Gamma radiation effect on some structural and optical properties of CZO thin films

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Abstract

thin films of cobalt doped ZnO were deposited on a glass substrate using chemical spray pyrolysis technique. Absorbance and transmittance spectra were recorded in the wavelength range (300-900) nm before and after irradiation. XRD reveals that the as deposited thin film were hexagonal polycrystalline. The optical parameters such as, optical energy gap , reflectivity ,extinction coefficient and refractive index were determined before and after irradiated by gamma ray. It has been found that all the studied parameters were influnced by radiation.

Introduction

ZnO represents am important material in large area of applications due to their characteristics such us: high refractive index [1], good electrical conductivity and optical transparency [2], high mechanical and thermal stabilities [3]. Its exciton binding energy is quite large with a value of 60 meV, which ensures an efficient excitonic emission up to room temperature [4], in addition, its also exhibits the features of non-toxicity, low cost and high abundance [5]. For all resons above ZnO was a promising candidate material for advanced device applications due to the above characteristics and unique combination of its physical properties-optical, electrical, magnetic, piezoelectric and ferroelectric.It has a variety of potential applications such as, sensors [6], laser diodes [7], solar cells [8], transparent electrode [9], acoustic resonators [10], heat mirrors [11], and schottky diodes [12]. Several deposition methods could be used to prepare ZnO thin films including sol-gel deposition [13], chemical vapor deposition [14], Rf magnetron [15], thermal evaporation [16], chemical bath deposition [17] and spray pyrolysis [18].

The aim of this work is to study the effect of gamma radiation on the structural and optical properties of cobalt doped zinc oxide.

Experimental details

CZO thin films were prepared on a glass substrate by the spray pyrolysis technique .The $ZnCl_2$ and $CoCl_2$ salts (0.1 M) were dissolved in deionized water in separate beakers. Aqueous solutions of $ZnCl_2$ and $CoCl_2$ were used as the source of Zn and Co respectively 0.5 percentage of $CoCl_2$ were added to the ZnO solution in order to obtain CZO. The Substrate temperature was regulated at 400 ^oC, the solution rates were kept constant at 5 ml/min.

These conditions were selected because lower temperatures gave low film growth rates, thereby requiring excessive amount of solution, and high temperatures risked volatilization of the solution prior to reaching the substrates, resulting in poorly adhered films. Yhe thickness of the obtained films was about 400 nm. A ^{137}Cs were used as gamma ray source with 3 μci for 6days. XRD data were recoded by Philips PW 1840 using Cu K_α radiation , wavelength 1.54Å. Absorbance and transmittance were recorded by double beam spectrophotometer UV-1700-1650 UV-Visiblerecording spectrometer supplied from Shimadzu (Japan).

Results and discussions

The structural properties of cobalt doped zinc oxide grown at 400 ^oC with an atomic concentration of 5% are analyzed by XRD before and after irradiation by gamma rays as can be seen in Fig. (1) and Fig. (2), it can be found that all the films are polycrystalline with hexagonal and wurtzite structure and have a preferred orientation along(101) , the c- axis perpendicular to the substrates. The crystallinity is improved by gamma radiation as can be clearly seen from the full width at half maximum (FWHM). The transmittance spectra of CZO thin films are shown in Fig. (3).The CZO thin films show high transmittance in the visible region and increase gradually in the wavelength range (420-700) nm as the wavelength increase. The transmittance of the deposited films after irradiation were decrease in comparison with the transmittance before irradiation, but the behavior of the curves remain the same.The optical absorption spectra of CZO thin films were obtained in the wavelength range 350 to 900 nm the optical absorbance was measured from these spectra. According to Tauc the dependence of the absorption coefficient α on photon energy $h\upsilon$ is taken the from [19]:

