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RESEARCH ARTICLE

# Opto-electronic properties of chemically deposited Al doped CdO thin films

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## ABSTRACT

Al doped Cadmium oxide (CdO) films were deposited by spray pyrolysis technique. The influences of Al doping (1%, 2%, 3% and 4%) on optical and electrical properties were studied. The transmission spectra of these films indicate sharp absorption edge and high optical transparency in visible range. The optical band gap value decreased from 2.46 to 2.38 eV with increasing the Al content. The dc electrical resistivity of Al: CdO thin films were decreased from $8.96 \times 10^{-4}$ to $3.42 \times 10^{-4}$ ($\Omega$ cm) with increase in Al concentration.

**Keywords:** Thin films; Cadmium oxide; spray pyrolysis; Optical properties; Electrical conductivity

## INTRODUCTION

The metal oxide semiconductor materials have attracted much attention owing to their potential applications in various electronic and photovoltaic devices. These oxide thin films of transparent conducting oxides (TCO) such as doped zinc oxides, indium oxides, tin oxides and cadmium oxides have attracted much more attention because of their low resistivity and high optical transmittance [1–6]. These TCO films are widely used for many applications such as in flat panel display, light emitting diodes and photovoltaic cells [7-9]. Among these TCO, cadmium oxide (CdO) has received considerable attention for solar cell application due to its low electrical resistivity and high transparency in the visible range of solar spectrum [10]. Different techniques such as sol–gel [11], DC magnetron sputtering [12], radio-frequency sputtering [13], spray pyrolysis [4], chemical vapor deposition [14], chemical bath deposition [15], and pulsed laser deposition [16] have been used to deposit CdO thin films. Spray pyrolysis method is very easy to handle and also it is cost effective as well.

Considering various application of CdO films in various technologies we have decided to prepare CdO films and Al doped CdO thin films by spray pyrolysis method and to study the optical and electrical properties of as deposited thin films.

## METHODOLOGY

The basics of spray pyrolysis technique are spraying a solution on a heated substrate. This method is an economically attractive. All the chemical reagents used in the experiments were obtained from commercial sources as guaranteed-grade reagents and used without further purification. The amorphous glass substrates supplied by Blue Star Mumbai, were used to deposit the CdO thin films. Before the deposition of CdO thin films, glass slides were cleaned with detergent and distilled water, then boiled in chromic acid (0.5 M) for 25 min, then slides washed with double distilled water and further ultrasonically cleaned for 15 min. Finally the substrates were degreased in AR grade acetone and used for deposition.

### *2.1. Thin film preparation*

Al doped CdO films were prepared on preheated glass substrate using a spray pyrolysis technique. Spray pyrolysis is basically a chemical process, which consists of a solution that is sprayed onto a hot substrate held at high temperature, where the solution reacts to form the desired thin film. The spraying solution was prepared by mixing the appropriate volumes of 0.5 M cadmium sulphate ($CdSO_4$) and distilled water. The aluminum nitrate was used as a dopant. The optimized values of important preparative parameters are shown in bracket viz. airflow rate which is used as carrier gas (1.2 kg/cm$^2$), spray rate (2.5 ml/min), distance between substrate to nozzle (28 cm), solution concentration (0.5 M) and quantity of the spraying solution (30 ml). The substrate temperature was kept at 350 $^0$C. After the deposition; the films were allowed to cool naturally at room temperature.

### *2.2. Characterization of thin films*

Optical transmittance and reflectance spectra with respect to glass substrate at RT were taken by using a double beam spectrophotometer (UV-1601 PC Shimadzu) with wavelength range (300–1100 nm).. Electrical resistivity (ρ) of the films was measured at room temperature by two-probe resistivity technique and by providing silver paste for ohmic contacts at the edges of the films.

