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Studying The Optical Properties of CdO and CdO: Bi Thin Films

Zain A. Muhammad * ***Ahmed T. Hassan *****
Yasmeen Z. Dawood*

* Al-Mustansiriyah University, College of Education, Physics Department
** Ministry of Education, Directorate General for Education/ Baghdad AL-Karkh / 1

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Abstract:

Cadmium Oxide and Bi doped Cadmium Oxide thin films are prepared by using the chemical spray pyrolysis technique a glass substrate at a temperature of (400^0C) with volumetric concentration (2,4)%. The thickness of all prepared films is about (400±20) nm. Transmittance and Absorbance spectra are recorded in the wave length ranged (400-800) nm. The nature of electronic transitions is determined, it is found out that these films have directly allowed transition with an optical energy gap of (2.37) eV for CdO and (2.59, 2.62) eV for (2% ,4%) Bi doped CdO respectively. The optical constants have been evaluated before and after doping.

Key words: (CdO-Bi) Thin Films, Optical Properties.

Introduction:

Cadmium Oxide (CdO) is one of these important semiconductors oxides which use for a variety of application, including ,smart window ,sensor, solar cell, optical communication, anti-reflection coatings and phototransistor and flat panel display photodiodes [1-7].Various techniques have been used to deposited CdO thin films such as sol-gel [8], chemical bath deposition [9] chemical vapor deposition [11] The spray pyrolysis [14] . In this paper CdO and (CdO:Bi) thin film is prepared by spray pyrolysis technique in addition to investigating their optical properties by using (PU- 8800- UV/VIS Spectrophotometer).

Experimental Details:

The CdO solution is prepared with (0.1M) using cadmium acetate (Cd $(CH_3COO)_2 . 2H_2O$) as a precursor salt and distilled water as a solvent (100 ml). Bi doped CdO thin films are prepared with (0.1M) using Bismuth nitrate pentahydrate ($Bi(NO_3)_3 \cdot 5H_2O$) which is dissolved in a distilled water (25 ml). Preparing films are sprayed on borcilecat glass substrate after cleaning them and putting them on an electrical heater for about (30mins). Each spraying period lasts for about (8 sec) followed by about (5mins) waiting period to avoid a too strong cooling of the substrate. By using weighting method and electronic balance Metter AE-160), the thickness of all prepared films is (400±20) nm. It has been found out that the following deposition parameters give good stoichiometric form surface: substrate temperature (400^0C), spray rate (10 ml /min), air pressure (10^5 N/m^2), distance between sprayer nozzle and substrate of (29±1) cm.

The transmittance and absorbance spectra have been recorded in the wave lengths ranged (400-800) nm by using (PU-8800-UV/VIS Spectrophotometer) with two bands provided by Philips Company. Put the glass substrate like the glass used for spraying in the back window, and then put the deposited film in to be a source window .All the processes happen in the room temperature.

Calculations:

Reflectance can be evaluated from the following relation.

R + T + A = 1 …………. (1)

The absorption coefficient (α cm^{-1}) is calculated in the fundamental absorption region using Lambert law (fig (4)) [15].

$I = I_o \exp(-\alpha t)$ ……. (2)

t is film thickness , I is the intensity of transmitted light.

If (I / I_o) = T then α=Ln (1/ T)/t…(3)

to measure the optical band gap for the thin films, we use the Tauc's relation as follows[16]:

$\alpha h\upsilon = A(h\upsilon - Eg)^n$………….(4)

where A is constant, hν photon energy, Eg the optical energy gap and an index (n) could take different values according to the type of electronic transition.

The extinction coefficient (K_o) can be calculated by the following relation [17]:

$K_o = \alpha \lambda / 4\pi$ ……..(5)

λ: is wave length and α: The absorption coefficient.

Refractive index, one of the fundamental properties of an optical can be evaluated from the relation [8].

$$n = \left[\frac{(1+R)^2}{(1-R)^2} - \left(k_o^2 + 1\right) \right]^{1/2} + \frac{(1+R)}{(1-R)}$$ ….(6)

The real (ε_1) dielectric constant and imaginary (ε_2) dielectric constant are determined using the relation:

$\varepsilon_1 = (n^2 - K_o^2)$ ....(7)

$\varepsilon_2 = (2 n K_o)$ .... (8)

Results and Discussion:

The spectral distribution of transmittance (T) and absorbance (A) is measured using UV-Visible spectrophotometer in the range 400-800 nm for Cadmium Oxide and Bi doped Cadmium Oxide thin films as in Figure(1) and Figure (2) respectively. From these figures, the decrease of transmittance at 4 % Bi doped cadmium oxide and increase at 2 % Bi doped cadmium oxide can be noticed both in the range about (500-800)nm. Also, we notice the absorbance in the lower wave length increase with increasing Bi-doping in the CdO thin films and decrease directly with wave length.

