Studying The Topographic and Morphology Structure of CdO:In Thin Films

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Abstract. Cadmium oxide thin films was deposited by thermal oxidation method, on glass substrate with the thickness (300 ± 10)nm and deposition rate (1.25)nm/sec. The films doped with the (In) with the different ratios(1,2,3)%. The topographic and morphology structures of films are characterized by (XRD), (SEM) and (AFM) techniques. XRD investigation showed all films have polycrystalline structures with the preferred orientation (111) plane. The results of microscopic testing proved that presence the nanostructures and all the films were homogeneous and smooth, with a characteristic nano grain size, by scanning electron microscope (SEM), which show that fact formation of all nanostructures with different shapes and grain size. In addition, the results of atomic force microscope (AFM) show that presence nanostructures and there is effect of In-dopant on the root mean square (RMS) roughness of the films, where it increases while the grain size decreases with the increasing of In-dopant.

Key word: Cadmium oxide (CdO), structure, topographic and morphology and roughness.

1.Introduction

In recent decades, the decreasing of energy is the most problem facing humanity, so researchers have facing light on transparent conductive oxide materials because they have many applications, especially in the field of photovoltaic devices[1,2,3]. An example of transparent conduction oxides are indium oxide, tin oxide, zinc oxide and cadmium oxide[4,5]. Cadmium oxide (CdO) belongs to a group of transparent conductive oxides (TCO), and it can be defined as an inorganic compound, a subordinate to cadmium compounds (Cd) [6,7]. As for the nature of the crystal structure, CdO has a cubic, faceted centered crystal structure (FCC) with a lattice constant (a) equal to (4.69Å), which is similar in nature to the composition of NaCl [8]. The nature of the crystal structure of CdO, where the unit cell of a face centered cubic contains four lattice points, and each lattice point has a basis composed of two ions: an ion (Cd2+) and an ion (O2-), thus including a cell One unit has four positive cadmium ions and four negative oxygen ions, meaning it includes four molecules of the (CdO) compound. The positive cadmium ions occupy the eight heads of the cubic cell and the centers of its six faces as well, while the negative oxygen ions occupy the center of the cubic cell and the middle of its twelve sides. Thus, each ion is surrounded by six opposing ions, and it is the first neighbor of that ion [9,10]. The compound cadmium oxide (CdO) is classified in materials science as a transparent semiconductor material,
belonging to the group (II-VI) of the periodic table [7]. The surface topography of cadmium oxide (CdO) films has been studied by P.Sakthive and at.el[11]. The morphological properties for cadmium oxide (CdO) have been studied from before M.Anltha and at el[12]. 

In this research, studying the effect indium doped with the CdO in the structural, surface topographic and surface morphology properties of the thin films are characterized by (XRD),(AFM)and(SEM) techniques.

2. Experimental

pure and doped (CdO:In) thin films synthesis by using thermal evaporation technique under pressure about (2x10⁻³) mb with the thickness about (300±10)nm with the deposition time (4 min) at room temperatures. CdO thin film were grown onto soda-lime glass slides of (2.5 × 2 × 1)mm³ dimension were used as substrate. Before starting the deposition process, the glass must be cleaned, as they are washed with running water and one of the cleaning powders to get rid of stains or remnants of materials or dust stuck to them, after which they are placed under running water for 15 minutes to ensure the removal of the cleaning powder and then immerse it in a basin of distilled water to be washed automatically by An Ultrasonic device for 15 minutes. Then the glass slides are immersed in the same basin of high-purity ethyl alcohol (99.99) purity, to be washed automatically by the same previous device for the same period, after which the glass slides are dried by filter paper and then exposed to a dry air stream by (Blower), and then the weight of the material is calculated by a sensitive electronic balance (Precisa). It has a sensitivity range up to (10⁻⁴ mg) and the weight sufficient for the required thickness is placed in a container of molybdenum metal, Then the glass slides were placed on the sample holder vertically at a distance (10 cm) from the molybdenum metal.

