrum with the highest value of approximately 0.20 for slide 5H and 0.04 for slide 1H. This will have a useful application in antireflection coating.

Fig. 5 shows the variation of refractive index with wavelength. Refractive index of approximately 2.50 was obtained for this film. This high refractive index value makes CdO thin film a good material for photovoltaic application.

Fig. 6 shows the variation of extinction coefficient with wavelength. Slide 5H grown at 5hrs deposition time with the highest film thickness has approximately 0.20 in the Vis/Nir region of the electromagnetic spectrum, while that with the lowest film thickness grown at 1hr deposition time has approximately 0.00 in the Vis /Nir region of the electromagnetic spectrum.

Fig. 7 is a plot of absorption coefficient squared (α^2) versus photon energy hυ for CdO thin film. The optical bandgap energy of CdO thin films were determined from this graph by extrapolating the straight portion of the graph to $\alpha^2=0$. The values obtained are 3.85eV, 3.95eV, and 4.0eV for slide 3H, 2H and 1H respectively. This is in agreement with the range of 3.37 – 4.64eV obtained for as grown films by [28].

CONCLUSION

We have successfully fabricated good quality thin films of CdO by CBD technique using glass substrate. The films were found to have high transmittance of approximately 100 % for the film with the lowest thickness and lowest deposition time and average transmittance of approximately50% for the film with highest film thickness with the highest deposition time. The optical absorption study reveals that CdO thin films have bandgap range of 3.85eV-4.00eV and a refractive index of 2.50. The reflectance of the deposited film was found to be generally low. Our results also revealed that the thickness of the films were dependent on the time of growth. These properties makes CdO Thin film useful as a transparent conductive material, photodiodes, phototransistors, photovoltaic cells, transparent electrodes, liquid crystal displays, IR detectors, and anti reflection coatings.

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