Reflectance can be calculated from the relation (1). We observe from figure (3) that reflectance has a maximum value (80 %) at about 450 nm for all films and decrease with increasing the wavelength. The absorption coefficient (α cm^{-1}) is calculated in the fundamental absorption region using Lambert law (figure (4)).

From the relation (4) we have been estimated The band gap of the films. The Cadmium Oxide has a direct band gap ranging (2.2 - 2.7) eV [17]. To obtain the optical band gap Eg, the graph $(\alpha h\upsilon)^2$ of (hυ) versus was plotted. by extrapolating the straight line to the hυ axis at (αhυ) = 0 as shown in Figure (5), we can measure the optical band gap energies Eg. We notice from figure (5) that Bi doping increases the optical energy gap, this is explained on the basis of quantum size effect. The obtained values of Eg (2.37, 2.59 and

2.62 eV) are in good agreement with those reported for CdO thin films prepared by other techniques [13-14].

Figure (6) shows the extinction coefficient (K_o) as a function of wave length with different doping concentration of Bi. The extinction coefficient decreases as the wave length increases, and it increases as the doping concentration increases.

The value of refractive index (n) are calculated by using equation (6). from Figure(7) It is seen that the refractive index n changes with the wave length and shows peak, In the region between 400 and 500 nm.

Figures 8 and 9 show the variation of the real and imaginary dielectric constant with the wave length for CdO and (CdO:Bi) thin films . The complex dielectric constant characterize the optical properties of any solid material [19]. We notice that the shape of the (ε_1) curve with the wave length is the same as the refractive index curve. Also, Imaginary part of dielectric constant (ε_2) has the same behavior as the extinction coefficient (K_o) because they are joined by previous relation (8).

Conclusions:

Undoped and Bi doped CdO thin film on the glass substrates have been prepared by Chemical Spray Pyrolysis technique. Optical energy gap is increased with an increase of Bi doping .The obtained values of Eg (2.37, 2.59 and 2.62 eV) Bi doping affect all optical constants.

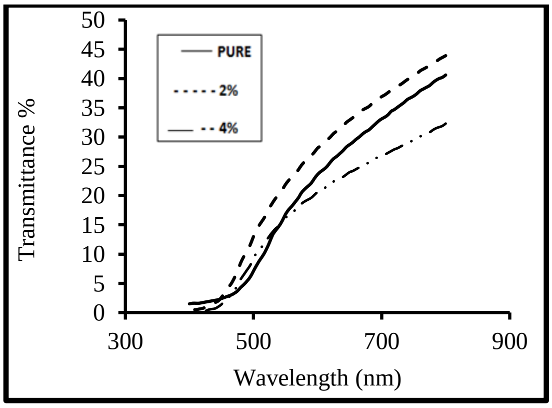


Fig. (1): Transmittance versus Wave Length For CdO and (CdO:Bi) Thin Films.

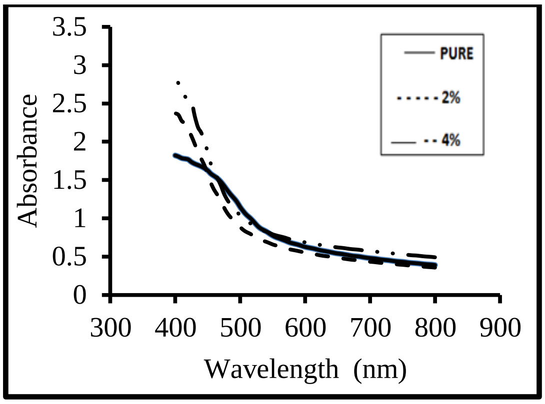


Fig. (2): Absorbance versus Wave Length for CdO and (CdO:Bi) Thin Films .

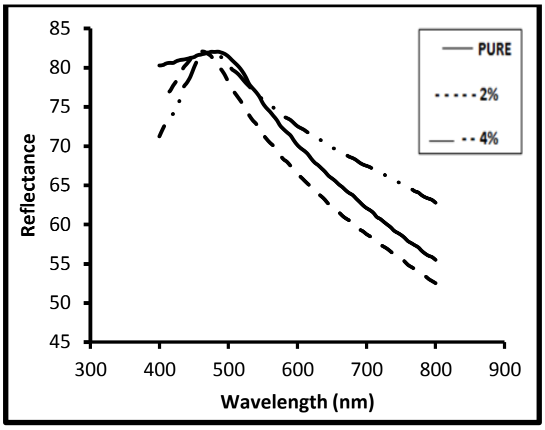


Fig. (3): Reflectance versus Wave Length for CdO and (CdO:Bi) Thin Films .

