Growth Nanostructured CdO Thin Film via Solid-Vapor Deposition

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Abstract— **Cadmium Oxide (CdO) thin films have been prepared by vacuum evaporation method on Si (111) substrate at room temperature using CdCl2 as a source of Cd. Detailed structural properties of the films are presented using XRD and SEM. The films was pure polycrystalline CdO phase with high crystallinity. The lattice constant average crystallite size of the nanocrystalline CdO thin films were calculated. SEM image confirm the formation nanostructure. Energy dispersive X-ray analysis spectra of CdO thin films shows the presence of Cd and O peaks only, no additional peaks attributed to impurities or contamination are observed.**

Keywords— **Nanostructured CdO; Solid-vapor deposition; quantum size effect.**

I. INTRODUCTION

Nanometer-sized semiconductors have attracted considerable attention over the past few years because of their unique physical properties. Moreover, their optical and electrical properties are different from that of the bulk counterpart, thereby offering new potential applications [1]. Cadmium oxide (CdO) has high electrical conductivity and high optical transmittance with a moderate refractive index in the visible region of the solar spectrum [2]. CdO thin films are wide, direct band-gap semiconductors with an optical energy gap of about 2.4 eV at room temperature. CdO, with its cubic structure, is also a II-VI n-type semiconductor with donor defects, such as Cd interstitials and oxygen vacancies. CdO is a degenerate, n-type transparent semiconductor with wide energy gap and high electrical conductivity. Its high conductivity is due to the increased crystallite size at high substrate, moderate mobility and high carrier concentration. These properties make it useful for a wide of rang applications in transparent electrodes[3], solar cells[4], photovoltaic device[5], photodiodes[6], gas sensors[7].

CdO thin films are prepared by many physical and chemical techniques such as activated reactive evaporation [8], dc-magnetron reactive sputtering [9], metal organic chemical vapor deposition [10,11], vacuum evaporation [12], electrochemical deposition [13], pulsed laser deposition [14], electron beam evaporation [15], spray pyrolysis [16], sol–gel [17], RF magnetron sputtering [18], andsuccessive ionic layer adsorption and reaction [19]chemical bath deposition techniques[20], microwave-assisted chemical bath deposition [21].In this study, we present a very simple and low cost synthesis method is presented, in which the required temperature is attainable in a short time: thermal evaporator (VS). Nanostructures CdO was successfully obtained at definite distances away from the evaporation source without the use of any metal catalyst.

II. PEXPERIMENT DETAILS

Nanosturctures CdO was deposited on nSi (111) substrates via solid-vapor deposition method under argon gas flow using Cadmium chloride (CdCl2) as a source of Cd. Si-substrate (1cm × 1cm) was cleaned to remove the oxide layer. Argon gas flow was used to purify the tube, and then the sample was placed inside the tube while argon gas was continuously injected into the system at a rate of 500 sccm (0.5 cm3/min). After that, 1 g of CdCl2 as source was placed in a small ceramic boat, and placed in quartz tube of 4 cm in diameter and 110 cm in length inside the tube furnace fixed at its center. The substrate was placed inside the quartz tube at 15 cm away from the center of the tube furnace. The source CdCl2 and Si-substrate was heated at temperature of 580°C for a fixed period of time of 30 min under constant flow of Ar gas 500 sccm. The process ran for three hours then cooled down to room temperature.

III. CHARACTERISATIONS

The film thickness was measured using an optical reflectometer (Filmetrics F20). The structure of the prepared thin films were examined using high-resolution X-ray diffraction (HR-XRD) using X'Pert Pro MRD diffractometer (PANalytical Company) system equipped with Cu-Kα radiation wavelength (λ = 0.15418 nm) operating at 40 kV and 20 mA. Morphology and microstructure of the film was investigated by scanning electron microscopy (SEM) using Jeol JSM-6460 LV microscope operating at 10 kV and attached to energy dispersive X-ray spectrometer (EDX) for elemental chemical composition determination.

IV. PRESULTS AND DISCUSSION

A. Structural Characterization.

Figure 1 shows the evolution of X-ray diffraction patterns of CdO thin film deposited on Si (111) by VS method. It is clear that all the film is polycrystalline with good crystallinity. XRD pattern clearlyindicate the presence of five peaks located at 2θ = 33.0292, 38.3302, 55.3510, 66.0023, and 69.276° indexed as (111), (200), (220),(311),and (222). respectively. The observed diffraction peaks were indexed within a cubic rock salt (NaCl) type structure, as confirmed using a standard JCPDS card (ICCD-PDF4 No. 01-075-0591). The film was found to be well crystallized as indicated by sharp XRD peaks [22]. The main features of the diffraction patterns are similar but the relative intensity of the diffraction peaks varies without the appearance of new phases aside from cubic CdO. A preferred orientation of the deposited film along (111) directions was observed.The texture coefficient TC was used to determine the preferred orientation by the following equation [23]:

$$TC(hkl) = \frac{\frac{I(hkl)}{I_o(hkl)}}{\sum_n \frac{I(hkl)}{I_o(hkl)}} \times 100\% \qquad (1)$$

Where I(hkl) is the measured relative intensity of plane (hkl), Io(hkl) is the standard intensity of plane (hkl), and n is the number of diffraction peaks. TC(hkl) = 1 represents films with randomly oriented crystallites, whereas higher values indicate the abundance of grains oriented in a given (hkl) direction. The highest TC value was obtained for (111) plane for the prepared nanostructures CdO thin films.