## RESULTS AND DISCUSSION

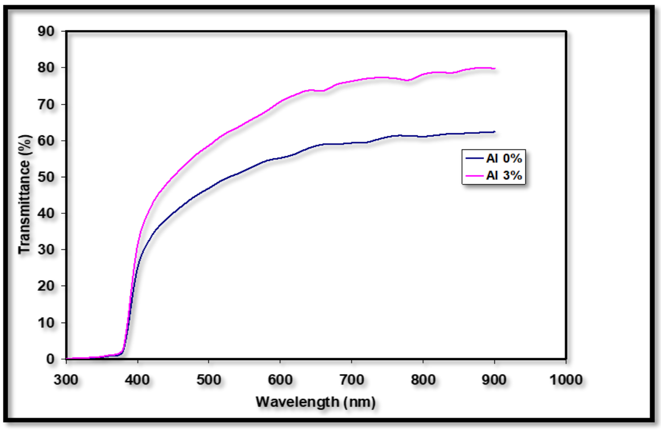


**Fig. 1:** Optical transmittance spectra of undoped and 3% Al doped CdO thin films

### *3.1. Optical properties*

The optical transmission spectra of spray deposited Al: CdO films conducted at room temperature, in the wavelength range from 300 nm to 900 nm are depicted in Fig. 1. All the transmission spectra of these films indicate sharp absorption edge and high optical transparency in visible range suggesting good quality of the films. It can be observed from Fig. 3 that the transmission values of the films are at short wavelengths (≤ 520 nm) and high at longer wavelengths. This is related to the energy of incident light, when energies of photons are smaller than the band gap of CdO film. They are insufficient for excitation of electrons from valance band to conduction band [17].

The optical band gaps for the sprayed Al: CdO thin films are calculated on the basis of the optical spectral absorption using the following well-known relation [18]

$$\alpha h\nu = A\left(h\nu - E_g\right)^n \quad (1)$$

where A is constant, Eg is the separation between valance band and conduction band, n is constant equal to 1 for direct band gap semiconductors and 4 for indirect band gap materials. In the present investigation the optical absorption coefficient is of the order of $10^4$ cm$^{-1}$, supporting the direct transition of the material [19-20]. The variation of $(\alpha h\nu)^2$ vs. hν is linear and shown in Fig. 2, which means that the mode of transition in these films is of direct nature. The extrapolation of these curves to energy axis for zero absorption coefficient value gives the optical band gap energy. With increase in Al content energy band gap decreased from 2.46 eV to 2.38 eV. The decrease in band gap energy with increase in film thickness is commonly observed phenomenon in semiconducting thin films [21-23].

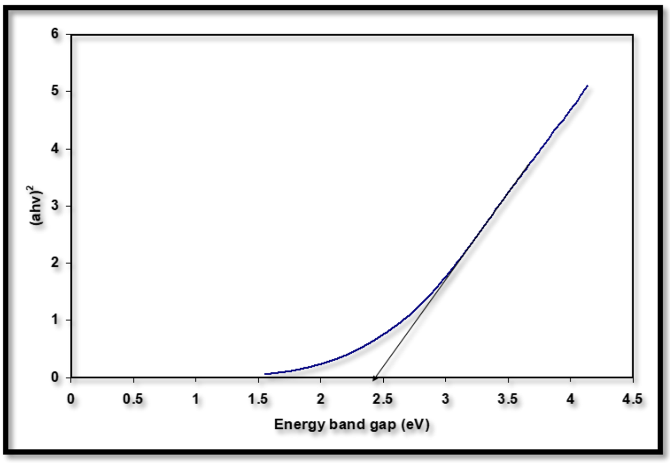


**Fig 2:** Variation of $(\alpha h\nu)^2$ with photon energy for 2% Al doped CdO thin film

### *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 Al content variation affects the resistivity magnitude of CdO thin films. The dc electrical resistivity of Al: CdO thin films were decreased from $8.96 \times 10^{-4}$ to $3.42 \times 10^{-4}$ (Ω cm) with increase in Al concentration.

## CONCLUSION

In this study, the influence of Al doping on the optical and electrical properties of CdO thin films grown on amorphous glass substrates by spray pyrolysis was investigated. CdO has direct band gap which is suitable for photovoltaic solar cell, and the energy gap was calculated as 2.46 eV-2.38 eV after doping of Al. These values are in good agreement with the literature. The dc electrical resistivity of Al: CdO thin films were decreased from $8.96 \times 10^{-4}$ to $3.42 \times 10^{-4}$ (Ω cm) with increase in Al concentration.

**Conflicts of interest:** The authors stated that no conflicts of interest.

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