The Effect of Temperature Annealing on the Electrical and Electro - Optical Properties of Cadmium Oxide Thin Films Prepared by SILAR Method

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Abstract

Cadmium oxide thin films have been prepared on glass substrate at 363K temperature by SILAR (successive ionic layer adsorption and reaction)technique using cadmium acetate solution . The CdO thin films were annealed at 673 and 773 K under atmosphere for 45 min. The electrical and electro – optical properties were studied. Electrical studies showed that the thermal-electrical conductivity and activation energies influenced by thin films annealing . The photoconductivity of CdO thin film for annealed and non- annealed films are studied. It was found that electrical conductivity increased with annealing temperature .

Key word : Thin film; Cadmium Oxide; Silar Technique and Photoconductivity .

تأثير التلدين الحراري على الخواص الكهربائية والكهروضوئية لأغشية اوكسيد الكادميوم المحضرة بطريقةSILAR

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الخلاصة

حضرت اغشية اوكسيد الكادميوم على قواعد زجاجية بدرجة حرارة 363K بتقنية SILAR و باستخدام محلول خلات الكادميوم . لدنت الاغشية المحضرة بدرجتي حرارة 673 ,773K و 45 min. في الهواء . دُرست الخصائص الكهربائية والكهرو بصرية للأغشية المحضرة ، الدراسات الكهربائية اشارت الى توصيل الكتروني حراري وان طاقة التنشيط الحرارية تتأثر بالتلدين الحراري للأغشية المحضرة . ودرست خصائص التوصيل الضوئي لأغشية (CdO) الملدنة وغير الملدنة حراريا ومن خلال قياسات (تيار – جهد) في حالة الظلام والاضاءة و تبين ان المعاملة الحرارية تؤدي الى زيادة التوصيل الكهربائية لهذه الاغشية .

الكلمات المفتاحية : غشاء رقيق ؛ اوكسيد الكادميوم ؛ تقنية الترسيب بالطبقة الأيونية المتعاقبة والتوصيلية الكهربائية و الضوئية.

Introduction

Thin film exhibiting high electrical conductivity and photo optical properties which can be developed efficiently to let it used extensively for variety of applications such as photovoltaic (PV) solar cell(Man *et al*.,2006),phototransistors (Su *et al*., 1984), photodiodes (Kondo *et al*.,1971)and gas sensors (Shinde *et al*.,2007), etc. The transparent conductive oxide films (TCO) such as indium–tin oxide, tin oxide, zinc oxide, cadmium oxide (CdO)…… etc., CdO received less attention because of their narrow band gap energy (direct band gap _ 2.5 eV, indirect band gap _ 2.1 eV) (Galicia *et al*.,2000). However, these films show higher mobility value (m = 130 cm^2/ V s) (Cruz, *et al*.,2005) which is necessary for high conductivity. CdO thin films have been prepared by different techniques such as dc reactive ,magnetron sputtering (Subramanyam *et al*.,2001), spray pyrolysis (Uplane *et al*., 2000), successive ionic layer adsorption and reaction (SILAR) (Mane, and Han,2005), metal organic vapor-phase epitaxychemical bath deposition [Herrero *et al*.,2000], [Pe´ rez*et al*.,2004], sol–gel[Cruz *et al*.,2005], and electro deposition [Hana *et al*.,2005]. SILAR,distinguished as the layer-by-layer deposition process of anionic and cationic from the precursor. This method employs to improve both growth rateand thin film quality, without the need of costly vacuum evaporation process. (Eze,2005).

Materials and Methods

In the present work, CdO films have been deposited onto a glass substrate by immersion in Cd_2^+ source and 2%H_2O_2 solutions, at bath temperature 90ºC. The cadmium acetate solution became alkaliny (pH 8.3) by ladding aqueous ammonia (20 - 40)%. The used glass slides were cleaned with detergent and chromic acid, followed by rinsing in water. Then glass substrate was immersed in a 2% H_2O_2 solution after immersion into cadmium acetate solution.