. After the completion of the deposition process, samples are left in the evaporating chamber until reaches their temperature at R.T, and for the completion of the crystallization process and to prevent the broken forms or cracks occurring in them if they are suddenly cooled. The samples are then prepared for thermal oxidation, so the precipitation product of the cadmium metal(Cd) at RT was used to prepare (Cd) film, after that put it cd in oven with temperature (550K) for 2 hours, after it the sample is cooled using the slow cooling method for 24 hours obtain onto CdO thin film. Thus color changed of the films from gray to brown. After that, cadmium oxide was doped with indium, with doping ratios of (1, 2 and 3)% by thermal evaporation technique.

The Cadmium oxide thin film composition has been studied using x-ray diffraction (6000 SHIMADZU-Japan of Cu kα (1.54 Å)), To study surface topographic, use atomic force microscopy (AFM) . Either to study the morphology of the surface was used field-emission scanning electron microscopy (FESEM;MIRA3,TESCAN) with EDS detector (Bruker Quantax 200-Z10).

3. Results and Discussion

3.1. Structural Properties

The XRD pattern of CdO film deposited by thermal vacuum evaporation method at room temperature is shown in fig(1). It also shows the characteristics of the peaks that located at angles(2θ: 33.12°, 38.40°, 55.61°, 66.24°, 69.39°) corresponding to the (111), (200), (202), (311) and (222) plane respectively which is in matches with(American slandered for testing materials(ASTM) card number(96-9006674),Table(1) shows a matching between the experimentally measured CdO and ASTM the structure of thin films polycrystalline from cubic type. It can be clearly seen that film preferentially orientation along(111) crystallographic directions and this is in agreement with the result obtained by spray pyrolysis technique[13] pulsed laser deposition[14] and sol-gel method [15].
3.2 Force Microscope (AFM) analysis

AFM analysis is important to study the topographic surface of thin films and to calculate the roughness, rms, grain size and thickness of films as displayed in fig. (2). It is seen that the films display similar surface topographies. Table 2 shows the average grain size of the prepared thin films, the surface roughness and the Root Mean Square (RMS). In general, the grain size depends on chemical composition and doping, whereas the grain size decreases with increasing the indium doping ratio. It is around 68.59 nm to 54.92 nm and the rms as shown in table (2). Also, we note from this table that the grain size decreases, with the increasing in the doping ratio, and the roughness increases with increasing doping ratio. And this agreement with M. Anlthla at el[12], and this indicates the possibility of using these films in the fabrication of solar cells.

Table 2. Average Grain size, Roughness and root mean square for CdO thin films pure and different In ratios.

| sample     | Average grain size (nm) | Roughness average (nm) | RMS (nm) |
|------------|-------------------------|------------------------|----------|
| Pure CdO   | 68.59                   | 1.37                   | 1.61     |
| CdO:In 1%  | 65.22                   | 2.84                   | 3.36     |
| CdO:In 2%  | 56.32                   | 2.93                   | 3.38     |
| CdO:In 3%  | 54.92                   | 4.12                   | 4.96     |
Figure 2. AFM images of a. pure b. 1% c. 2% d. 3% doped CdO thin films.
3.3. Field-emission scanning electron microscopy (FE-SEM) analysis

In order to obtain a clear and accurate picture of the shape and nature of the distribution of grain or crystals within the surface of the prepared film, scanning electron microscopy (FE-SEM) was adopted, due to its high analysis power and magnification power of up to 2 million times compared to a light microscope. FE-SEM was used to study the surface morphology of thin films. Micrographs of pure CdO and doped thin films deposited on glass substrate are given in Fig.(3). It is clear that the thin films have regular shape and uniform size. The agglomeration of the nanoparticles was observed on the glass substrate and the agglomeration increased with the increase of the indium ratios as shown in the fig.(3).

