CdO/FTO Schottky photodetector with enhanced spectral responsivity and Specific detectivity prepared by electrolysis method

Ahmed N. Abd¹, Muhaj Talib Abdullah², Saad Khalid Rahi¹, Nadir F. Habubi³.
¹Department of physics, College of science, Mustansiriyah University, Baghdad, Iraq.
²Department of Physics, Faculty of Science, University of Zakho, Iraq.
³Department of Physics, Faculty of Education, Mustansiriyah University, Baghdad, Iraq.

ahmed_naji_abd@yahoo.com

Abstract. One of the important materials for applications in many photoelectric filed [just like solar cell, optoelectronic and other kinds on devices] is cadmium oxide thin films. There are several physical or chemical synthetic methods have been used to prepare transparent CdO films as described by many researchers. The X-ray diffraction study has confirmed the formation of CdO with nano-size scale. For this research CdO/FTO thin film has been prepared by electrolysis. The thin film is investigated by XRD, SEM and AFM surface morphology properties. XRD analysis showed that CdO films are a polycrystalline and exhibit cubic crystal structure with (111, 200, 311 and 222) orientation and the preferred orientation is 111. AFM and SEM were applied to study the morphology and estimate the surface roughness of the films obtained. (RMS) found that film roughness was 21.7 nm. The CdO film are n-type semiconductors and possess a direct optical band gap around 2.4 eV as shown in optical property studies.

1. Introduction
Cadmium oxide is significant II–VI semiconductor [1]. This type of semiconductors is vastly used as transparent conductive oxides in many physical applications now a day, particulary in optoelectronic devices such as smart windows, optical communication, flat panel display, phototransistor etc [2], diodes and transparent electrodes. Also recorded a band gap of (2.32eV). Various methods such as thermal evaporation, sputtering, activated reactive evaporation, spray pyrolysis deposition [3, 4], and successive ionic layer adsorption and reaction [5], were employed to prepare thin films of CdO.

2. Materials and Methods
The method which has used here is electrolysis, and this is done by putting two electrode electrodes. The positive electrode is a piece of cadmium (1 cm wide and 1 cm thick), while in the other end a FTO glass is used very high Cadmium used net (in the color of lead) applied with electrolyte solution 80 ml distilled water and 10 ml HCl 99.9. A voltage of 5 volte applied to the solution and then the current will be about 300 mA. We observe an emergence of bubbles moving from the positive electrode to the
negative electrode (the distance between them is 1 cm ± 1 mm) and the electrolyte solution is stuck to the negative. This process takes from 10 to 12 minutes, until the color of the cadmium changes to a celery color which is the color of cadmium oxide. This solution is then deposited on glass slides (with area 2.5 cm × 1.5 cm and 2 mm thickness) by distillation casting process. This method is indicated putting a glass plate on a heater until it reaches the temperature measured by thermocouple equal to 70°C after that, add three drops of the solution on the glass to form the thin films.

3. Results and discussion

3.1. X-ray diffraction

(XRD) spectra of the CdO thin film show in Fig. 1. The presence diffraction peaks: (111), (200), (220), (311) and (222) planes illustrated the polycrystalline nature of the CdO films compound with cubic NaCl structure. XRD seven peaks coincide with those of cubic crystal structure according to ASTM card No. 05-0640 [6]. The observed ‘d’ and ‘a’ have a value [Table (1)] with a good agreement to the standard ‘d’ and ‘a’ value taken from (ASTM) data as shown in Table (1).