The lattice constant of the nanocrystalline CdO thin film was determined by fitting the more intense diffraction peak using a Gaussian function and is given by [24]:

$$a = d \, (h^2 + k^2 + l^2)^{1/2} \qquad (2)$$

Where h, k and l are the Miller indices; and d is the interplanar space. The calculated lattice constant value was found to be 4.6948 Ao, which os slightly than that for bluk, which clearly indicates that the crystallisation and stress occurring during the growth hence resulting in lattice expansion.

The average crystallite size (Cs) of nanostructured CdO can be calculated from the well-known Scherrer's formula [23]:

$$Cs = \frac{(k\lambda)}{\beta \cos} \qquad (3)$$

Where K is a constant (0.94), λ is the XRD wavelength (0.15418 nm), and β is the full width at half maximum (FWHM) of a defined diffraction peak. It is found that the crystallite (grains) size of the thin film is about 12 nm.

B. Microstructural Analysis

SEM image rveals that the surface morphology of the grown CdO on Si-substrate is at the nanoscale regime, by the presence of cauliflower-like shaped microstructure formed by platelets oriented along (111) direction of Si-substrate and in agreement with XRD analysis.

Energy dispersive X-ray analysis spectra of CdO thin film is reported in Figure 3, with the corresponding quantitative chemical analysis is reported. It is very important to note that no additional peaks attributed to impurities or contamination are observed, thus confirming the purity of the prepared thin film as confirmed previously by XRD analysis..

V. CONCLUSION

In this study, we report on the synthesis of pure CdO nanostructures deposited on Si-substrates by thermal evaporation method without the use of any metal catalyst. It was confirmed that that he films has nanostructure by SEM observation. Nanostructures CdO thin films exhibit a cubic rock salt (NaCl) type structure as confirmed by XRD analysis. Both lattice constant and crystallite (grains) size were determined for the CdO nanostructures.
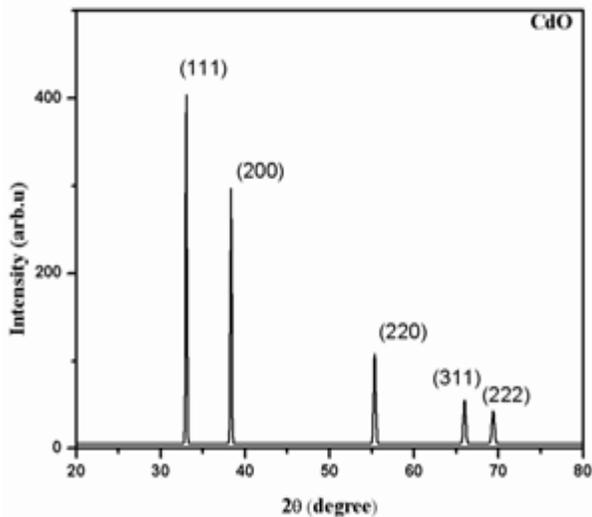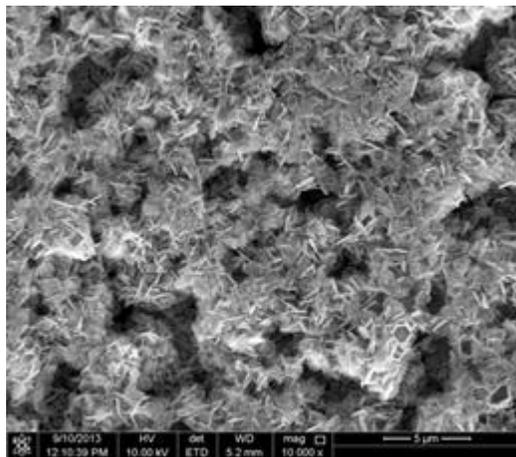
Fig. 1 XRD of nanostructures CdO thin films deposited using thermal evaporator (VS)

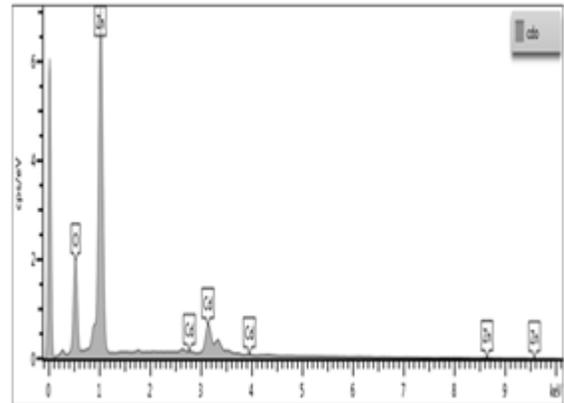**Fig. 2 SEM images of nanostructures CdO thin films deposited using thermal evaporator (VS)a figure caption.**

Fig. 3 EDX spectrum of nanostructures CdO thin films deposited using thermal evaporator (VS)

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