PREPARATION AND STUDY CHARACTERISTICS OF CdO THIN FILM

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Abstract

Cadmium thin film have been prepared by vacuum evaporation method on a slide of glass substrate at room temperature and then oxidation process of thin film using oven in air, the crystal structure of the sample was studied using X-ray diffraction, the transmission and absorption characteristics were measured in the wavelength range (300-1000 nm) and the direct band gap energy was determined and found to be 2.45 eV ,the extinction coefficient was studied ,the electrical characteristics were measured, the electrical conductivity was 3×0^{-2} (Ω.cm), the carriers concentration was 8.9×0^{14}(cm^{-3}).

Keyword: Cadmium oxide , vacuum evaporation, oxidation process.

Introduction

Cadmium (Cd) is a soft, ductile, silver-white metal that belongs together with zinc and mercury to group IIb in the Periodic Table. It has relatively low melting (320.9 °C) and boiling (765 °C) points and a relatively high vapour pressure. In the air cadmium is rapidly oxidized into cadmium oxide, cadmium oxide is used in batteries, electroplating baths, pigments, plastics, synthetic products[1].

The wide band gap properties of semiconductors, like CdO, are of interest particularly for applications such as solar cells and transparent electrodes TCO [4]. Measurements of nonlinear optical properties are very interesting from the point of the view of optoelectronic and all optical devices such as lasers modulators and optical switches [5, 6]. Cadmium oxide CdO is conducting, transparent in the visible region with a direct band gap of 2.5eV. CdO is an n-type Semiconductor [8, 7]. Various techniques have been employed to prepare CdO thin films such as spray pyrolysis [9], sputtering [10, 11], solution growth [12], activated reactive evaporation [13], pulsed laser sputtering [13] and sol-gel method [7].

CdO films have a cubic structure such as NaCl, lattice constant equal 4.69 Å. At growth temperature below 250°C, the films are weakly crystallized, with grains randomly oriented on the glass substrate. At temperatures above 300°C, the CdO films are strongly crystallized, with a preferred (200) orientation.[3] CdO films have a dark brown color , mass density 8.15 g/mol , molten temperature at 1773K [5] .

In this work the CdO thin film was prepared by thermal evaporation technique of Cd and oxidation process of the film using thermal method, this is a new method to produce CdO thin film and all characteristics optical and electrical were studied and compared with previously work.

Experimental

Cd thin films were deposited on an optically cleaned slide of glass substrates (area 25mm × 2mm) at room temperature by using thermal evaporation in a vacuum of 10^{-5} torr using balzer coating system. The substrates were mounted directly over the Mo boat with about 18cm separation. The thickness of deposition film was about 50 nm which calculated from the gravimetric method. The oxidation process was occurred using quartz tube oven under static air at condition (250C°/25min).

The crystal Structure of CdO film was investigated using XRD analysis (Cu Kα source; λ= 1.54506 Å) with scan speed of 3°/min with 2θ mode. The transmittance measurement was performed using spectrophotometer (Shimadzu type) in the spectral range 300-1000nm.

To measure the electrical properties, ohmic contacts have been made on CdO film by depositing of high purity Al film of 500 nm

thickness through special thin metal sheet mask. Hall coefficient measurement was done by measuring of current were measured in air atmosphere by using "Keithley 614" electrometer under a room temperature to investigate the conductivity type of the CdO film. The electrical conductivity measurements of CdO film at temperature range (300-500K) using thermocouple.

Result and Discussion

1. X-ray characterization

The representative XRD patterns for CdO thin films was shown in Fig.(1), the figure reveals a polycrystalline structure of the film. In this diffraction pattern, the peaks at 2θ (38.30, 44.50) correspond to diffraction from (111) and (200) planes of the CdO cubic phase, respectively [8]. It can be also observed that the respective diffraction pattern exhibits additional peaks at 2θ (37.30,40.60) and. these peaks correspond to the (002), (100), planes of the Cd crystalline phase and indicate that in respective films there is small amount of unoxidized Cd grains mixed with oxide. After the thermal oxidation.

2. Optical properties

Fig.(2) illustrate the transmittance of CdO in the wavelength range (300-1000)nm, it is obvious that the film give a good transparency with the visible an NIR regions the Figure show the transmittance is increase with increase wavelength , the transmittance is a vary according to type and structure lattice of material and it is depend on thickness of the film according of equation [5]

$$I=I_o e^{-(\alpha d)} \quad \text{.....(1)}$$

I, I_o are the transmitted and incident light intensities respectively, α is absorption parameter of material , d is thickness of film.

