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Optical and electrical properties of CU doped CdO thin films for detector applications

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Abstract

Optical and electrical properties of CdO and Cu doped CdO thin film were presented in this work. The Cadimium Oxide (CdO) semiconducting films are deposited on glass and Silicon substrate by pulsed laser deposition (PLD) method. The structural and optical properties of the growth films are presented. The crystalline structure was studied by X-ray diffraction (XRD) having found the presence of the CdO cubic phase. Optical absorption measurements showed that films has high absorption coefficient in the UV region, whereas it is transparent in the visible region for CdO film, and it is increasing and shifted toward the visible region for Cu doped CdO film. The direct band gap energy was determined and found to be and 2.3 eV, comparing with that the Cu doped CdO film which found to be 2.2eV.The electrical measurements shows that the conductivity increase when Cu doped CdO.

Key word: Cu doped Cadmium Oxide, pulse laser deposition, optical properties, electrical properties, photoconductive detector.

1.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].

There are several methods developed for the synthesis of CdO films such as spraypyrolysis [2, 3], sputtering, chemical bath deposition (CBD), pulsed laser deposition, MOCVD, sol-gel spin coating method and thermal evaporation technique [4].

The wide band gap properties of semiconductors, like CdO, are of interest particularly for applications such as solar cells and transparent electrodes TCO [5].

First reports of the use of pulses of laser radiation to remove, or 'ablate', material from a solid (or liquid) target followed close on the heels of the first ruby lasers becoming available in the early 1960s. Given the obvious efficiency of the material ablation process, it was but a short step before pulsed laser ablation was first employed as a route to thin film deposition[6].

Cadmium oxide (CdO) one of these important semiconductors oxide which has high optical properties. According to these properties it has vast applications. Where it show high transparency in the visible region of solar spectrum and has high electrical properties which were represented low ohmic resistance. Although it is difficult to obtain simultaneously a high transmission coefficient, thin films have been carried out[7] .

Pulsed laser deposition PLD can be successfully employed to many classes of materials such as metals, semiconductors, dielectrics, ferroelectrics, electro-optic and giant magneto-resistance oxides, organic materials, polymers, magnetics, composites etc[8]. Phase pure and doped CdO thin films exhibit some extraordinary properties due to which they are popular in various semiconducting, optoelectronic industries, and for the fabrication of IR mirrors, thin film resistors, low emissive windows etc.[9]. Deposition parameters in PLD process play key role in determining various properties of CdO thin films. Gupta et al. reported the effect of deposition parameters on various properties of Sn, Ti, Al and In doped CdO films prepared by PLD technique [9, 10, 11, 12]. In this work pure CdO and cu doped CdO films were deposited on glass and silicon by pulse laser deposition. The electrical, structure and optical properties were studied.

2. Experimental Work

0.01wt% Cu-doped CdO target for PLD was prepared by solid-state reaction method.The pulsed laser deposition experiment was carried

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out inside a vacuum chamber in (10^{-3}Torr) vacuum condition.The focused Nd:YAG SHG Q-switching laser beam incident on the target surface makes an angle of 45° with it.The films were deposited on glass and silicon wafer at substrate temperature (T=573 K) with rate of deposition equal to 0.5 nm/sec. The deposition was carried out using a Q –switched Nd:YAG laser with a frequency second radiation at 532 nm (pulse with 10 nsec repetition frequency 6Hz), for 250 laser pulse. Structural analysis of thin film was done by X-ray diffractometer (XRD) usig (XRD-6000), supplied by SHIMADZU.

The thickness of the prepared film was measured by laser interferometer technique. The thickness of the film determined by this procedure is in the range (± 800- 1000) nm. The Hall measurement is determined by using HMS3000 Hall measurement setting. Optical properties were investigated by OPTIMA SP-3000 UV-VIS spectrometer. The variation of photoresponsivity of CdO photoconductive UV detector with the bias voltage was carried out under the illumination with UV diode of 2.5 mWatt power of 385 nm wavelength.The operation circuit diagram of CdO photoconductive detector is shown in Figure(1).

