The Structural and Surface Morphology Properties of CdO thin films prepared via R.F.magnetron sputtering

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ABSTRACT

In this paper, CdO thin films having different thicknesses 100, and 200 nm were deposited onto glass substrates by a radio frequency (R.F.) magnetron sputtering process using CdO target under Ar pressure. The sputtering deposition was performed by using R.F. power of 100W. X-ray diffraction (XRD) results suggested that the deposited CdO films were polycrystalline and after annealing becomes single crystal with recognized peak in (111) at 33°. The mean size of crystallization calculated for 100 and 200 nm thin films of CdO before annealing were found to be 14.8nm and 24.6 nm respectively.

Keywords: - CdO : Thin Film; Nanostructure; Optical; Sputtering RF.

1. INTRODUCTION

Cadmium oxide (CdO) attracts a great attention due to its electrical and optical properties. CdO is an n-type semiconductor with direct band gap at approximately 2.3 eV. This films have been widely studied for optoelectronic applications in transparent conducting oxides (TCO), solar cells, smart windows, optical communications, flat panel displays, photo-transistors, as well as other types of applications like IR heat mirror, gas sensors, low-emissive windows, thin-film resistors, etc [1-4]. Many physical and chemical preparation techniques such as pulsed laser deposition, sputtering, chemical vapor deposition, reactive evaporation, spray pyrolysis, etc. have been used in order to obtain CdO films. It was experimentally established that its properties are very sensitive to the film structure and deposition conditions [5,6]. Magnetron sputtering is particularly useful when high deposition rates and low substrate temperatures are required [7]. In RF magnetron sputtering, cathode and anode are changeable and for very short cycles, target functions as anode which cause the removal of insulating layer. By doing so, the process can continue [8, 9].

In this paper, the structural and optical properties of CdO film obtained by RF magnetron sputtering technique have been investigated.

2. EXPERIMENTAL DETAILS

CdO thin films were prepared by RF magnetron sputtering system with cadmium oxide target of 99.99% purity on glass substrates. The glass substrate was cleaned by ethanol followed by distilled water rinse, subsequently samples are placed in beaker contain distilled water inside ultrasonic device for 2 hour at 353K. The substrates and target were fixed in the chamber of magnetron sputtering system. The base pressure of the deposition chamber was kept at 6 × 10−5 Torr. The argon gas was introduced into the chamber through a flow controller with fine adjustments the sputtering was performed under Ar (99.999%) atmosphere supplied as working gas through mass-flow controller. The crystal structure of CdO films were checked by X-ray diffraction technique, (XRD) patterns were obtained with a (SHIMADZU Japan -XRD600) automatic Diffractometer using the CuKa radiations (λ=1.54059 Å) in the range of 2θ between 25° and 75°. Surface morphology was studied using (VEGA3-TESCAN model, USA) scanning electron microscope (SEM). Atomic force microscopy (AFM) measurements were carried out using (SPM model AA 3000 Angstrom Advanced Lns., USA) to determine the nanocrystalline topography and grain size of the films.

3. RESULTS AND DISCUSSION

3.1 Structural Properties

The crystalline structure for CdO thin film can be recognized be studying the phase of (XRD) for that material, when a beam of (XRD) from mono wavelength incident on the film surface will exhibit peaks on limit angles for each material because of reflecting of Bragg on parallel crystalline surface .The XRD patterns for the investigated CdO samples
prepared at room temperatures and constant deposition time as well as those deposited at different thicknesses (100 and 200 nm) are shown in Fig. (1). And after annealing at 450°C the XRD pattern are shown in Fig. (2).

The structure of CdO thin films were formed to be polycrystalline and after annealing becomes single crystal with recognized peak in (111) at 33°C. These results in agreement with the standard CdO X-ray diffraction data file [N 1997 JCPDS prevalent].