Figure 3. FESEM images of a. pure b.1% c.2% d.3% doped CdO thin films.
3.4. EDX analysis

Figure 4: shows the (EDX) analysis attached with the FE-SEM measurements, as it clearly shows the presence of the cadmium element with two energies represented by (L$_{\alpha}$, L$_{\beta}$) and oxygen at the k$_{\alpha}$ energy line, which indicates the presence of the CdO thin films. We also have the silicon element at the energies lines (k$_{\alpha}$, L$_{\alpha}$ and k$_{\beta}$) which can be explained by the presence of glass slides. It also indicates the type and concentration of the elements.

![EDX spectra](image)

Figure 4. EDX spectrum of a. pure b. 1% c. 2% d. 3% doped CdO thin films.

4. Conclusions
1. The possibility of obtaining undoped CdO thin films successfully synthesis by thermal evaporation method. And in agreement with the standard card (96-900-6674).

2. It was found through the measurements of the atomic force microscope (AFM) that there was a slight increase in the surface roughness coefficient with an increase in the doping ratio. The best results were when doping ratio (3%), as its value was between (1.37 - 4.12) nm, as well as a decrease in the grain size with an increasing in the doping ratios. In addition to demonstrating the advantages of the thermal evaporation technique in vacuum and distinguishing it from other methods of preparation by producing thin films of uniform thickness and uniform grain diffusion of equal and at nanoscale for all the prepared thin films.

3. Scanning electron microscopy (SEM) examinations showed that indium doping was an important factor in improving surface specifications with better density for diffusion of grain in a consistent coordinate size with an increase in the number of grain in the film by increasing the ratio of doping which affects the quality and quality of the film, as well as the fact of dimensions of these structures and the shapes of the grain. With the decrease of the crystal size, the increase in the ratio of doping.

References
[1] L Yu B O Donnel P cabarrocas 2010 Solar. Energy Materials. Solar. cells 94, 1855-1859.
[2] T Meng B. McCandless W Buchanan E. Kimberly and R. Birkmire 2013 J. Alloys Compd. 556 39-44.
[3] F Yakuphanoglu 2010 Appl. Surf. Sci 257 1413-1419.
[4] K L Chopra 1983 Thin Film Devices Application ( Plenum Press, New York).
[5] R A Smith 1987 Semiconductors 2nd Edition Cambridge University.
[6] A F Holleman and E Wiberg 2001 Inorganic Chemistry (Academic Press San Diego).
[7] R C Weast and M. J. Astle 1979 Handbook of Chemistry and Physics (CRC Press).
[8] A F Wells 1984 Structural Inorganic Chemistry 5th Edition, Oxford Classic Texts in the Physical Sciences (Clarendon Press, Oxford).
[9] B S Mitchell 2004 An Introduction to Materials Engineering and Science (for Chemical and Materials Engineers John Wiley & Sons Inc).
[10] S A Hameed S A H Zainab Ansaif J A Faik Taha A Ayesh Habeeb 2020 NeuroQuantology Vol. 18, Issue 4, 20-26.
[11] P Sakthivel S. Asaithambi M. Karuppaiah S. Sheikfareed, R Yuvakkumar G Ravi 2019 Journal of materials science, part of springer Nature.
[12] M. Anltha. N. Anltha. K. Saravanakumar. L. Kulandalsamy. L. Amaraj(2018) Applied physics A, 560-573.
[13] S. Ahmed, M. S. I. Sarker, M. M. Rahman, M. Kamruzzaman, M. K. R. Khan 2018 Heliyon Vol 4 Issue 8, 00740, 1-16.
[14] Ghusson H Mohammed Ahmed M. Savore Mohammed Hadi Shinen, Kadhim A. Adem 2015 Eng & Tech. Journal, Vol 33, Part (B), No.5 919-931.
[15] F Yakuphanoglu 2011 Solar Energy 85 2704-2709.