$$(\alpha h\upsilon)^{1/r} = A(h\upsilon - E_g) \quad (1)$$

Where E_g is the optical band gap, A is a constant and r = ½ for an allowed direct energy gap. In order to determine the optical band gap of the CZO thin films before and after irradiated γ - rays $(\alpha h\upsilon)^2$ was plotted versus $h\upsilon$. the direct band gap was obtained by extrapolating the linear part to zero concatenate. A typical plot of $(\alpha h\upsilon)^2$ versus $h\upsilon$ of CZO before and after irradiation is shown in Fig. (4) and Fig. (5) respectively The optical band gap of CZO before irradiation was estimated to be 3.2 eV, this value increases to be 3.31 eV after irradiation by gamma .these results might be explained due to the improvement in crystallinity. Fig. (6) and Fig. (7) shows the refractive index (n) and extinction coefficient (k) as a function of wavelength before and after irradiation respectively calculated in the wavelength range (350-900) nm as follows [20]:

Where R is the reflectivity and k the extinction coefficient [21]which is:

$$n = \left(\frac{1+R}{1-R}\right) + \sqrt{\frac{4R}{(1-R)^2} - K^2} \quad (2)$$

$$k = \frac{\alpha \lambda}{4 \pi} \quad (3)$$

Where (□) the absorption coefficient and (□) is the wavelength. The refractive index reach 3.63 and then decreases gradually as the wavelength increase while after irradiation the refractive index increase in the wavelength range (420 – 900) nm and it seems to be nearly constant in comparison with the sample before irradiation. The behavior of the refractive index is related to the carrier concentration due to increase the amount of oxygen vacancies so the refractive index increases clearly [22].On the other hand the extinction coefficient increase with irradiation as a result of decrease in the transmittance which cause the increase of the absorption coefficient.

Conclusions

CZO thin films were grown successfully by chemical spray pyrolysis using cobalt as a donor element in ZnO, XRD analysis reveals that the intensity of (101) peak increase after irradiation due to improvement of the film crystallinity. The refractive index increases after irradiation while the extinction coefficient decreases.

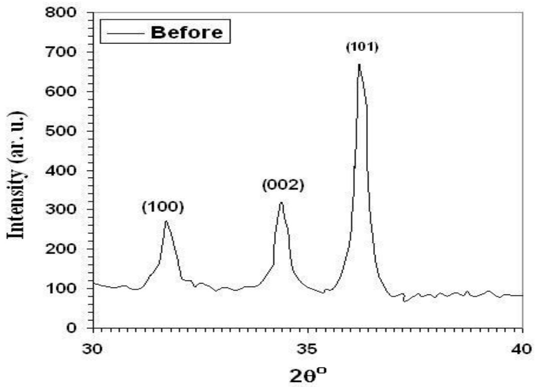

Fig. (1)XRD for the as grown thin films before.

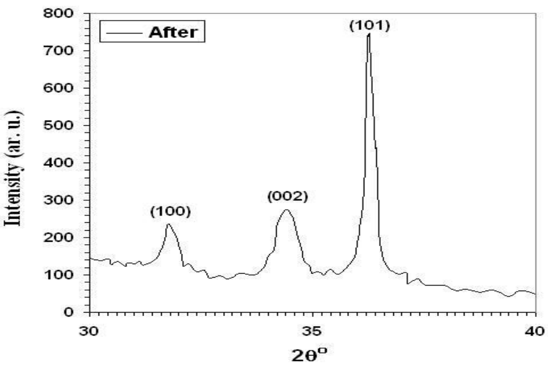

Fig. (2) XRD for the as grown thin films before after.

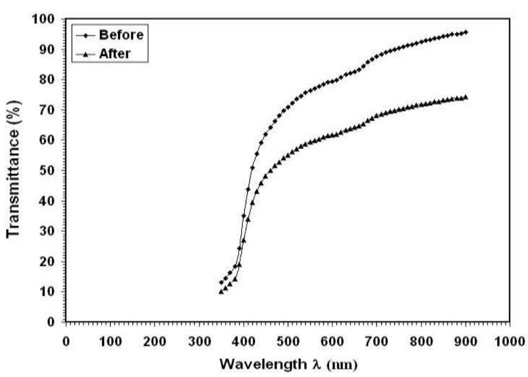

Fig. (3) Transmittance versus wavelength of CZO thin films before and after irradiation.

