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Effect of seed layer on surface morphological, structural and optical properties of CdO thin films fabricated by an electrochemical deposition technique

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ABSTRACT

Cadmium oxide (CdO) thin films were grown on Indium Tin Oxide (ITO)-coated glass substrates by an electrochemical deposition technique using $CdCl_2 \cdot 6H_2O$ (0.02 M) and KCl (0.1 M) solutions at a bath temperature of 70 °C and a pH of 6.0. The CdO thin films were produced without seed layers and with seed layers. The surface morphological and structural properties of the CdO thin films were studied by X-ray Diffraction (XRD) and Scanning Electron Microscopy (SEM). The optical properties of the samples were studied by UV–VIS spectroscopy. The X-ray diffraction results revealed that the crystallite sizes of the CdO thin films produced using seed layers at currents of −600 μA and −800 μA were 60.9 and 53.0 nm, respectively. However, the crystallite size of the CdO thin film produced without a seed layer at a potential of –0.71 V was 56.9 nm. Furthermore, the energy band gaps of the CdO thin films produced using seed layers at currents of −600 μA and −800 μA were 2.140 and 2.283 eV, respectively, while the energy band gap of the CdO thin film produced without a seed layer at a potential of −0.71 V was 2.215 eV.

1. Introduction

Cadmium oxide (CdO) is an n-type semiconductor with high electrical conductivity. CdO thin films are transparent in the visible spectral region with a direct band gap between 2.2 and 2.7 eV [1,2]. CdO has applications in optoelectronic and photovoltaic devices. Transparent conducting CdO films have been successfully used for many applications, such as gas sensors, photodiodes, phototransistors, photovoltaic solar cells, smart windows, optical communications, flat panel displays, and transparent electrodes [1,3,4]. CdO has a cubic NaCl-type crystal structure with a lattice parameter of 4.695 Å [5].

CdO thin films can be prepared by several physical and chemical deposition techniques, such as pulsed laser deposition [6], magnetron sputtering [2], sol–gel methods [7], spray pyrolysis [8], chemical bath deposition [9], vapor evaporation [1], and electrodeposition [4,10,11]. Among these techniques, electrodeposition is an important method that is used to grow metal oxide films from aqueous solutions. The advantages of this method compared with other techniques include its low process temperature, low cost, and large-scale deposition, as well as the ability to control film morphology [4,11,12]. Numerous studies have investigated the electrodeposition of CdO. In these studies, CdO thin films were deposited directly onto indium-doped tin oxide (ITO)-coated glass [4,13,14]. In 1999, Izaki et al. proposed a two-step electrolysis process to prepare dense and defect-free ZnO films. This process entailed the pretreatment of the substrate at a more negative potential for nucleation and subsequent film growth by potentiostatic deposition, which uses less negative potentials [15]. Nucleation effects can also play a role in determining the subsequent growth mode [12]. In the present work, we report the effects of seed layers formed by electrochemical pretreatment on the surface morphology and structural and optical properties of CdO thin films. The CdO thin films were characterized by X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM) and UV–VIS spectroscopy.

2. Experimental

The substrates comprised ITO-coated glass with a sheet-resistance of approximately 8–12 Ω/sq. The area of the substrates was approximately 1 cm^2. Prior to deposition, the substrate surface was cleaned in the medium for 5 min in acetone then 5 min in ethanol and then rinsed with deionized water. The deposition solution

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contained 0.02 M $CdCl_2 \cdot 6H_2O$ and 0.1 M KCl as the supporting electrolyte. The temperature of the solution was maintained at 70 °C, and the pH of the solution was 6.0. To increase the effect of the dissolved oxygen, the oxygen was introduced into the solution by bubbling during each growth period and prior to starting the experiment. The electrochemical deposition was performed in a conventional electrochemical cell with three electrodes. The working electrode was the ITO substrate. A platinum wire was used as a counter electrode, and a silver/silver chloride (Ag/AgCl) electrode was employed as the reference electrode. The deposition of the CdO thin films consisted of two steps: a galvonostatic process to deposit the seed layers and a potentiostatic process for subsequent film growth. Typically, two cathodic currents, −600 μA and −800 μA, were used for seed layer deposition, and the deposition duration was 15 s. For the subsequent CdO film growth, the deposition potential was maintained at −0.71 V, and the deposition duration was 30 min. The CdO thin films were annealed at 450 °C for 1 h.

The electrochemical deposition process was performed by a VersaSTAT 3 potentiostat/galvanostat. The structural characterization of the CdO thin films was carried out by XRD (Rigaku RINT 2000 spectrometer) using Cu kα radiation in the Bragg–Brentano configuration. Optical absorption spectra of the CdO thin films were obtained in the wavelength range from 400 to 600 nm using a Perkin–Elmer Lambda 2 UV–VIS double-beam spectrometer. The morphologies of the surfaces were analyzed by SEM (ZEISS EVO 50 EP).

