Characteristics study of nanostructured CdO prepared by spray pyrolysis

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ABSTRACT. In this paper, nanostructured cadmium oxide films were prepared by chemical spray pyrolysis technique. The structural, morphological and optical characteristics of synthesized films are investigated as function of concentration. AFM results revealed that the root mean square of surface roughness is increased with cadmium concentration. XRD investigation confirmed that the films are polycrystalline with cubic structure. SEM study displayed that the synthesized films have particle size in the range of 25-100nm depending on cadmium ion concentration. The optical properties revealed the films have maximum average optical transmittance of 78% for film sprayed with 0.1 M. The optical band gap of the CdO film prepared with 0.25 M was 2.65eV. The optical band gap increased as the film molarity .

1. INTRODUCTION

Cadmium oxide films are very promising semiconductor due to its high optical transparency and high electrical conductivity. CdO is n-type with wide direct optical band gap of 2.4 eV at room temperature. It was used widely in many application such as transparent electrodes, solar cells , photo transistors ,gas sensors, photodetectors [1-3]. Many methods was employed to synthesis CdO thin films e.g sputtering , thermal evaporation , laser deposition ,rapid thermal oxidation of cadmium , sol-gel , chemical bath deposition and spray pyrolysis [4-8]. The spray pyrolysis technique was used extensively for TCOs film preparation due to its simplicity and large area formation. It is reported that the properties of sprayed films are strongly depended on preparation conditions for instance substrate temperature ,spray rate , distance between nozzle and substrate and cooling rate[9]. Here, we report on synthesis of nanostructured CdO films by spray pyrolysis technique .The dependence of film characteristics on the molarity was also studied.

2. EXPERIMENTAL

For deposition of CdO films, a aqueous solution of cadmium acetate $(\text{CH}_3\text{COO})_2\text{Cd} \cdot 2\text{H}_2\text{O}$ was sprayed with cadmium ion concentration ranging from 0.1M to 0.25M on cleaned hot glass substrates using home- made spray pyrolysis system. The distance between the glass nozzle and substrate was 19cm. The substrate temperature was kept around 400°C and the spray rate was around 1.5cc/min. The carrier gas used in this study was compressed air . X-ray diffractometer (XRD-6000, Shimadzu) was used to study the structural properties of prepared films. Scanning electron microscope SEM (T-scan Vega III Czech) and atomic force microscope AFM (AA 3000 Scanning Probe Microscope) were employed to investigate the surface morphology of grown films. The optical properties of films was studied with aid of UV-Vis spectrophotometer (Union space international LTD UV-1601) in spectral range of 300-1100nm.

3. RESULTS AND DISCUSSION

Fig.1 shows the XRD patterns of nanostructured CdO films prepared with different cadmium ion concentrations. All the grown films are polycrystalline in nature with cubic structure, the diffraction peaks noticed at 33° , 38.6° , 55.7° , 66.5° and 69° which corresponded to (111), (200), (202), (311) and (222) planes, respectively are indexed to bulk CdO according to JCPDS Card No. 65-2908. The XRD pattern of CdO film prepared at 0.1M revealed that the (200) plane grew predominantly than the other diffracted planes and its intensity decreases as cadmium ion concentration increase. The intensity of (111) plane increased with concentration due to the fact that the surface energy density of (111) plane is very low compared to other planes [8]. The particle size D of the film was estimated from Scherrer's formula.

$$D = \frac{0.9\lambda}{\beta \cos\theta}$$

Where λ is x-ray wavelength, β is angular line width of half maximum intensity, and θ is Bragg's angle. The values of average grain size was in the range of 18-25nm and it is noticed that it is slightly changed with concentration. Fig.2 displays the transmittance of CdO films prepared at various concentrations of cadmium, it is clear that increased the concentration resulted in decreasing the film transmittance. The average optical transmittance of CdO films were 68-78% and the maximum transmittance was observed for film synthesized at 0.1M. The optical energy gap of CdO films was calculated by plotting $(\alpha h\nu)^2$ versus photon energy $h\nu$ and the extrapolation of linear part to the photon energy axis give the value energy gap as shown in Fig.3. Table 1 lists the values of optical energy gap as function of cadmium concentration. From table 1 it is obvious that the optical energy gap increased with increasing of concentration due to decreasing of particle size and this point will supported with the results of SEM and AFM. The maximum value of energy gap obtained for CdO films was 2.65eV which is larger than that for bulk CdO (2.4eV). Increasing the energy gap of film can be ascribed to quantum size effect.

Fig.1. XRD patterns of sprayed CdO films prepared at different concentrations

Fig.2. Transmittance of CdO films synthesised at various concentrations

Fig.3. $(\alpha h\nu)^2$ versus photon energy plot for CdO film prepared at 0.1 M

Fig.4 shows the 2D and 3D AFM images of CdO films prepared at various concentrations. AFM images confirmed that the CdO films prepared with low concentration have particles with spherical shape and in nanosized. These particles are aligned vertically.

Fig.4. 2D and 3D AFM images of nanostructured CdO films prepared at (a) 0.1 M and (b) 0.15 M (c) 0.2 M and (d) 0.25 M

Continued

The average particles size is noticed to decrease with increasing the concentration. On the other hand, the root mean square of surface roughness increases as concentration increased as shown in table 2. Fig.5 shows the SEM images of CdO films prepared at 0.1M and 0.15M. It is clear that the particles have elongated particles and semi-spherical shape with different sizes .The CdO film prepared with 0.1M gave an average particles size of 87nm , while the film prepared with 0.15M have particles with 45nm average size. Particles agglomeration was noticed for all prepared CdO films. The SEM image of film prepared with 0.25M (not shown) revealed the particle size around 25nm. The disagreement in particle size found from XRD and SEM can be attributed to the agglomeration of particles as well as the increasing the value of FWHM in XRD may be comes from the stress not due to the decreasing of particles size .

Fig.5 SEM images of nanostructured CdO films prepared at (left) 0.1 M and (right) 0.15 M

Table 1. Optical energy gap for CdO films prepared at various cadmium concentrations

Cadmium Concentration(M)	Energy gap (eV)
0.1	2.30
0.15	2.38
0.2	2.52
0.25	2.65

Table 2. Surface roughness and grain size as function of cadmium concentrations

Cadmium Concentration(M)	Surface roughness (nm)	Average grain size(nm)
0.1	2.34	100
0.15	4.1	89
0.2	4.47	75
0.25	5.28	71

4. CONCLUSION

Nanostructured CdO films was synthesised by using spray pyrolysis technique. The effect of cadmium ion concentration on the structural, morphological, structural, and optical properties of grown films has been demonstrated. XRD confirmed that the grown films have cubic structure. The prepared films have different particle s sizes in the range of 25-100nm with semi-spherical shape. The values of optical energy gap for CdO films prepared at high concentration were larger than that for bulk CdO at room tepmerature.

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