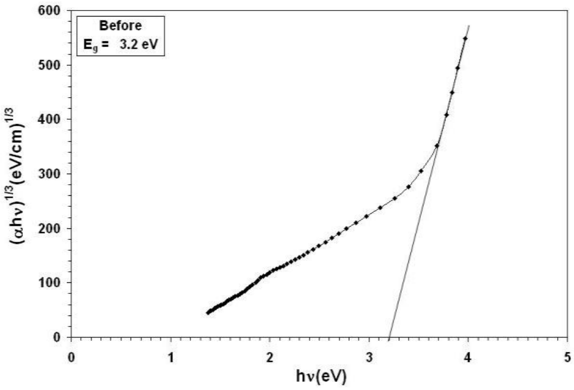

Fig. (4) $(\alpha h\nu)^2$ versus photon energy for CZO thin films before irradiation.

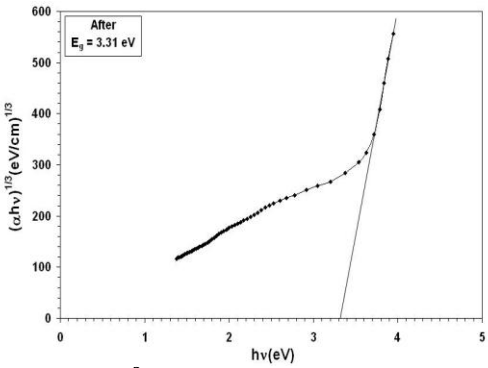

Fig. (5) $(\alpha h\nu)^2$ versus photon energy for CZO thin films after irradiation.

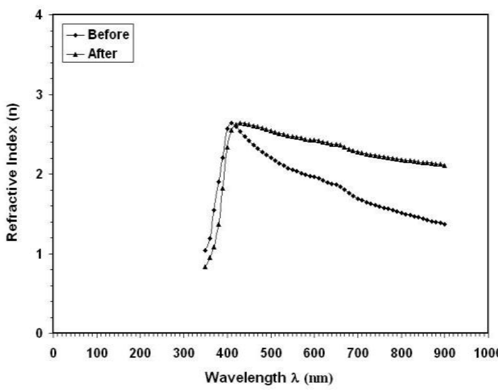

Fig. (6) refractive index versus wavelength of CZO thin films before and after irradiation.

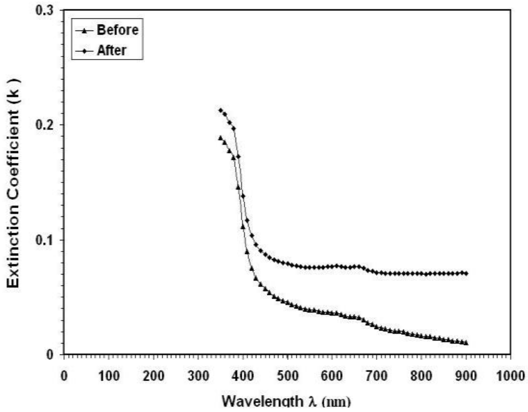

Fig. (7) extinction coefficient versus wavelength of CZO thin films before and after irradiation.

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تأثير أشعة كاما على بعض الخصائص التركيبية والبصرية لأغشية CZO الرقيقة

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الملخص

حضرت أغشية رقيقة من اوكسيد الخارصين المشوب بالكوبلت على قواعد من الزجاج بتقنية التحلل الكيميائي الحراري، سجل طيفي النفاذية والامتصاصية في مدى الأطوال الموجيةnm(300-900) قبل وبعد التشعيع. أثبتت تقنية حيود الأشعة السينية بان الأغشية المرسبة كانت متعددة التبلور ومن النوع السداسي.

حددت قيم بعض المعلمات البصرية مثل، فجوة الطاقة البصرية ، معامل الخمود ومعامل الانكسار قبل وبعد التشعيع . لقد وجد بان قيم جميع هذه المعلمات قد تأثرت بالتشعيع.