This Figure it is obvious that the transmittance increased in the wavelength region (400-700)nm and in the wavelength region (700-1000) the transmittance seemed approximately constant with increase wavelength due to high reflection for this region and far from the wavelength cut_{off} .

The Fig.(3) show behavior of in absorption coefficient versus photon energy of the film, the absorption coefficient increase with increase photon energy the absorption is obey to transit electron from valance band to conductor band .The transmittance and absorption are good agreement that in Ref. [16].

The CdO is a material with a direct band gap, For such band to band transitions the dependence of absorption coefficient a versus photon energy is given by the eq. [13]:

$$(\alpha h\nu)=A(h\nu - Eg)^{1/2} \quad \text{.....(2)}$$

where A is a parameter independent of hv and Eg is the optical band gap energy. Ploting the dependence of $(\alpha h\nu)^2$ vs. hv, the value of Eg can be determined by extrapolating the linear portion of this plot to $(\alpha h\nu)^2 = 0$. The obtained values of Eg, (2.45 eV) is good agreement with other work for CdO thin films prepared by other techniques [14,15].

Fig. (5) show the extinction coefficient (K_{ex})versus wavelength, The extinction coefficient are means attenuation in electromagnetic wave passing through a media the extinction coefficient increase sharply with the increase of the incident photon energy (hv), the extinction coefficient was calculated from equation [5].

$$K_{ex}= \frac{\alpha\lambda/}{4\pi} \quad \text{.....(3)}$$

3. Electrical properties

Another important electrical property of semiconductors is the carrier density. This is typically measured using the Hall effect, whereby a magnetic fields establishes a potential gradient across a two-dimensional sample which is perpendicular to the direction of the field. The size of this potential difference (called the Hall voltage V_H) is a measure of the carrier density N. Hall voltage is negative for n-type semiconductors and positive for p-type semiconductors If a current I is applied to a sample of thickness d and a magnetic field B is directed into it, the carrier density is given by [6].

$$N = \frac{BI}{edV_H} \quad \text{.....(4)}$$

where e is electron charge.

The equation (4) can be written as

$$R_H = \frac{V_H}{I}.\frac{d}{B} \quad \text{.....(5)}$$

Where R_H Hall effect is given by

$$R_H = \frac{1}{Ne} \quad \text{.....(6)}$$

Plotting the V_H *vs* I with constant B shown in Fig.(6), the slope V_H/I was determined value (10^4 V/I) is substituted in equation (5) the R_H obtained value (7×10^3 cm^3/C) where B=70×10^{-3} tesla, d=5 mm.

The carrier density was determined from equation (4) obtained value (8.9×10^{14} cm^{-3}) the CdO thin film is n-type semiconductor due to sign of the Hall voltage or the Hall effect is negative for n-type semiconductors and positive for p-type semiconductors.

The activation energy is calculated from equation (7).

$$\ln\sigma=\ln\sigma_o\ (-Ea/2K_BT) \quad \text{.....(7)}$$

where K_B is Boltzman constant, σ_o is conductivity at zero temperature The electrical conductivity of CdO thin films were measured as a function of temperature T, in the range of (300-500 K). Fig. (7) depicts the conductivity ln (σ) versus the inverse of temperature. The electrical conductivity starts increasing with increasing temperature .the activation energy is (0.172 eV) calculated by equation [6]

$$E_a=2K_B.\text{slope} \quad \text{.....(8)}$$

This is result a slightly different with other reported Ref.[15] this is due to preparation method and metal contact type.

The Table (1) show comparison of our results with previous results.

Table (1)

No.	E_g (eV)	E_a (eV)	carrier density (cm^{-3})	Resistivity (Ω.cm)at300k	Method preparation	Ref.
1	2.45	0.17	8.9×10^{14}	3×10^{-2}	Evaporation Cd And then oxidation	Present work
2	2.33	0.07	–	1.9×10^{-3}	Evaporation CdO	[15]
3	2.4	–	–	3.3×10^{-2}	PVD	[14]
4	2.2	–	2×10^{20}	4.87×10^{-4}	Dc magnetron sputtering	[16]