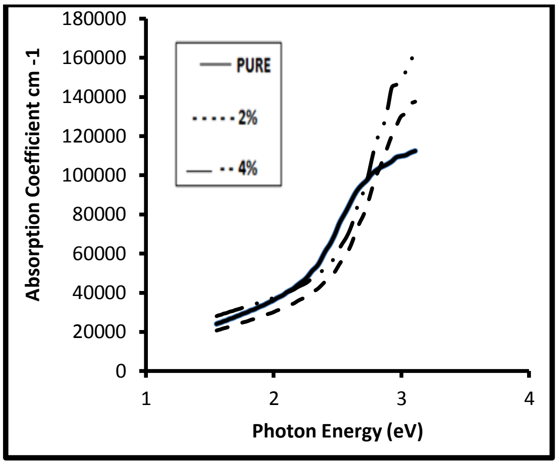


Fig. (4): Absorption Coefficient versus Photon Energy for CdO and (CdO:Bi) Thin Films .

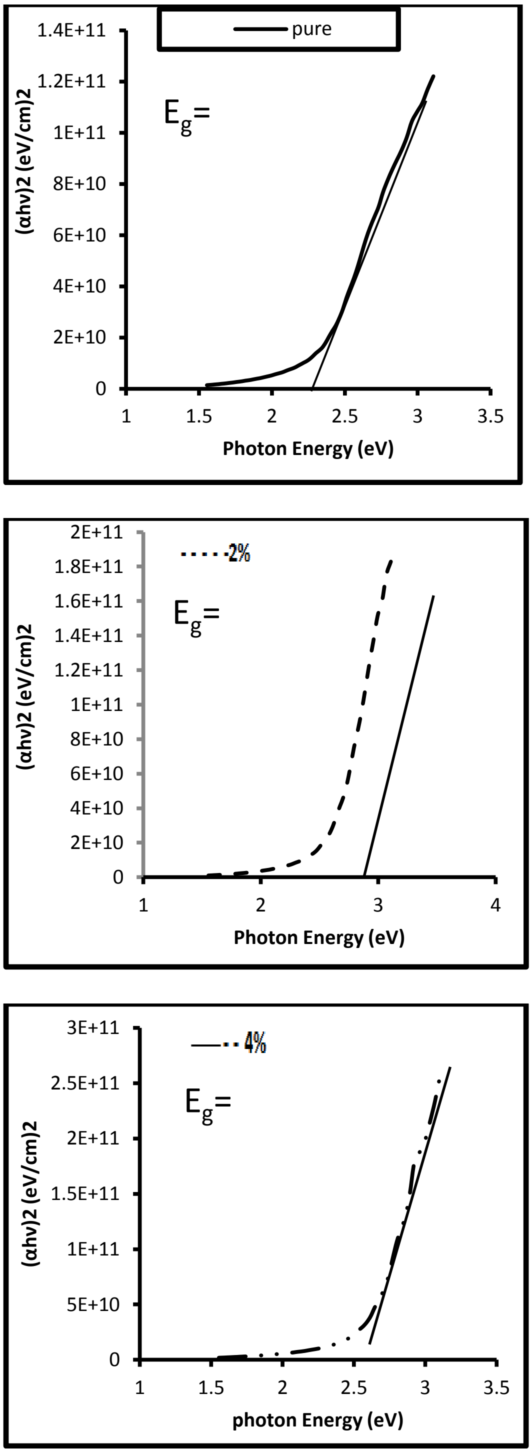
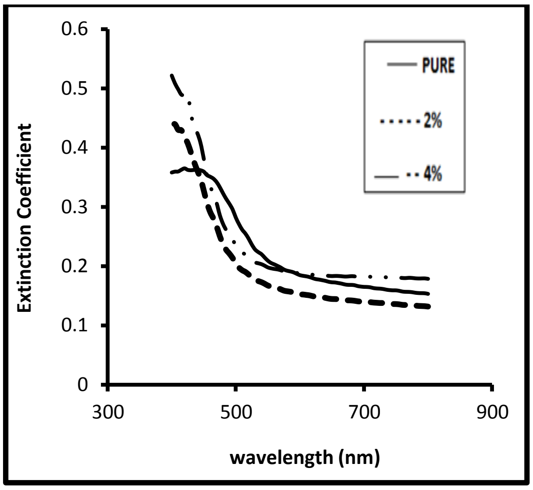


Fig. (5): Allowed Direct Energy Gap for CdO and (CdO:Bi) Thin Films .



