Influence of Irradiation on some Optical Properties of (CdO) Thin Films Prepared by Spray Pyrolysis

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Abstract. In this research, the irradiation influence on optical properties of Cadmium oxide thin films deposited on glass substrate via spray pyrolysis method were studied. The thickness of the prepared thin films were 400 and 500 nm respectively. The flow rate was 10 ml/min and the substrate temperature was held constant at 450°C. The thin films are irradiated with gamma ray from Cs-137 of energy 0.662 MeV, the irradiation time is two weeks. The optical absorption and transmission was studied by using UV-Visible spectrophotometer. The absorption coefficients increase after irradiation, while the optical band gaps for 400 nm (CdO) decrease after irradiation from 2.32 to 2.27 eV and for 500 nm (CdO) from 2.30 to 2.12 eV.

Introduction

Cadmium oxide (CdO) is one of the promising transparent conducting oxides (TCOS) from II to VI groups of semiconductors which has a great potential use for optoelectronic devices [1]. CdO has high optical transmittance in the visible and NIR region [2]. CdO has several attractive properties, high density (8150 Kg/m³), low resistivity, high melting point (1500 °C) [3]. It is an n-type semiconductor [4]. So, it was used in many industrial productions like solar cells, flat panel display optical communications, smart windows, photo transistors, Infrared detectors, ceramic glasses, storage batteries and other optoelectronic applications [5-11].

Many techniques have been adopted to prepare CdO thin films such as, sol-gel, successive ionic layer adsorption and reaction (SILAR), pulsed laser deposition, sputtering and chemical spray pyrolysis [12-17], the literature survey of the effect gamma radiation on undoped CdO thin films is scarce Fabbrri et al. studied the effect of ion irradiation formation of CdO microcrystal [18] while Hassouni et al. studied the effect of gamma irradiation on the optical properties of Mg doped CdO thin films [19].

The aim of this work was focused on study of gamma rays influence on some optical, properties of CdO thin films.

Experimental

Chemical spray pyrolysis technique was used to deposit Cadmium Oxide (CdO) thin films on glass substrates at a constant temperature of (450 °C). The spraying setup and preparation technique have been described elsewhere [20].

A solution of concentration (0.1M) of (Cd(NO₃)₂.4 H₂O) was prepared by dissolving (3.0847 g) in (100ml) distilled water according to equation (1) [21]:

\[ M = \frac{W_t}{M_w} \times (1000/V) \]  (1)

The spray solution used of 0.1 M of high purity cadmium nitrate dissolved in 100 ml distilled water was sprayed toward the substrate. The atomization of the solution into a spray of fine droplets was carried out by the nozzle, with the help of compressed air as the carrier gas. The flow rate of the solution was 10 ml/min, spraying time was 10 lasted by 2 minutes to avoid excessive cooling. The nozzle to substrate distance was (30) cm. The optical absorption and transmission was studied by using UV-Visible spectrophotometer (Schimadzu V-1800 UV-Visible Recording Spectrophotometer) in the wavelength range (300-900) nm.
Results and Discussion

Optical absorbance spectra of the films are measured in the wavelength range (300-900) nm as shown in Fig. 1 and Fig. 2 which explains the relation between absorbance and wavelength before and after irradiation. Before irradiation, the absorbance reduced with the increase of wavelength as illustrated in Fig. 1. After irradiation, the absorbance decreases with the increase of wavelength for 500 nm thin film more than that for 400 nm thin film till 525 nm photon wavelength as shown in Fig. 2, absorbance values of thin film 400 nm in thickness was less than that of 500 nm over wavelengths 525-900 nm.

![Figure 1. Relation between absorbance and wavelength for CdO thin films before irradiation.](image1)

![Figure 2. Relation between absorbance and wavelengths for CdOthin films after irradiation.](image2)

The relation between transmittance and wavelength before and after irradiation was illustrated in Fig. 1 and Fig. 2. The two graphs show sharp rise in transmittance which indicate that the thin films has a good crystallinity [22]. Three factors can reduce the values of transmittance, including high surface scattering reduced the transmittance, impurity center and oxygen deficiency [23].

Before irradiation, the transmittance increases with the increase of wavelength and obtain a higher value of the transmittance for the thin film of thickness (400) nm at the wavelength (900) nm.
After irradiation, the transmittance for CdO thin film thickness of 500 nm is higher than that of 400 nm till 525 nm wavelength. On the other hand, the transmittance for the thin film of thickness 400 nm is higher than that of thin film 500 nm over the ranges 525-900 nm wavelength as shown in Fig. 4. It is clearly seen that radiation affected the CdO thin film especially at low wavelength region below 550 nm. This change in transmittance could be attributed to the increase in localized energy state due to the induced effect of gamma ray [19].

![Figure 3](image3.png)

**Figure 3.** Relation between transmittance and wavelength for CdO thin films before irradiation.

![Figure 4](image4.png)

**Figure 4.** Transmittance versus wavelength of CdO thin films after irradiation.

The mathematical relationship of absorption coefficient ($\alpha$) is following [24]:

$$\alpha = 2.303 \frac{A}{t}$$  (2)

A: Absorbance; t: Film thickness.

The dependence of $\alpha$ versus photon energy for the as deposited thin films was shown in Figs. 5 and 6 representing the absorption coefficient ($\alpha$) for thin films before and after irradiation respectively. It can be observed that the irradiation lead to decrease the absorption coefficient for these films which make it low accuracy and the absorption edge shifted toward long wavelength region (red shift).
The relation between \((\alpha h\nu)^2\) and photon energy shown in Fig. 7 and Fig. 8. The values of energy gap was found to be decreased from (2.32-2.27) eV for 400 nm thin film thickness and (2.30-2.12) eV for 500 nm thin film thickness before and after irradiation respectively, due to the increase in density of localized states of the band gap, which causes a shift to lower values [25].
Figure 7. Relation between $(\alpha h\nu)^2$ and photon energy before irradiation.