3. Results and discussion

3.1. Structural properties

Fig. 1 shows the XRD patterns of the deposited CdO thin films on the ITO-coated substrate without and with the seed layers. Apart from the characteristic peaks of the ITO substrate, the CdO thin films both without and with the seed layer exhibited crystal orientations along the (111) diffraction plane of pure CdO with a cubic structure. For the CdO thin films both without and with the seed layer, the (111), (200), (220), (311), and (222) diffractions were related to cubic CdO. For all the CdO films, the crystallite size (D) in the perpendicular direction was estimated using Scherrer's relation [16]:

$$D = \frac{0.9\lambda}{\beta Cos\,\theta} \quad (1)$$

where λ is the X-ray wavelength, θ is the Bragg diffraction angle, and β is the full width at half maximum (FWHM) of the mean peak in the XRD pattern. The average crystallite sizes calculated for each sample are shown in Table 1.

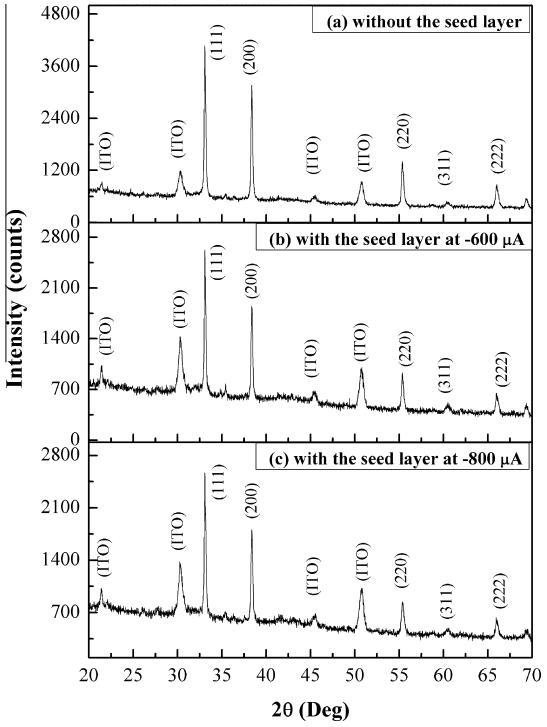

Fig. 1. XRD patterns of the CdO thin films (a) without a seed layer, (b) with a seed layer at −600 μA and (c) with a seed layer at −800 μA.

3.2. Optical properties

Fig. 2a shows the optical absorption spectra of the deposited CdO thin films on the ITO-coated substrate without and with the

Table 1
Crystallite sizes measured by XRD and the energy band gaps of the CdO thin films without a seed layer and with a seed layer.

Sample	The crystallite size (nm)	E_g (eV) (±0.006 eV)
Without the seed layer	56.9	2.21
With the seed layer at −600 μA	60.9	2.14
With the seed layer at −800 μA	53.0	2.28

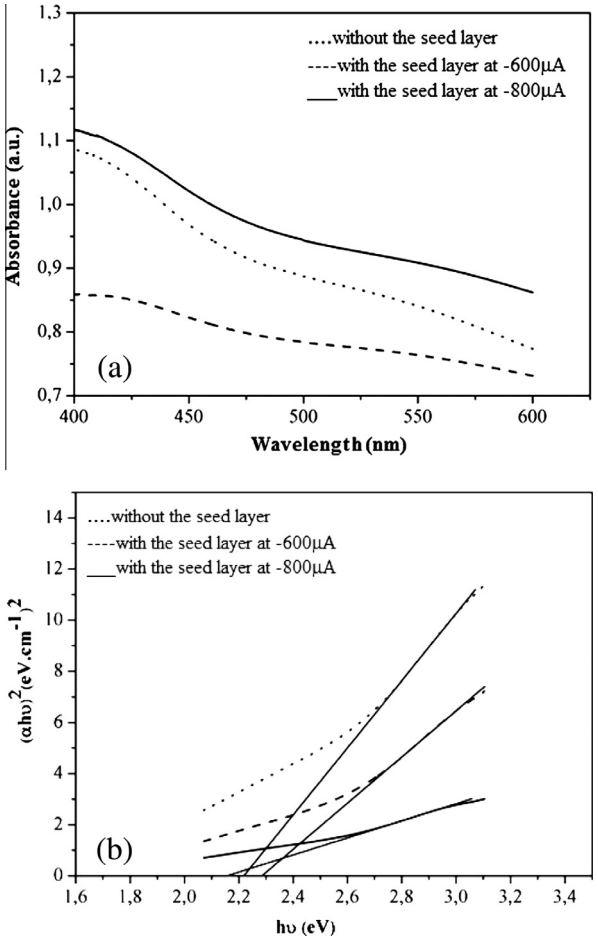

Fig. 2. Optical absorbance spectra (a) and the corresponding $(\alpha h\nu)^2$ versus $h\nu$ plot (b) of the CdO thin films without a seed layer and with a seed layer at a current of −600 μA or −800 μA.