The mean crystallite size has been obtained with Scherer relation:

\[ D = \frac{k\lambda}{\beta\cos\theta} \]  

where \( D \) is the crystallite size, \( k \) is a fixed number of 0.9, \( \lambda \) is the X-ray Wavelength, \( \theta \) is the Bragg’s angle in degrees, and \( \beta \) is the full-width-at-half maximum (FWHM) of the chosen peak. The mean size of crystallization calculated for 100 and 200 nm thin films of CdO is found to be (14.8) nm and (24.6) nm before annealing and (15.2) nm & (27.4) nm after annealing respectively.

![Fig. (1) XRD patterns of CdO thin film of 100 nm and 200nm thickness at room temperature.](image1)

![Fig. (1) XRD patterns of CdO thin film of 100 nm and 200nm thickness at room temperature.](image2)
3.2. Morphology: (AFM) analysis

Typical AFM images for CdO films with two different thicknesses (100 and 200) nm which were taken to support the XRD observations are shown in Fig. 3 before annealing and Fig. 4 after annealing.

Fig. (3): AFM images for CdO thin films of thickness 100nm and 200nm before annealing.
AFM scans of the surface morphology were carried out to study the change in the surface morphology of the films. These images show that the film is homogeneous and it has a large number of vertically aligned (columnar) grains, uniformly distributed features with no pinholes or island structures are observed in all the thin films. It can be seen in Fig. 4 that the surface roughness of the CdO film is changed with the increase of sample thickness. The increase of sample thickness indicate that the increase in the surface roughness affects the surface characterization of the films and leads to changes in the optical, electronic, and vibrational transitions of the material. [10]. Nanoscale surface roughness of the films was calculated by section analysis of the height image. The section analysis of the height image indicated increase in nanoscale roughness for films with increasing thickness. The grain size and the root-mean-square (RMS) roughness of the samples were estimated from AFM images and the results have been shown in table (1). It is evaluated that the surface roughness of the films depends on the distribution of particles on surface of the films.

Table (1): The values of surface roughness, root square and grain sizes for CdO thin films.

<table>
<thead>
<tr>
<th>Film thickness (nm)</th>
<th>Surface Roughness (nm) before</th>
<th>RMS (nm)</th>
<th>Grain Size (nm)</th>
<th>Surface Roughness (nm) before</th>
<th>RMS (nm)</th>
<th>Grain Size (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.563</td>
<td>0.687</td>
<td>2.99</td>
<td>11.5</td>
<td>13.6</td>
<td>31.3</td>
</tr>
<tr>
<td>200</td>
<td>8.27</td>
<td>9.76</td>
<td>41.4</td>
<td>9.9</td>
<td>11.9</td>
<td>57</td>
</tr>
</tbody>
</table>

Fig. (4): AFM images for CdO thin films of thickness 100nm and 200nm after annealing at 450 oC.
It is observed from Table (1) of AFM analysis that the average grain size and surface roughness increase with increasing of film thickness. It also observed that the grain size increased after annealing the samples with 450 °C as shown table (1). The disagreement between the grain size determinations from XRD and AFM measurements is expected because the AFM measurement directly visualizes the surface grains only without considering the degree of structural defects [11], while the XRD determination is based on the grain size of the defect-free volume [12] (common lattice defects in metal oxide semiconductors are for instance oxygen vacancies and metal atoms on interstitial lattice sites) [13]. So, we conclude that an average grain observed by the AFM contains other larger size crystallites belonging to different orientations, as observed in the XRD [11].

4. CONCLUSION

After reviewing the results that have been obtained and discussed, the following remarks are concluded from the present work:
The structural and surface morphology properties of these films were investigated before and after annealing at 450 °C. Well adherent, homogeneous, smooth and crack-free thin films with nano-grain size were successfully grown on glass substrate utilizing R.F. magnetron sputtering method.XRD patterns shows that the structure of CdO thin films were formed to be polycrystalline and after annealing becomes single crystal with recognized peak in (111) at 33°. The mean size of crystallization calculated for 100 and 200 nm thin films of CdO is found to be 14.8 nm and 24.6 nm respectively.

REFERENCES


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