Figure 8. Relation between $(\alpha h\nu)^2$ and photon energy after irradiation.

Conclusions
1. Optical measurements confirm the nature of electronic transition which was allowed direct electronic transition.
2. Strong absorbance at a wavelength range of (300-500) nm made cadmium oxide films suitable for solar cell.
3. The optical energy gap values affected by gamma radiation by decreasing its value.
4. Thin films of 500 nm thickness were more affected by gamma ray in comparison with other thicknesses.
References

[1] A. Gulino, G. Tabbi, CdO thin films: a study of their electronic structure by electron spin resonance spectroscopy, Applied Surface Science. 245(1) (2005) 322-327.

[2] M. Ristic, S. Popovic, S. Music, Formation and properties of Cd(OH)₂ and CdO particles, Materials Letters. 58(20) (2004) 2494-2499.

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

[4] Y.S. Choi, C.G. Lee, S.M. Cho, Transparent conducting ZnₓCd₁₋ₓO thin films prepared by the sol-gel process, Thin Solid Films. 289(1-2) (1996) 153-158.

[5] R.A. Al-Anssari, N.F. Habubi, J.A. Abd, Fabrication and characterization of n-CdO:In/p-Si thin film solar cell, Journal of Electron Devices. 17 (2013) 1457-1464.

[6] K. Sankarasubramanian et al., Chemical spray pyrolysis deposition of transparent and conducting Fe doped CdO thin films for ethanol sensor, Materials Science in Semiconductor Processing. 40 (2015) 879–884.

[7] R.H. Bari, S.B. Patil, Nanostructured spray pyrolysis zinc doped CdO thin films for LPG gas sensor, Journal of Nanoscience and Technology. 2 (2016) 104–108.

[8] R.N. Bulakhe, C.D. Lokhande, Chemically deposited cubic structured CdO thin films: Use in liquefied petroleum gas sensor, Sensors and Actuators B: Chemical. 200 (2014) 245–250.

[9] S. Millesi et al., Nanostructured CdO thin films for water treatments, Materials Science in Semiconductor Processing. 42 (2016) 85–88.

[10] K. Usharani et al., Characteristic analysis on the suitability of CdO thin films towards optical device applications – substrate temperature effect, Int. J. Thin. Fil. Sci. Tec. 4(2) (2015) 89-96.

[11] S. Cheemadan, A. Rafiudeen, M.C.S. Kumar, Highly transparent conducting CdO thin films by radiofrequency magnetron sputtering for optoelectronic applications, Journal of Nanophotonics. 10(3) (2016) 033007.

[12] C.J. Diliegros-Godines et al., Structural, electrical and optical properties of tin doped cadmium oxide thin films obtained by sol–gel, J. Sol-Gel Sci. Technol. 70(3) (2014) 500–505.

[13] A.C. Nwanya et al., Synthesis, characterization and gas-sensing properties of SILAR deposited ZnO-CdO nano-composite thin film, Sensors and Actuators B. 206 (2015) 671–678.

[14] L.L. Pan et al., Bandgap variation in grain size controlled nanostructured CdO thin films deposited by pulsed-laser method, Journal of Materials Science: Materials in Electronics. 25 (2014) 1003–1012.

[15] M.A. Islam et al., Effect of oxidation on structural, optical and electrical properties of CdS thin films grown by sputtering, Optik. 126(21) (2015) 3177–3180.

[16] Y. Aouna et al., Effect of annealing temperature on structural, optical and electrical properties of zinc oxide (ZnO) thin films deposited by spray pyrolysis technique, Optik. 126(24) (2015) 5407–5411.

[17] M.A. Rahman, M.K.R.Khan, Effect of annealing temperature on structural , electrical and optical properties of spray pyrolytic nanocrystalline CdO thin films, Materials Science in Semiconductor Processing. 24 (2014) 26–33.

[18] F. Fabbri et al., Ion irradiation induced formation of CdO microcrystals on CdTe surfaces, Materials Letters. 92 (2013) 397–400.
[19] M. H. Hassouni et al., Effect of Gamma Irradiation on the Optical Properties of Mg doped CdO Thin films deposited by Spray Pyrolysis, International Letters of Chemistry, Physics and Astronomy. 11 (2013) 26-37.

[20] W.J. DeSisto, R.L. Henry, Preparation and characterization of MgO thin films deposited by spray pyrolysis of Mg(2,4-pentanedionate)2, Journal of Crystal Growth. 109 (1991) 314-317.

[21] R.L. Johnson, Characterization of piezoelectric (ZnO) thin films and the fabrication of piezoelectric micro-cantilevers, M. Sc. Thesis, Iowa State University, Ames, Iowa, 2005.

[22] M.M. Beevia, M. Anusuyab, V. Saravananc, Characterization of CdO thin films prepared by SILAR deposition technique, International Journal of Chemical Engineering and Applications. 1 (2010) 151-154.

[23] H.M. Ali et al., Properties of transparent conducting oxides formed from CdO alloyed with In2O3, Thin Solid Films. 515(5) (2007) 3024–3029.

[24] G. Busch, H. Schade, Lectures on Solid State Physics, Pergaman Press, London, 1976.

[25] T.K. Muity, S.L. Sharma, Effect of gamma radiation on optical and electrical properties of tellurium dioxide thin films, Bull. Master Sci. 31(6) (2008) 841-846.