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Physical Properties of Chemical Spray Deposited Al doped CdO Thin Films

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ABSTRACT

The purpose of this work is to study the influence of Al doping (1%. 2% and 3%) on structural and surface morphological properties of the CdO thin films prepared by spray pyrolysis technique. These films were characterized for the structural and morphological properties by means of X-ray diffraction (XRD) and scanning electron microscopy (SEM). As deposited CdO films are polycrystalline with (111) preferential orientation. The information on crystallite size is obtained from the full width-at half-maximum (FWHM) of the diffraction peaks. The optical band gap value decreased from 2.46 to 2.38 eV with increasing the Al content.

Keywords: Thin films; X-ray diffraction; Cadmium oxide; spray pyrolysis; Optical properties.

1. INTRODUCTION

Transparent conducting metal oxide semiconductor materials have attracted much attention owing to their potential applications in flat panel display, smart windows, light emitting diodes, heat reflectors, electronic, photovoltaic devices and solar cells[1–4]. Its high electrical conductivity and high optical transmittance in the visible region of the solar spectrum along with a moderate refractive index make it useful for various applications such as transparent electrodes, phototransistors, photodiodes, gas sensors, etc.[5-6]. CdO is an n-type semiconductor with a rock-salt crystal structure (FCC) and possesses a direct band gap of 2.2 eV [7]. Besides, the CdO will be attractive in the field of optoelectronic devices by making heterostructures with ZnO which has band gap energy of 3.3 eV. CdO thin films have been prepared by various techniques such as sol–gel, DC magnetron sputtering, radio-frequency sputtering, spray pyrolysis, pulsed laser deposition, chemical vapor deposition, and chemical bath deposition[8-14].

Further, among these methods, the spray pyrolysis is unique and cost effective compared to other methods requiring high vacuum environment. It is one step method operating at atmospheric pressure with very short production time[15-17]. This can be used to tune the band gap of materials. Due to these economical and flexible experimental conditions, spray pyrolysis has been employed to deposit CdO thin films and to study various properties of the films. The crystalline structure and optical properties of the films were studied as a function of the Al content in CdO.

2. EXPERIMENTAL DETAILS

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). After the deposition, the films were allowed to cool naturally at room temperature. All the films were transparent and well adherent to the substrate, were further used for structural and morphological characterizations.

2.2. Characterization of thin films

The film thickness of the as-deposited films was measured by a well-known gravimetric weight difference method using sensitive microbalance and assuming bulk density of CdO (8.15 g/cm^3). The structural characterization of the films was carried out by analyzing the X-ray diffraction (XRD) patterns obtained using Philips PW-3710 X-ray diffractometer with CuKα radiation (λ = 1.5406 Å), within the 2θ range of angles between 20 and 80^0. The surface morphology of the spray-deposited CdO thin films on glass substrate was carried out using JOEL-JSM 5600.

3. RESULTS AND DISCUSSION

3.1 Film thickness

Film thickness has a strong impact on the structural and optical properties of the device. Film layer thickness was measured by gravimetric weight difference method using the relation,

$$t = \frac{m}{\rho A} \quad (1)$$

Where, m is the mass of the film deposited onto the substrate, A is the area of the deposited film and ρ is the bulk density of CdO (8.15 g/cm^3). Thicknesses of as-deposited thin films were found to be in the range from 280 nm to 400 nm.

3.2. X-ray diffraction analysis

The XRD patterns of as-deposited CdO thin films as function of deposition temperatures are shown in Fig. 1. All the films are observed to be well grown with polycrystalline textures having cubic CdO phase. For all films, major crystalline texture is (1 1 1)-oriented one (JCPDS card No.: 75-0592). The intensity of the major reflex increased with increase in Al content. For the CdO films, the main characteristic peaks are assigned to the (1 1 1), (2 0 0), (2 2 0) (3 1 1) and (2 2 2) planes.

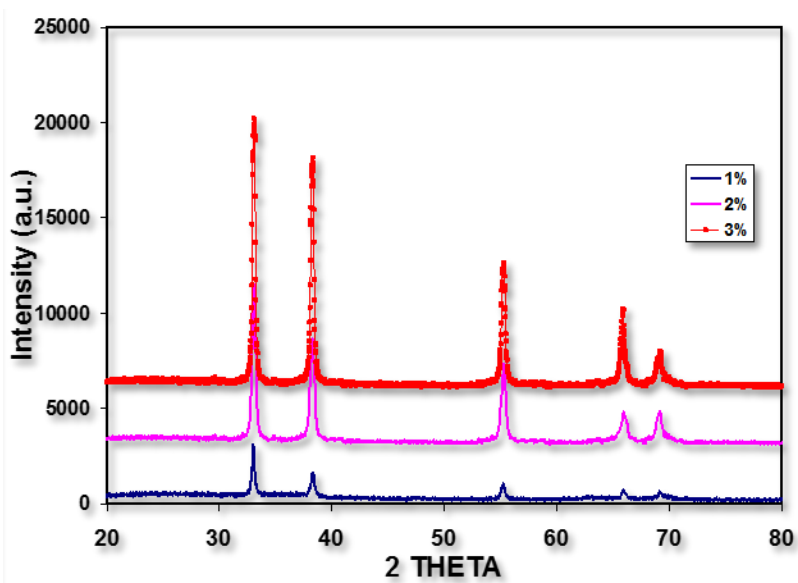

Fig. 1 XRD Spectra of Al doped CdO thin films.