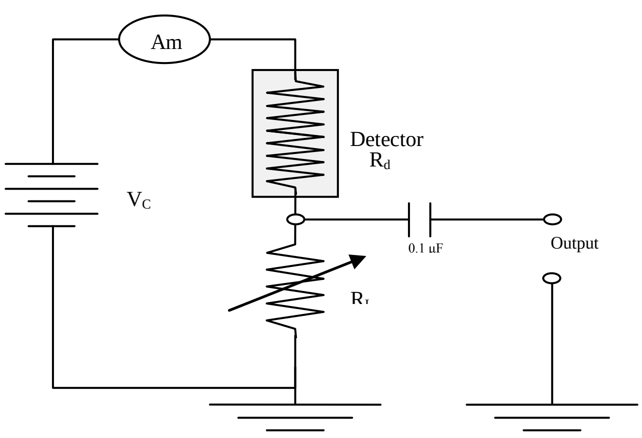


Fig. 1. The operation circuit diagram of CdO photoconductive detector.

3. Result and Discussion

3.1X-ray Characterization

The X-ray diffraction (XRD) patetern of the undoped and Cu doped CdO thin films deposited on n-type silicon substrate is illustrated in Figure (2); the figur reveals a polycrystalline structure of the film. In this diffraction pattern, the peaks at 2θ (33.3, 38.6, 55.6) correspond to diffraction from (111) and (200) and (220) planes of the CdO cubic phase, respectively.

It is apparent from this figure that all films are preferentially orientated along (111) crystallographic directions and the preferential orientation peak for Cu doped film became sharper and more intense. This may be attributed to the crystallinity of the CdO film being improved with Cu doping.

There are no additional peaks without CdO upon doping indicates the solubility of the dopant in the crystal structure. This result is comparable with results obtained by [13, 14, and 15].

3.2. Optical properties

The absorption spectrum of the CdO and Cu doped CdO thin films deposited on glass substrates is shown in Figure (3).

The Figure shows high absorption coefficient in the UV region, whereas it is transparent in the visible region for CdO film, and it is increasing and shifted toward the visible region for Cu doped CdO film.

Figure (4) shows the optical transmittance spectra with wavelength from 400 nm to 1100 nm of the undoped, and Cu doped CdO thin films. It is observed from this figure that the films show high transmission in the visible region and low transmission in the UV region. The optical transmittance increases for Cu doped CdO film.

Assuming direct transition, the dependance of $(\alpha h\nu)^2$ on the photon energy hν is plotted following Tauce relation [15, 16] and the graph is illustrated in Figure (5).

The extrapolation of the linear part of the above plot to (αhν)2 =0 gives the energy gap values of the CdO and Cu doped CdO films, which were found to be about 2.3 and 2.2 eV respectively. It can be noticed from this figure that the value of energy gap is decreasing for Cu doped CdO film. These values are in a good agreement with the values presented by other workers [17].

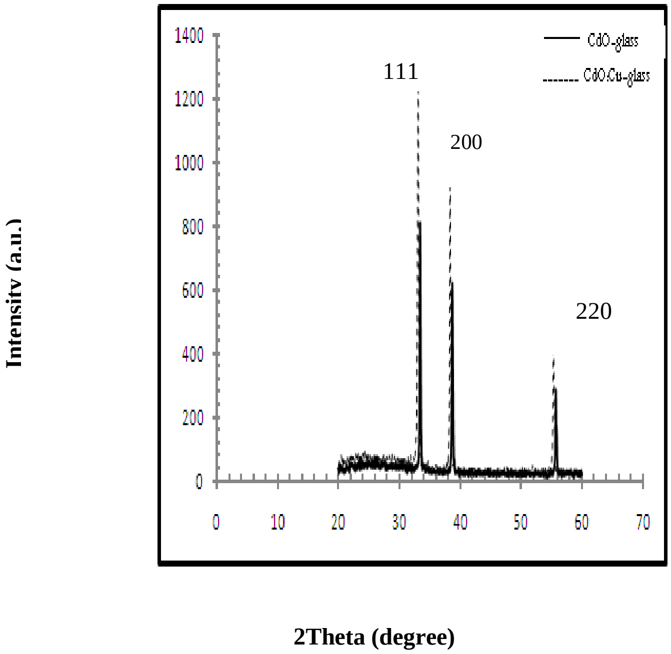


Fig.2. XRD pattern of CdO and Cu doped CdO thin films.