![X-ray diffraction pattern of CdO thin films at room temperature.](image)

**Figure 1.** X-ray diffraction pattern of CdO thin films at room temperature.

| 2 Theta (deg) | hkl (plane) | FWHM (deg) | d Å | D Å | η x10^-4 lines²/m⁴ | δ x 10^-4 Lines/m² |
|---------------|-------------|------------|-----|-----|---------------------|---------------------|
| 26.4074       | CdO (110)   | 0.26       | 3.37| 30.70| 64.32               | 10.60               |
| 37.6552       | CdO (200)   | 0.25       | 2.38| 32.30| 61.14               | 9.58                |
| 51.4222       | CdO (211)   | 0.22       | 1.77| 39.39| 50.14               | 6.443               |
| 33.7721       | SnO₂ (101)  | 0.27       | 2.66| 29.56| 66.82               | 11.44               |
| 61.7446       | SnO₂ (310)  | 0.12       | 1.50| 76.70| 25.75               | 1.69                |

3.2. SEM ANALYSIS

CdO is used as buffer layer or window layers. The image of SEM analysis can be seen in figure (2), it can be observed a not compact morphology just like cauliflower morphology and not uniformly covered the glass substrate, also there are some needle like morphology, these needle shape might be due to
contaminant. Farther more there are some semi spherical can be shown between the Grains or agglomeration of small crystallites or tiny crystallites with the crystallite size of 40 nm.

Figure 2. SEM analysis of CdO/FTO layer.

3.3. Atomic Force Microscopy
The AFM study shows the 2D and 3D- images of the CdO layers. The AFM images of the thin film show coverage of glass surface by CdO grains with some gaps appeared between them. The 2D-AFM image shows a configuration of a nano-crystallites for the deposited CdO thin film with the sizes in the range of (20-45) nm as shown in Figure (a). These results have a good agreement with the results acquired from SEM images in the previous part. The 3D-AFM images CdO thin film notes non-similarity at the surface of the as-deposited CdO layers can be observed in Figure (b). The AFM images were analyzed in terms of average surface roughness (Ra). The average surface roughness (Ra) of the prepared CdO thin film was found to be 18.4 nm.

Figure 3. The AFM analysis of CdO/FTO thin film a): in 2D and b): in 3D.

4. UV–visible spectra and FT-IR

4.1. Transmission Measurements
The optical properties of the prepared CdO films has been studied extensively. The transmission spectra of cadmium oxide (CdO) vs. wavelength in the range (200 nm to 900 nm is shown in figure (4). The
transmission increase with increasing wave length and have maximum transmission at (900 nm), and from this figure CdO films spectra exhibit visible transmittance, just upper than 35 % for a wavelength 900 nm. The crystallographic and optical properties of the deposited films were dependent on the deposition conditions: substrate temperature, solvent and process time [7-9].

Figure 4. Plot of transmittance of grown film against wavelength.

4.2. Absorbance Measurements
The nature and value of the CdO optical range gap can be calculated using the absorption of membranes that correspond to electron excitation from the range of repentance to the conductivity range. The UV–visible absorption spectrum of CdO thin films is observed in Fig. 6. To determine the possible transformations, the \((\alpha h\nu)^2\) vs. photon energy is drawn in the inner shape of Figure 4. The corresponding band gap is obtained from the induction of the straight part of the graph near the absorption edge to the \(h\)-axis. The value of the direct band gap was found to be 2.4 eV and is larger than the larger quantity of CdO. The effect of quantification on the sample may be the reason for this blue shift of the gap value in the range.

Figure 5. Plot of absorbance of grown films against wavelength.
4.3. Reflectance Measurements \((R)\)

The reflection is defined as the ratio of the reflected intensity rays to the estimate of the intensity of the resulting radiation [10]. Reflection is calculated from absorption spectra and permeability of all processed thin films. We observed that the reversal curve increased slightly with increasing wavelength, as in Fig. 7.

\[ R = \frac{1}{n^2} \]

It has appeared in Figures (8) as a function of the length of the film wave (CdO). The shape of the curve with the wavelength is the same as the curve curve because the relationship between them increases with photon energy.
Figure 8. Plot of refractive index of grown film against wavelength.

4.5. **FT-IR studies**

FTIR was used to determine the chemical bonding and functional groups in the CdO nanoparticles within the range of the waves from 400-5000 \( \text{1/cm} \). Figure 9 shows the FTIR spectrum of the CdO nanoparticle with ranges in \( \sim 2329, \sim 1602, \sim 1385, \) and \( \sim 702 \text{ (1/cm)} \). The broad absorbance range can be set to \( \sim 2329 \text{ cm}^{-1} \) for the corresponding CO2 scaling vibration [11]. The range on \( \sim 1602 \text{ (1/cm)} \) is set to H2O curvature [12]. The OH/H2O functional group presents in the system may be due to atmospheric water vapours [13]. The broad bands located at \( \sim 1385, \) and \( \sim 702 \text{ (1/cm)} \) observed as CdO stretching modes [14].