The grain size, strain, lattice parameter, dislocation density and texture coefficient were estimated form the XRD pattern. The grain size was estimated using Scherer's equation[17]

$$D = \frac{0.94\lambda}{\beta \cos\theta} \qquad (2)$$

where λ is the wavelength of incident X-ray, β is the full width at half maximum (FWHM) measured in radians and θ is the Bragg's angle of diffraction peak.

3.3. Morphological studies

Fig. 2 shows the typical SEM micrographs of CdO films. It can be obviously seen from Fig. 2 that the film has not a smooth and homogeneous surface morphology with a holes and cracks. But also, all the films are compact, dense and adhered well to the substrates. The surface properties of the CdO films appear to change significantly as a function of Al dopant. At some favorable nucleation centers overgrown grains and cloudy splashes are also seen. This is one of the uniqueness found in spray pyrolysis technique and such type of film morphology is useful in sensing properties.

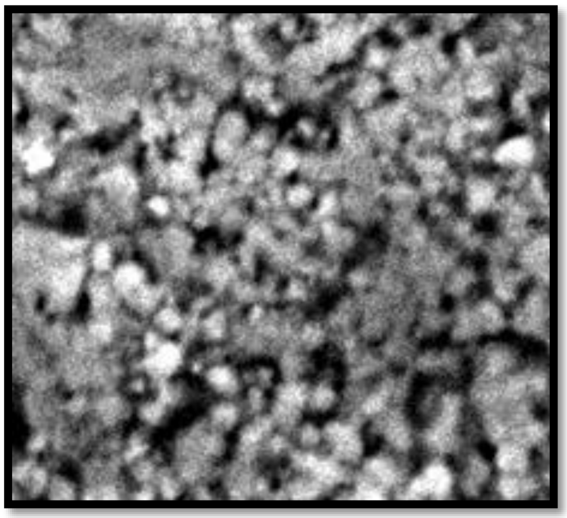

Fig. 2 SEM micrograph of Al: CdO (2%) thin film.

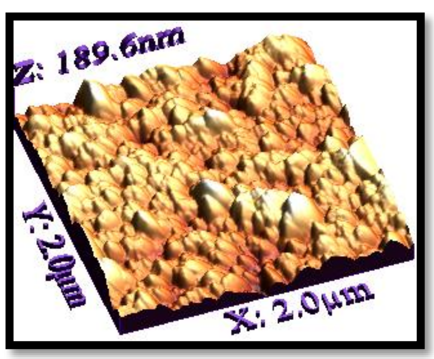

Fig. 3 AFM micrograph of Al: CdO (2%) thin film.

3.4. Optical properties

The optical transmission spectra of spray deposited CdO films conducted at room temperature, in the wavelength range from 400 nm to 1050 nm are depicted in Fig. 3. All the transmission spectra of these films indicate sharp absorption edge and high optical transparency in visible range suggesting good quality of the films. The optical band gaps for the sprayed CdO thin films are calculated on the basis of the optical spectral absorption using the following well-known relation[21]

$$\alpha h\nu = A\left(h\nu - E_g\right)^n \qquad (3)$$

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}. With increase in Al content energy band gap decreased from 2.46 to 2.38 eV.

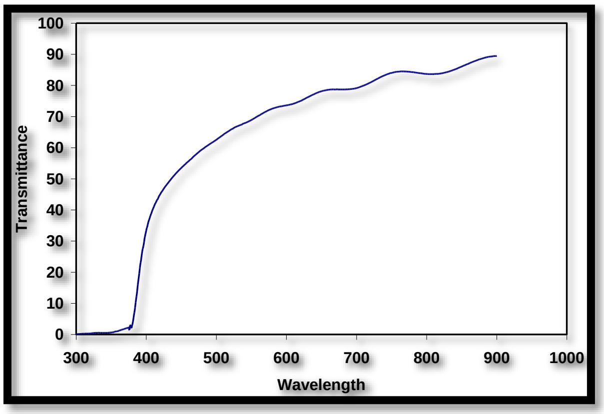

Fig. 3 Optical transmission spectra of 2% Al doped CdO films

4. CONCLUSIONS

In this study, the influence of the Al dopant on the structural and surface morphological properties of CdO thin films grown on amorphous glass substrates by spray pyrolysis was investigated. From the X-ray diffraction (XRD) pattern, it was observed that the CdO thin films were polycrystalline with cubic structure. AFM and SEM analysis revealed the surface morphology of the films is uniform. One of the uniqueness found in spray pyrolysis technique and such type of film morphology is useful in sensing properties. As Al content is increased energy band gap decreased from 2.46 to 2.38 eV.

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