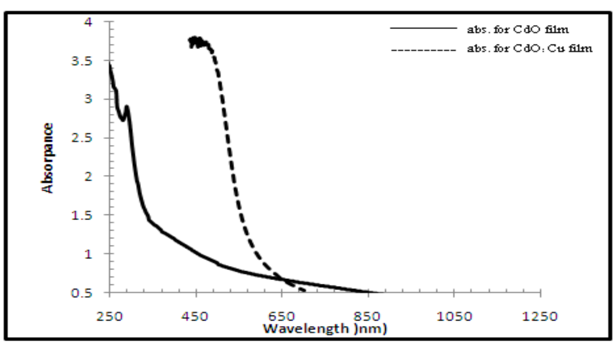


Fig.3. The absorpance spectrum of CdO and Cu doped CdO thin films deposited on glass substrate.

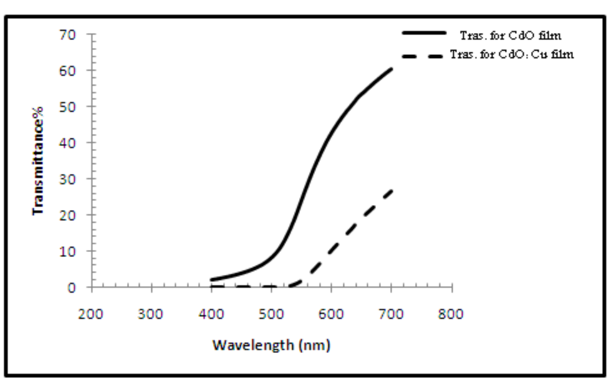
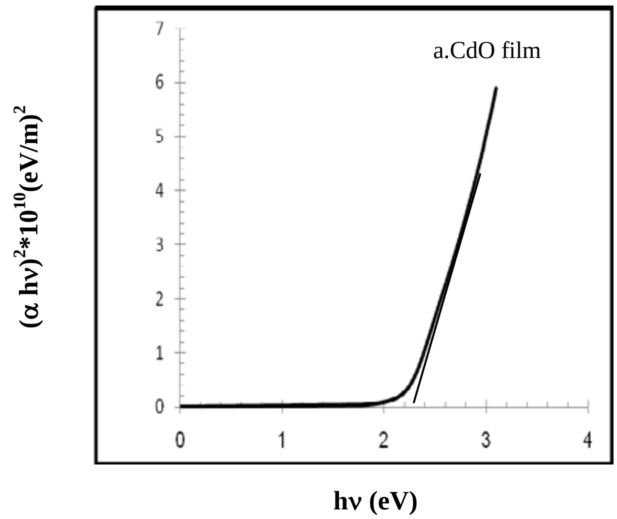


Fig.4. transmittance spectra for CdO and Cu doped CdO films.



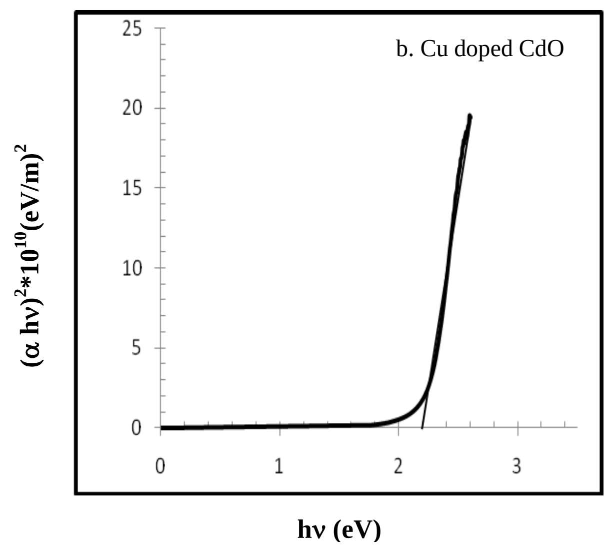


Fig.5. The $(\alpha h\nu)^2$ vs hν plot of a. CdO and b. Cu doped CdO thin films.