Figure 9. FT-IR spectrum of the CdO nanoparticles.

Figure (4-9, 10) show that the spectral responsivity and Specific detectivity curve of Shotky diode CdO/FTO consists of two peaks of response; the first peak is located at 610 nm due to the absorption edge of CdO/FTO nanoparticles.
5. Conclusion
The CdO films were deposited by electrolysis and drop casting technique. The structural and surface morphology properties of these films have studied extensively by using XRD, SEM, AFM and UV-Visible spectrophotometer, respectively. The obtained films are polycrystalline with cubic structure as shown in XRD pattern. The SEM images revealed a cauliflower surface with single mode size homogenous distribution of grains. The mean values of nano-clusters size and roughness for CdO were determined by using AFM. AFM imaging specified high smooth surfaces with small RMS roughness values (21.7nm) and the results show a good similarity of the film surfaces. While for the optical properties it was shown the films has a good transmittance and characterized CdO films are n-type semiconductors with a direct band gap of 2.4 eV as shown in optical property studies. Finally, from this work it may be concluded that this is a good technique for producing a nanostructure material.

Reference
[1] M. Ortega, G. Santane, A. Morales – Acevedo, (1999), Superficies Vacio 9, 294.
[2] Zhao Z, Moral D. L., Ferekides C. S., (2002), Electrical and Optical Properties of Tin-doped CdO Films Deposited by Atmospheric Metal Organic Chemical Vapor Deposition, Thin Solid Films, 413(1-2), 203-211
[3] M., Ristic’, S. Popovic’, S. Music’, (2004), Mater. Lett. 58, 2494
[4] M. Zaien, N. M. Ahmed, Z. Hassan, (2012), Growth of Cadmium Oxide Nanorods by Vapor Transport, Chalcogenide Letters Vol. 9, No. 3, (2012), p. 115 – 119
[5] A. A. Dakhel, F. Z. Henari, (2003), cryst. Res. Technol., 38, no. 11, 979.
[6] T. K. Subramanyam, S. Uthanna, B. Sinivasulu Naidu, (2001), Materials Letters, [14] (1998) 214, and appl. Surface science, 169, 529.
[7] I.I. Shagnov, B. P. Kryzhanovskii, V. M. Dubkov, (1981), Sov. J. Opt. Technol., 48, 280.
[8] MM Islam, MR Islam, J Podder, (2008), Optical and Electrical Characteristics of CdO Thin films Deposited by Spray Pyrolysis Method, Journal of Bangladesh Academy of Sciences, Vol 32, No 1.,
[9] R. Salunkhe, D. Dhawale, T. Gujar, C. Lohande, (2009), Mater. Res. Bull. 44, 364
[10] Alia A. Shehab and etal, 2014, The Structural and Surface Morphology Properties of Aluminum Doped CdO Thin Films Prepared by Vacuum Thermal Evaporation Technique, Ibn Al-Haitham Jour. for Pure & Appl. Sci, Vol. 27 (2) 2014.
[11] L. Bedikyan, S. Zakhariev, M. Zakharieva. Journal of Chemical Technology and Metallurgy, 48, 6, 2013, 555-558
[12] Areej A. Hateef, "studying the optical and electrical properties of (TiO2) prepared by chemical spray pyrolysis technique and their application in solar cell", thesis 2010

[13] T. Tsurumi, S. Nishizawa, N. Ohashi, T. I. Ohagaki, “J. Appl. Phys.”, (38), (1999), (3682)

[14] S. Balamurugan and etal, Synthesis of CdO nanopowders by a simple soft chemical method and evaluation of their antimicrobial activities, Pacific Science Review A: Natural Science and Engineering (2016) 1-5.