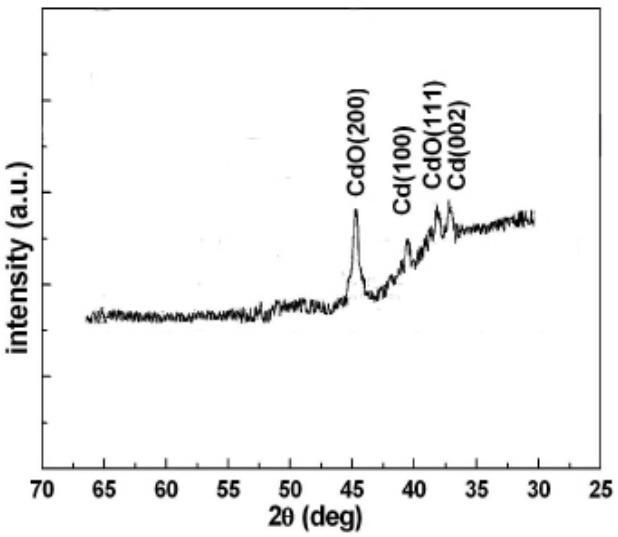

Fig. (1): XRD patterns (CuKα radiation) of CdO thin films deposited at substrate temperature of 300 K.

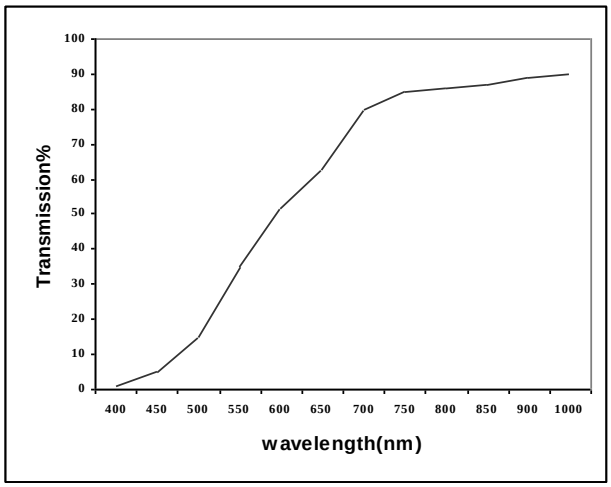

Fig. (2) : The optical transmittance (T)% as function of wave length(λ).

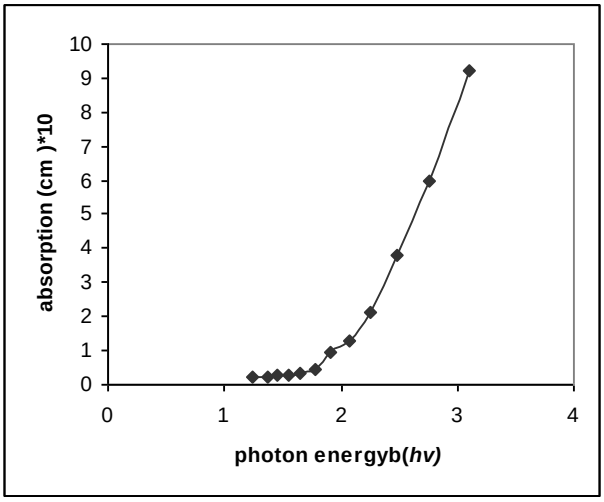

Fig. (3) : The absorption coefficient versus photon energy of films.

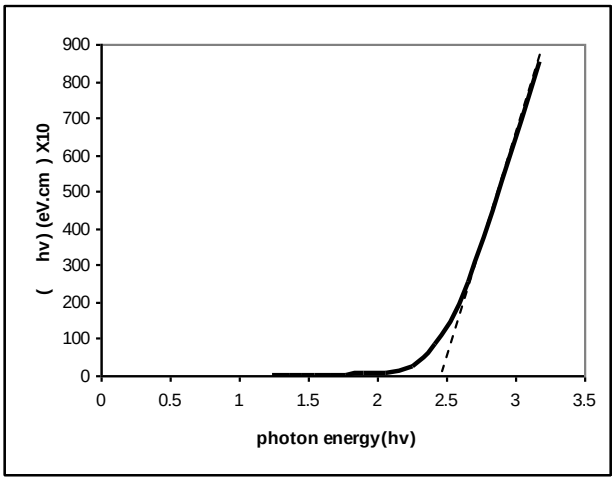

Fig. (4) : The $(\alpha hv)^2$ vs hv of the thin film CdO.

