Research Paper

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Optical and Electrical Properties of Spray Deposited Cdo Thin Films: Effect of Substrate Temperature

Physics

KEYWORDS : Thin films; X-ray diffraction; Cadmium oxide; spray pyrolysis

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ABSTRACT

The present paper reports on the study of the influence of deposition temperature on optical and electrical properties of the CdO thin films prepared by spray pyrolysis technique. These films were characterized for the structural, morphological, optical and electrical properties by means of X-ray diffraction (XRD), optical and electrical resistivity. As deposited CdO films are polycrystalline with (111) preferential orientation. The optical band gap value decreased from 2.46 to 2.38 eV with increasing the substrate temperatures. The electrical conductivity of the films was found to increase with increase in substrate temperature. The high conductivity of 6.17 × 103 (Ω-cm)-1 and high transparency (80%) was obtained for the film grown at 350 0C.

1. Introduction

In recent years, the metal oxide semiconductor materials have attracted much attention owing to their potential applications in electronic and photovoltaic devices. CdO is an importnat semiconductor with a rock-salt crystal structure (FCC) and possesses a direct band-gap of 2.2 eV [1]. Transparent conducting oxide (TCO) thin films such as zinc oxide, indium oxide, tin oxide, indium tin oxide and cadmium oxide have attracted considerable attention because of their low resistivity and high optical transmittance [2-3]. Due to their optical and electrical properties, TCOs are used for photovoltaic solar cells, phototransistors, liquid crystal display(s), optical heaters, gas sensors, transparent electrodes and other optoelectronic devices [4-5]. Among these TCOs, cadmium oxide (CdO) is not a popular TCO material due to its low optical band gap. However, CdO is a particularly interesting material because it is one of the semiconducting oxides with high carrier mobility, and has great potential for using in optoelectronic devices [6]. Cadmium oxide (CdO) films have been prepared by different methods such as sol–gel [7], chemical bath deposition [8], spray pyrolysis [9], direct current magnetron sputtering [10] and radio-frequency sputtering [11].

2. Experimental details

The CdO films were deposited on glass substrates by spray pyrolysis technique. In the preparation of CdO films 0.5M cadmium sulphate was diluted with double distilled water. Aqueous solution of cadmium sulphate was prepared and sprayed through specially designed glass nozzle onto a ultrasonically cleaned glass substrates. Spray rate 4 cc/min. was maintained constant by using air as a carrier gas. Substrate temperature of the heater was varied from 250 ^{0}C to 350 ^{0}C by using electronic temperature controller. The films prepared at different substrate temperature are denoted by C_{250}, C_{300}, C_{350} etc. where subscript denotes the substrate temperature. X-ray diffraction, morphological and optical studies were carried out for all samples.

The crystal properties of the films were assessed by X-ray diffraction (XRD, Philips PW-3710 model) and the film composition and morphology was analyzed by scanning electron microscopy (JEOL JMS-6300 Electron Microprobe). The optical properties were analyzed from the film transmittance data, which were recorded using a UV–VIS Shimadzu 3101-PC spectrometer.

3. Results and discussion
3.1. Optical characterization

In transparent metal oxides, metal to oxygen ration and crystal orientation decides the percentage of transmission. The information about physical properties, like band gap energy, band structure and optically active defects is determined from characterization of the films [12]. The optical transmittance of the film was studied in the wavelength range 300–900 nm. Fig. 1

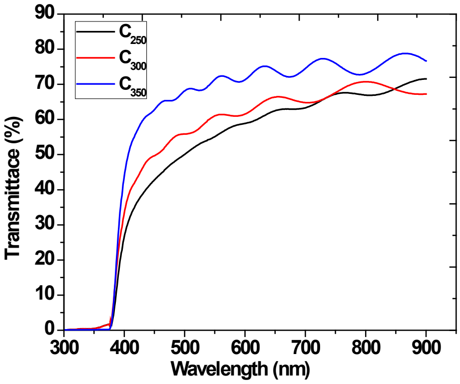

Fig. 1. Optical transmittance spectra of spray deposited CdO thin films.