CdO film thickness in terms of deposited film weight depends on the adsorption, reaction time period sand partially dissolution of deposited film in the cadmium solution at the beginning of each deposition cycle,(this is due to acess ammonia addition to solution)($Cd(CH_3COO)_2.2H_2O$) 99.99%). The deposition rate (Gonzalez, and Parra,1996), for CdO film deposition, adsorption period of 20 second, reaction period of 15 sec was considered. Freshly deposited films may contain defects such as oxide vacancies and also hydroxide phase. Annealing of films reduces the defects and removes the hydroxide phase along with recrystallization process. In this work , to obtain cadmium oxide without trace of hydroxide and oxide vacancies, the films were annealed at 300ºC in air atmosphere for 45min**.**. The prepared CdO thin films were annealed at (673 and 773) K under atmosphere for 45min.

Results and Discussion

Electrical and electro – optical measurement

Figure 1 shows CdO thin films resistivity with testing temperature (308 – 358)K that was decreased with temperature. The film showed semiconductors behavior, since resistivity decreased with temperature. This referred to increasing of grain size and electrons free path reduction which lead to electrons dispersal,(Dakhel, and Henari,2003).The CdO thin films weight gained after 160 cycles was 4.65 mg/cm^2.

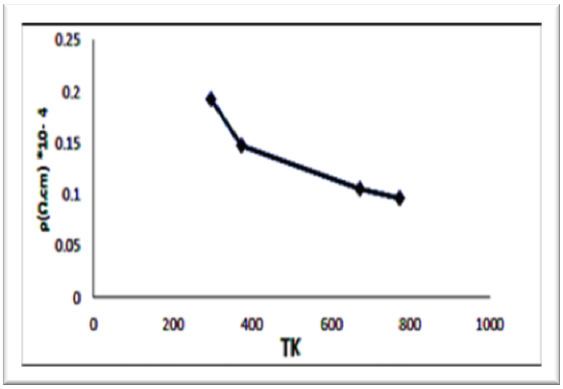

Fig.(1) The Resistivity of CdO Thin Film with Annealing Temperature

The equation for semiconductor electrical conductivity measurement from electrons and holes concentration (Meyer and Neldel, 1937; Ashok and Sharma , 1980) as follows **:**

$$\sigma = N_e\mu_N + P_e\mu_P \ldots..(3)$$

From the equation above electrical conductivity depend on two factors: the density of charge carriers and the mobility of these carriers in the material under the influence of an electric field.The mobility determined from the interaction between the electrons, in general semiconductor electrical resistivity depends on temperature($T^{3/2}$),(Su *et al*., 1984).Semiconductor have negative resistance coefficient with temperature , equation below to descent be the relation between conductivity and temperature**.**

Equation(4)[Sanatana *et al*., 1999].

as follows **:**

$$\sigma = \sigma_\circ ex[E_a/K_BT] \ldots\ldots\ldots (4)$$

Where **,**

$\sigma_\circ$: Constant Reiated to Conductivity at High Temperature

E_a:activation energy for electrical conductivity

K_B : Boltasmans Constant.

T:Temperature

Figure 2.shows that resistivity of both as-deposited and annealed film was decreased with testing temperature**,** indicating a semiconducting electrical behavior. Our results are in agreement with Shinde *et al*., (2005).The activation energies were calculated using equation (4).above Two activate energies for (CdO) thin films were founded, which means there are two types of charge carriers transition mechanism**.**The first at temperatures above room temperature for the charge carriers movement in the package levels inside the energy gap. The secondappear at higher temperatures,thermal excitation method, charge carriers movement tothe extende dlevels at conduction package depends on activation energy gained from heating.