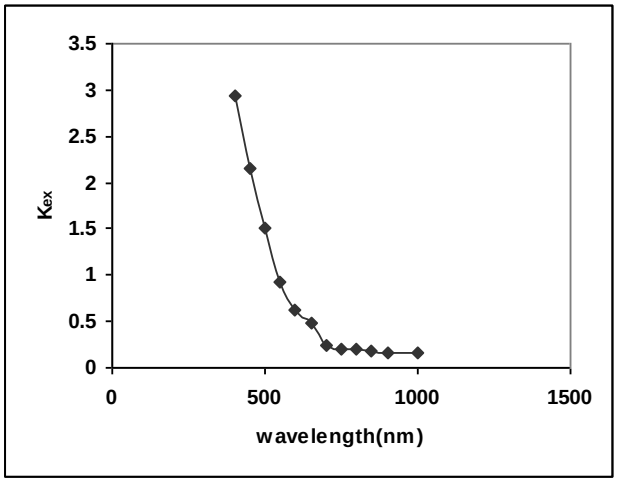

Fig. (5) : The extinction coefficient (K_{ex}) versus wavelength.

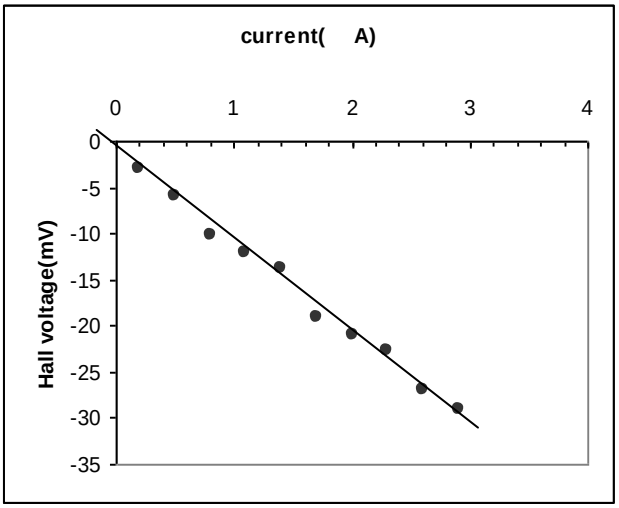

Fig. (6) : Hall voltage vs current pass through CdO thin film.

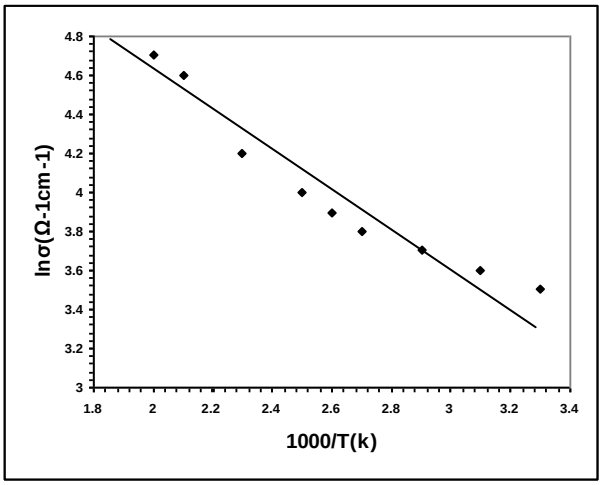

Fig. (7) : Reciprocal temperature dependence of electrical conductivity for CdO thin films.

Conclusion

The CdO thin film was prepared by thermal evaporation technique of Cd and oxidation process of the film using thermal method on a slide of glass substrate, XRD patterns for CdO thin films was show that CdO film a polycrystalline structure, cubic phase, the obtained values of the direct band gap is (2.45 eV), by the electrical measurement the film n-type conduction, the carrier density was determined and obtained value (8.9×10^{14} cm^{-3}), the activation energy is (0.172 eV).

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الخلاصة

تم تحضير غشاء من معدن الكادميوم بطريقة التبخير الحراري على شريحة من الزجاج الاعتياادي في درجة حرارة الغرفة ومن ثم أكسدة الغشاء بالفرن في الهواء تم دراسة التركيب البلوري للعينات بواسطة حيود الأشعة السينية إضافة الى دراسة النفاذية والامتصاصية للمادة ضمن المدى (300-1000 nm) ، تم حساب فجوة الطاقة المباشرة و وجد أنها (2.45eV) كذلك عامل الفقد مقابل طاقة الفوتون الساقط ،تم دراسة خواص الكهربائية و وجد أن التوصيلية الكهربائية ($3 \times 10^{-2}\Omega.cm$) وتركيز الحاملات الشحنة ($8.9 \times 10^{14}cm^{-3}$) .