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Structural, optical and electrical properties of transparent conducting hydrophobic cadmium oxide thin films prepared by spray pyrolysis technique

K. Sankarasubramanian [a], P. Soundarrajan [a], K. Sethuraman [a,*], R. Ramesh Babu [b], K. Ramamurthi [c]

[a] School of Physics, Madurai Kamaraj University, Madurai 625 021, Tamil Nadu, India
[b] Crystal Growth and Thin Film Laboratory, Department of Physics, Bharathidasan University, Tiruchirappalli 620 024, Tamil Nadu, India
[c] Department of Physics & Nanotechnology, SRM University, Chennai 603 203, Tamil Nadu, India

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ABSTRACT

Cadmium oxide thin films were deposited by spray pyrolysis method on the glass substrate at 300 °C using different concentration of cadmium acetate. X-ray diffraction (XRD) measurements show that the coated CdO film belongs to cubic crystal structure with preferential orientation along (1 1 1) direction. Wettability results revealed that the hydrophobic character of CdO thin film is enhanced with increase in the precursor concentrations. The surface morphology and roughness of the films were determined by Atomic Force Microscope (AFM). The average optical transmittance of CdO films in the range 400–800 nm, is about 80%. The resistivity, mobility and carrier concentration of CdO thin films were determined by Hall effect measurement. Photoluminescence (PL) spectra showed a strong emission peak around 590 nm.

* Corresponding author. Tel.: +91 452 2458471, +91 9445252309.
E-mail address: sethuraman_33@yahoo.com (K. Sethuraman).

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1. Introduction

Transparent conducting oxides such as cadmium oxide, zinc oxide, indium oxide, tin oxide find wide applications in optoelectronic devices, gas sensors and phototransistors [1–4]. In particular, cadmium oxide (CdO) is a promising material for solar cell applications due to its high electrical conductivity and high optical transmittance in the visible region of solar spectrum [5]. CdO is an n-type semiconducting material with the band gap energy of 2.16 eV at room temperature. Therefore, CdO is used as a window layer in heterojunction solar cell [6,7]. The conductivity, mobility and carrier concentration of CdO thin film are based on the creation of cadmium interstitial and/or oxygen vacancies that can be controlled by doping CdO with different metal ions or varying the physical parameters such as, work function, electron affinity and film thickness of the film. Several techniques have been used to deposit CdO thin films such as chemical vapor deposition [8], sputtering [6], chemical bath deposition [9], sol–gel [10], SILAR [11,12], thermal evaporation [13], layer by layer assembly [14] and spray pyrolysis [15–18]. Owing to simplicity and inexpensiveness, the spray pyrolysis is a better chemical method for the preparation of thin films with larger area coating and it provides an easy way to dope the elements in the required ratio proportion through the precursor solution [19]. In this work, we report on the deposition of CdO films using spray pyrolysis technique and studied the hydrophobic nature of the prepared CdO films with the role of precursor concentration on CdO thin films.

2. Experimental

CdO thin films were deposited on the glass substrates at 300 °C using spray pyrolysis technique. Cadmium acetate [$Cd(CH_3(COO)_2)$] was used as source material of Cd and double distilled water was used as solvent. Spray solution of 50 ml was prepared with various precursor concentrations (0.025, 0.05, 0.075, 0.1 M) of cadmium acetate. The optimized deposition parameters such as substrate-spray nozzle distance (25 cm), spray angle (about 45°), spray time (3 s), spray interval (30 s), carrier gas pressure (compressed air −40 kg/cm^2) and the flow rate of the solution (about 3 ml/min) were kept constant. The substrate temperature (T_s) was fixed at 300 °C. When increasing the concentration of precursor solution, color of the coated film was changed from pale yellow to bright yellow. The chemical reaction that takes place is as follows.

$$Cd(CH_3COO)_2 + 3H_2O \rightarrow CdO \downarrow + CH_4 \uparrow + 4H_2 \uparrow + 3CO_2 \uparrow$$

After deposition, the coated substrates were allowed to cool down to room temperature. Thickness of the films was measured using stylus profilometer (SJ-301, Mitutoyo). X-ray diffraction patterns were recorded using Philips X Pert PRO X-ray diffraction system (Cu Kα_1 radiation; λ = 1.54056 Å). The hydrophobic nature of the cadmium oxide thin film was confirmed by the wettability test. Surface characteristics were carried out by AFM (A100 SGS). The optical transmittance spectrum in the wavelength region 190–900 nm was recorded using UV–Vis spectrometer (Shimadzu UV-1601). The electrical properties of the films were studied using Hall measurements setup in vander Pauw configuration (Ecopia HMS-3000). Room temperature luminescence spectrum was recorded using (SHIMADZU-5301) spectrofluorometer.

3. Results and discussion

3.1. X-ray diffraction studies

XRD patterns of CdO thin films deposited at 300 °C using different precursor concentrations are shown in Fig. 1(a–c). The CdO films exhibit predominant diffraction peak along the (1 1 1) plane with cubic crystal structure and the peak positions are well agreed with JCPDS card no 75-0591. From the XRD analysis, it is observed that all the prepared CdO thin films are polycrystalline in nature. The (1 1 1) plane intensity was found to be increased with increasing precursor concentrations. It was observed that as the cadmium acetate concentration increases, the peak intensity increased correspondingly. This indicates the incorporation of more Cd^{2+} ions on the film during the pyrolysis process.