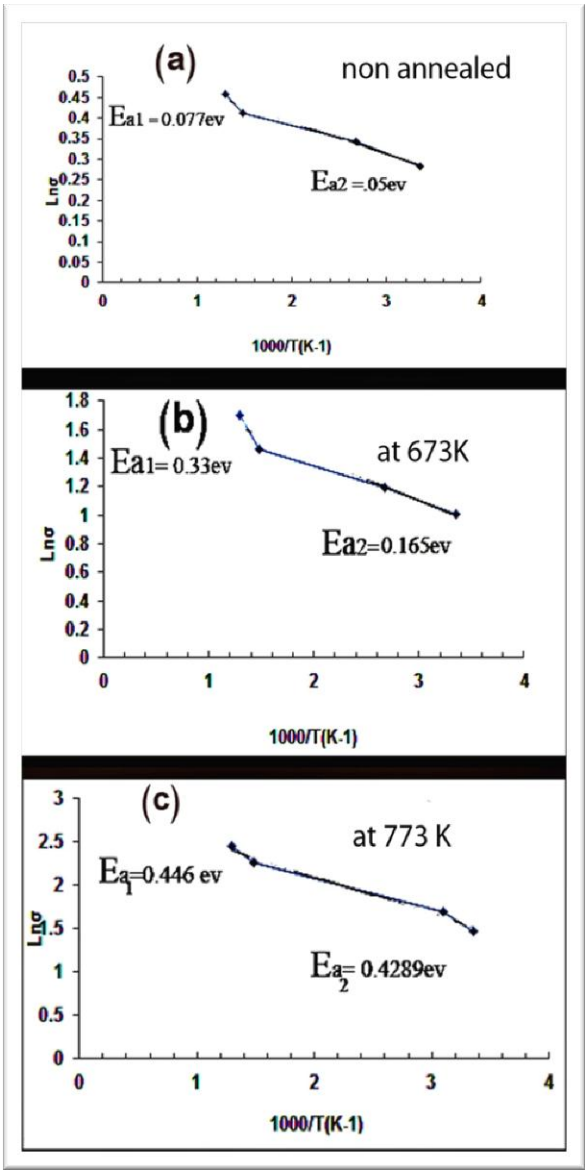

Fig (2) . Electrical Conductivity vs. Testing Temperature at Different Annealing Condition Function of Working Temperature(a)non annealed (b) 673K and (c) 773K.

Since cadmium oxide is a photo active material, it is expected that scaling their thin films with light may change their electro- optical properties. It was noted that Light current at (470LUX) was higher than dark current. Increasing light intensity to (800LUX) lead to current increasing too . For measuring dark and light currents as a function of operating voltage Al electrodes were deposited by thermal evaporation under vacuum. Figure 3. shows the variation of measured currents under different light intensities.With increasing photon energy of incident light mobility of charge carriers increased so the electrons could travels from a valence package to the conduction package. Under dark current test, the non-annealed CdO thin films, current values were higher than the currents of annealed CdO thin films, as shown in the figure 3: a, b, c.In general increasing of the annealing temperature will led to increase the crystalline size,thin films quality improvementand the crystalline structure then consequently the resistivity increases to reach it's maximum value.

Conclusions

The role of annealing temperature in the cadmium oxide thin films prepared by SILAR technique has been investigated. Increasing annealing temperature the thin films quality improved and consequently the electrical conductivity increases**.**

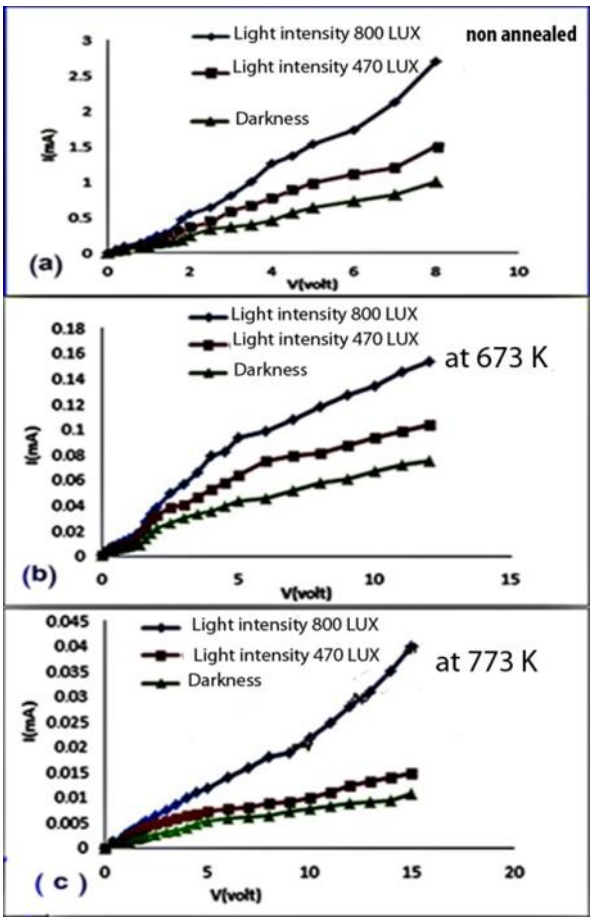

Fig. (3)Variation of Dark and Light Current as a Function of Applied Voltage at Different Annealing Condition :(a)non Annealed(b)673K and (c)773K

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