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4. Hall Measurements

The Hall measurements show that the dO and Cu-CdO films deposited on glass substrate are n-type semiconductor, The observed characteristics were supported from the measurement of resistivity, mobility and Hall coefficient as illustrated in table 1.

Table 1. Hall measurement for CdO and Cu Doped CdO.

Parameter	CdO	Cu doped CdO
Bulk concentration ($1/cm^3$)	-2.208E+19	-5.202E+19
Mobility ($cm^2/V.s$)	3.995E+1	9.233E+1
Resistivity (Ω.cm)	7.076E-3	1.300E-3
Conductivity (1/ Ω.cm)	1.413E+2	7.6965E+2

The result shows that the mobility and conductivity increase when cu doped CdO, where the resistivity decreases.

4. I-V characteristics

The current-voltage (I-V) characteristics of the fabricated device are illustrated in figure (6). The dark and photo illuminated currents increase linearly with bias voltage. The linear I-V curve is referring to the ohmic nature of the detector.

Figure (6) shows that the pure CdO samples have the same values for dark current and photo current when illumination by UV source with wavelength 385nm and 2.50mwatt incident power.

The increase of the photocurrent for the Cu-CdO detector samples are more than the increase of photocurrent for pure CdO. The maximum values of dark current registered for doped CdO is found to be about 65Amp at 5 Volt bias voltage whereas the photocurrent under UV source is 85 Amp at same bias voltage.

The photocurrent gain G of a detector is defined as the number of charge carriers between the two contact electrodes of a detector per second for each photon absorbed per second that is [18].

$$G = \tau / T_r \quad \ldots\ldots\ldots.1$$

Where : **τ** is the carrier lifetime , T_r is the transit time , it is express by[19] :

$$T_r = \frac{\ell^2}{\mu \cdot V_B} \quad \ldots\ldots 2$$

Since the dark current is about 65µA at 5 V bias whereas the photocurrent is85 µA at the same bias voltage the photoconductive gain of about 0.76.

The photoconductive gain (G) which is calculated from the ratio between the photocurrent to the dark current at the same bias voltage is given by the equation (1).Also ,the carrier life time (τ) was calculated after calculate T_r(transit time) using equation (2) using the values of G = 0.76, µ=9.233E+1 cm^2/ V.s as found from Hall measurements, L = 0.04 cm and V = 5V the carries life time (τ) was found to be about 2.634 µs.

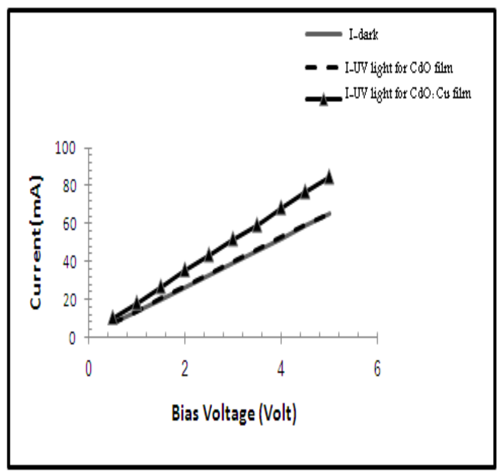

Fig.6. I-V characteristics of CdO and Cu doped CdO UV detector.

5.Conclusions:

The CdO and Cu doped CdO UV detectors prepared by pulse laser deposition technique were fabricated on glass and silicon substrates. The doped CdO with cu improved the photoconductive gain .The UV photoconductive detector shows an acceptable photoresponsivity. The speed of response of the cu doped CdO UV detector element deposited on silicon was 2.634µs.

Refrences:

[1] R. Kumaravel, K. Ramamurthi and V. Krishnakumarm, " Effect of Indium doping in CdO thin films prepared by spray pyrolysis technique" Journal of Physics and Chemistry of Solids ,71(11),2010,pp .1545-1549.