shows the effect of substrate temperature on optical transmittance of as-deposited CdO thin films on amorphous glass substrates. It is observed that the film transparency depends on the growth temperature. The percentage transmittance at 550 nm wavelengths of the films grown at 250 ^{0}C, 300 0C and 350 0C are 69%, 72% and 80% respectively. The effect of substrate temperature on optical band gap of CdO thin films has been determined from the data of transmittance vs. wavelength plot. The absorption coefficient is given by

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

where T is transmittance and d is thickness of the film. The film thickness is of as-deposited CdO films is calculated by gravimetric weight difference method and listed in Table 1. The relation between absorption coefficient (α) and the incident photon energy (hν) is given by the following equation [13]

$$(\alpha h\nu) = A(h\nu - E_g)^{\frac{1}{2}} \quad (2)$$

where the symbols have their usual meanings. For allowed direct transition, n = 1/2. 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 energy band gap (Eg) can be determined by extrapolating the linear regions of the plots to zero absorption. Fig. 2 shows the relationship (αhν)2 vs. (hν) for films grown at different deposition temperature. The observed straight-line behavior establishes that the films have a direct band gap. The determined optical band gap values are listed in Table1.

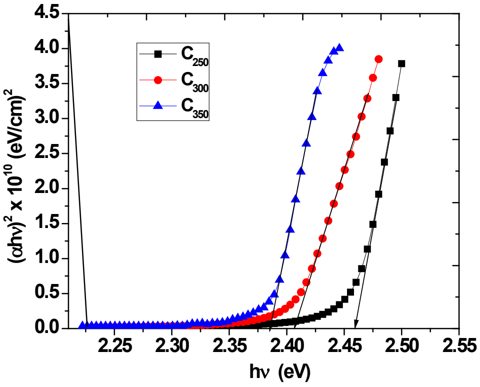

Fig. 2. Variation of (αhν)2 versus hν for CdO thin films.

Table 1. Some physical parameters of CdO thin films deposited by spray pyrolysis.

Sample Code	Depo. Temp. (0C)	Thick. (nm)	Cryst. size (nm)	Transmittance at 550 nm (%)	Band gap Eg (eV)
C250	250	310	22.6	69	2.46
C300	300	360	24.2	72	2.41
C350	350	395	25.8	80	2.38

3.2. Electrical properties

The D.C. two point probe method of dark electrical resistivity measurement was used to study the variation of electrical resistivity (ρ) with temperature in the range 300-550 K. The variation of resistivity (ρ) with reciprocal temperature (K−1) is depicted in Fig. 3. The deposition temperature variation affects the resistivity magnitude of CdO thin films because a more complete reaction occurs as the temperature is increased. The decrease in resistivity is also expected up to a certain temperature, (here 350 0C) considered as the optimum deposition temperature, above which the resistivity increases. A further increase in substrate temperature causes increase in the film resistivity.

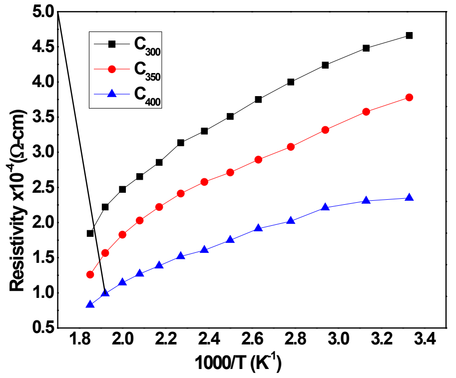

Fig.3. Variation of resistivity with substrate temperature for sprayed CdO thin films.

4. Conclusions

Transparent and conducting CdO films were deposited on glass substrates at different substrate temperate by economical spray pyrolysis method. The effect of deposition temperature on structural, morphological and optical properties was studied. The polycrystalline CdO thin films were confirmed to be cubic crystal structure. The as-deposited CdO films exhibit good optical transmittance with decreased band gap values. This suggests that these films have significant commercial relevance.

The dc electrical resistivity of CdO thin films were decreased with increase in deposition temperature.

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