Fig(6): Extinction Coefficient versus Wave Length for CdO and (CdO:Bi) Thin Films .

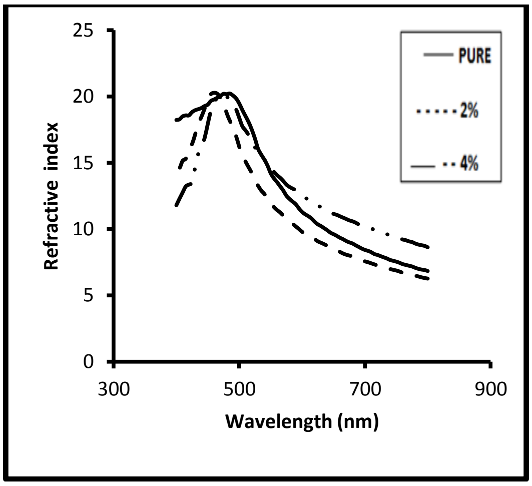
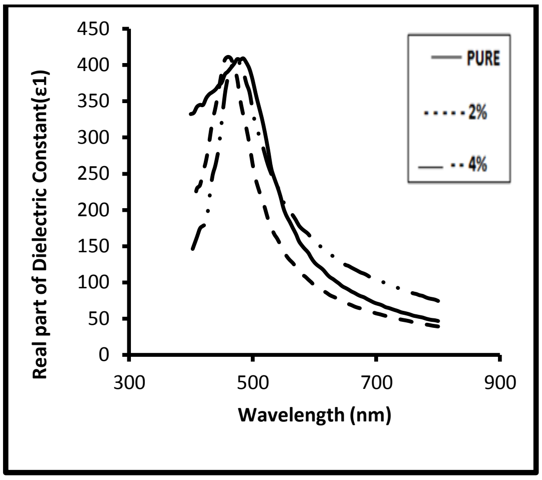
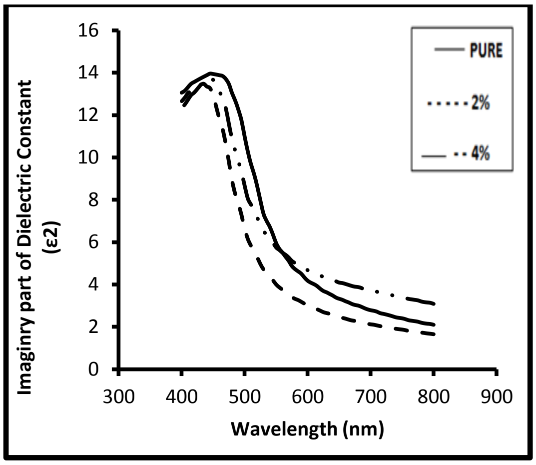


Fig. (7): Refractive Index versus Wave Length for CdO and (CdO:Bi) Thin Film.



Fig(8): Real part of Dielectric Constant versus Wave Length for CdO and (CdO:Bi) Thin Films.



Fig(9): Imaginry part of Dielectric Constant versus Wave Length for CdO and (CdO:Bi) Thin Films.

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دراسة الخواص البصريه لاغشية أوكسيد الكادميوم (CdO) غيرالمشوبة والمشوبة بالبزموث (Bi)

زين العابدين ماجد محمد* **احمد طالب حسن**** **ياسمين زيدان داود***

*الجامعه المستنصرية / كلية التربية/قسم الفيزياء
**وزارة التربية / المديرية العامة لتربية بغداد الكرخ/1

الخلاصة:
حضرت أغشية أوكسيد الكادميوم (CdO) غيرالمشوبة والمشوبة بالبزموث (Bi) باستخدام طريقة التحلل الكيميائي الحراري على قواعد منْ الزجاج بدرجة حرارة القاعدة (400^0C) وبنسب حجمية مختلفة %(2,4)، وكان سمك الاغشية المحضرة بحدود nm(20±400). تمت دراسة الخصائص البصرية للأغشية من خلال تسجيل طيفي الامتصاصية والنفاذية ولمدى الأطوال الموجية nm(400-800). تم تعيين طبيعة الانتقالات الالكترونية ووجد انها انتقالات مباشرة مسموحة, وكانت قيمة فجوة الطاقة البصريه لاوكسيد الكادميوم الغيرمشوب eV(2.37) والمشوب بالبزموث eV(2.59, 2.62) للنسب الحجمية (2%) ،(4%) على التوالي. كما تم حساب الثوابت البصرية قبل وبعد التشويب.

الكلمات المفتاحية: اغشية رقيقة ، اوكسيد الكادميوم المشوب بالبزموث ، الخصائص البصرية .