[2] P.M. Devshette, N.G. Deshpande, G.K. Bichile ,."Growth and physical properties of ZnxCd1-xO thin films prepared by spray pyrolysis technique". Journal of Alloys and Compunds. 463(1-2), 2008,pp. 576-580 .

[3] Ramiz A. Al-Anssari, Nadir F. Habubi, Jinan Ali Abd , ". Fabrication and Characterization Of n-CdO: In/p-Si thin films sollar cell". Journal of Electron Devices, 7,2013, pp.1457- 464.

[4] F. A. Benko, F. P. Koffyberg,1986. "Quantum efficiency and optical transitions of CdO photoanodes". Solid State Communications, 57(12), .1986,pp.901-903.

[5]D.B.Chrisey and G.K.Hubler, eds,. "Pulsed Laser Deposition ofThin films".Chap.1. John Wiley & Sons, New. York.1994.

[6] Hadia Kadhim J.Al-Ogili, ". Effect of thickness to the Structure Properties of CdO Thin Films". Eng. and Tech. Journal, 29(8),2011,pp.1536-1544.

[7] K. Siraj, PhD thesis, Institute of Applied Physics, Johannes Keple University Linz, Austria.2007.

[8] K. Siraj, M. Khaleeq-ur-Rahman, S.I. Hussain, M.S. Rafique, S. Anjum, " Effect of deposition temperature on structural, surface, optical and Magnetic properties of pulsed laser deposited Al-doped CdO thin films". Journal of Alloys and Compounds ,509(24),2011,pp. 6756–6762.

[9] R.K. Gupta, K. Ghosh, R. Patel, S.R. Mishra, and P.K. Kahol, " Highly conducting and transparent tin-doped CdO thin films for optoelectronic applications", Materials Lett, 62(25), 2008.pp.4103-4105.

[10] R.K. Gupta, K. Ghosh, R. Patel, P.K. Kahol, ."Highly conducting and transparent Ti-doped CdO films by pulsed laser dposition". Appl. Surf. Sci. 255,(12).2009,pp. 6252-6255.

[11] R.K. Gupta, K. Ghosh, R. Patel, S.R. Mishra, P.K. Kahol," Preparation and characterization of highly conducting and transparent Al doped CdO thin films by pulsed laser deposition". Cur. Appl. Phys. 9 2009,pp. 673-677.

[12] Mauricio Ortega, Guillermo Santana1, and Arturo Morales-Acevedo," Optoelectronic properties of CdO-Si heterojunctions". Superficies y J. Vacío. 9, 1999,pp.294-295.

[13] Faizullah, M. K. R. Khan, M. Mozibur Rahman," Pyrolized growth of (Al, N) dual doped CdO thin films and study of structural, surface morphology and opto-lectrical properties". International Journal of Materials Science and Applications A. F. M, 2(4), 2013,pp.124-127.

[14] Ramiz A. Al-Anssari, Nadir F. Habubi, Jinan Ali Abd ,".Fabrication and characterizatio of n-CdO: In/p-S thin film solar cell". Journal of Electron Devices. 17, 2013,pp.1457-1464.

[15].J.I. Pankove. Optical Processes in Semiconductors, Prentice-HallInc, Englewoord Cllifs, NJ.1971.

[16] AsamaNatik Naje, ."Optical characteristics of CdO nanostructure",physical review and research international,3(4),2014,pp.472-478.

[17] L.R. de León-Gutiérrez, J.J. Cayente-Romero, J.M. Peza-Tapia, E. Barrera-Calva, J.C. Martínez-Flores, M. Ortega-López, "Some physical properties of Sn-doped CdO thin films prepared by chemical bath deposition", material letters, 60 , 2006,pp.3866–3870.

[18]Ghusson.H.Mohammed,"Optoelectronic Parameters Of Pb_XS_{1-X} Thin Films"., M.Sc. Thesis, University of Baghdad, Dep. Of Physics.2002.

[19] Iman H.Khdayer, " Fabrication and studying the photoconducting characteristics of InSb Junction with silicon as asigle crystal semiconductor", Ph.D. Thesis , University of Baghdad, Dep. Of Physics.2005.