Thickness Influence on Structural and Optical Properties of ZnO Thin Films Prepared by Thermal Evaporation

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Abstract
A thermal evaporation technique was used to prepare ZnO thin films. The samples were prepared with good quality onto a glass substrate and using Zn metal. The thickness varied from (100 to 300) ±10 nm. The structure and optical properties of the ZnO thin films were studied. The results of XRD spectra confirm that the thin films grown by this technique have hexagonal wurtzite, and also aproved that ZnO films have a polycrystalline structure. UV-Vis measurement, optical transmittance spectra, showed high transmission about 90% within visible and infrared range. The energy gap is found to be between 3.26 and 3.14e.V for 100 to 300 nm thickness respectivly. Atomic Force Microscope AFM (topographic image) shows the grain size increased in the range (91.29 -110.11)nm.

Keywords: Thermal Evaporation, ZnO, Optical Properties, Structural Properties.

Introduction

The interest of researchers nowadays is focusing on the transparent conducting oxides (TCO)films are wide band gap semiconductors with low resistance and high transparency in the visible range for these reasons these materials are widely used in optoelectronic application [1]. Zinc oxide is an II-VI transparent conducting oxide (TCO) as material. This semiconductor has several favorable properties: good transparency, high electron mobility, the wide and direct band gap of 3.4 e.V at 300k [2]. With high exciton binding energy (60 meV).ZnO thin film has been extensively studied because of its potential application in various fields, for example, solar cells .piezoelectric devices, chemical sensors and ultraviolet (UV) light emitted.[3]. ZnO thin film has been prepared by various techniques such as thermal evaporation, pulsed laser deposition, molecular beam epitaxy, magnetron, sputtering, sol-gel, chemical vapor deposition and sprays pyrolysis [4]. The present work deals with ZnO thin films deposition using thermal evaporation .Films were prepared by thermal evaporation technique in a vacuum in this study. This technique is simple, low cost, friendly environment, can be employed to coat large surface area therefore economically advantage and easy to control the growth factors like film thickness and deposition rate[5].

Experiment

The metallic Zinc films were deposited by thermal evaporation technique (using Edward coating unit model (E306) under vacuum ($2.5x10^{-5}$) mbar onto clean substrate at different thicknesses (100, 200 and 300) ± 10 nm at R.T, a cylindrical chamber of height 8 cm at top substrate vacuum .Class substrate was cleaned to remove stains, substrate was cleaned surface contaminants and rinsing thoroughly with distilled water and ethanol and allowed to dry completely. The substrate was mounted on a rotating substrate holder and the metallic Zinc was placed in a molybdenum boat in thermal evaporation system . After preparation Zinc films were oxidized under 400 C^0at flow rates of oxygen 2.5 litter/ min for two hours to form ZnO thin films .After oxidation the samples were cooled at room temperature. X-ray diffraction with Cu Kα radiations (**λ**=1.54059 A) was used for the structural measurements. the UV-visible spectrophotometer was used for optical measurements.

Result and discussion

the X-ray diffraction spectrum of synthesized ZnO thin film deposited by thermal evaporation technique on the glass at a different thickness that is shown in figure (1).The XRD patterns of ZnO contains three main peaks (101) (100) and (002) direction. It was observed that all the films exhibit hexagonal wurtzite polycrystalline structure [6] was matched with the standards peaks (pdf card report No.00-036-1451). The grown film at 100 nm thickness has got the preferred orientation along the (101) direction. Films at 200 nm thickness showed an increase in the intensity along (100) direction and it has become the preferred orientation but the films at 300 nm thickness note that increase in the intensity along (002) direct with a great decrease in the intensity along (101) direct but still the preferred orientation is (100) direction.

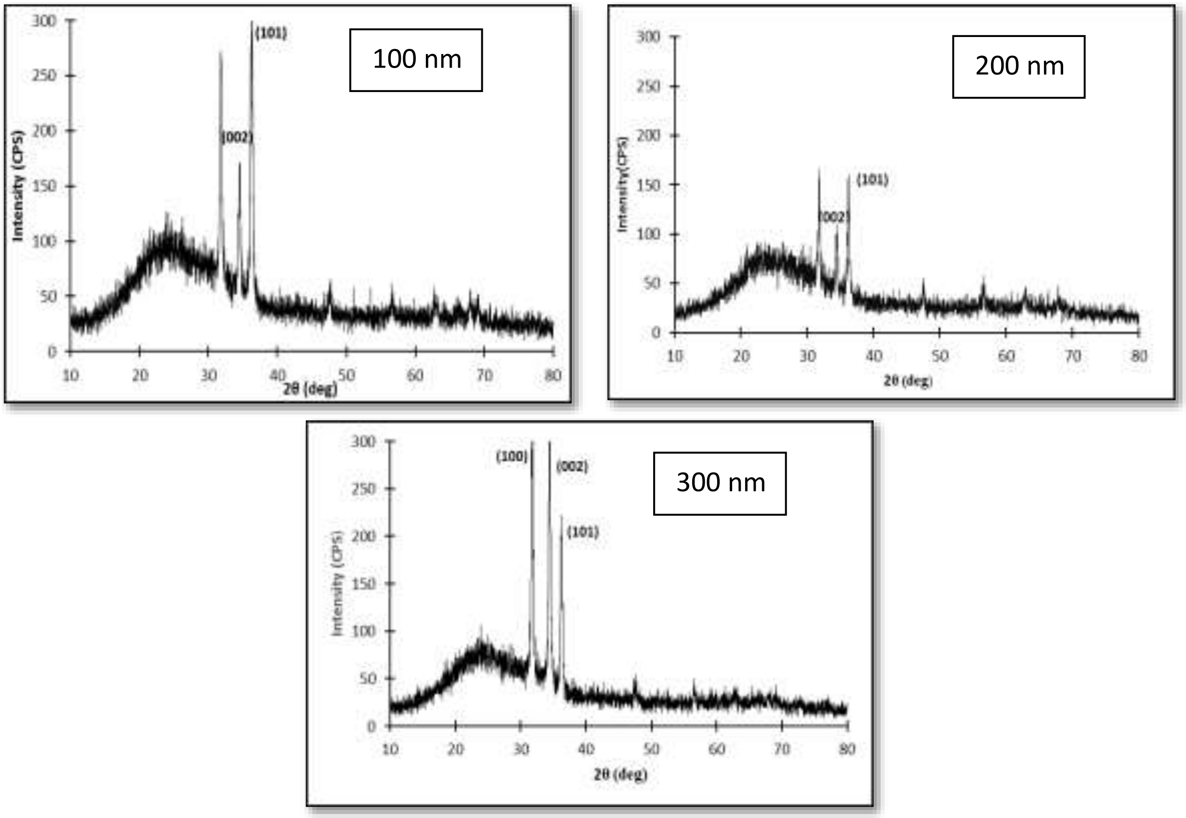


Figure (1): XRD patterns of ZnO thin films at a different thicknesses (a) 100 (b) 200 and (c) 300 nm.

Figure (2) shows the increase of peak intensity and decrease of the full width at half maxima (FWHM) to (200nm) thickness of ZnO film**[7],**where thickness increase makes atoms packet as good and improve in structure, this make (FWHM) decreases.

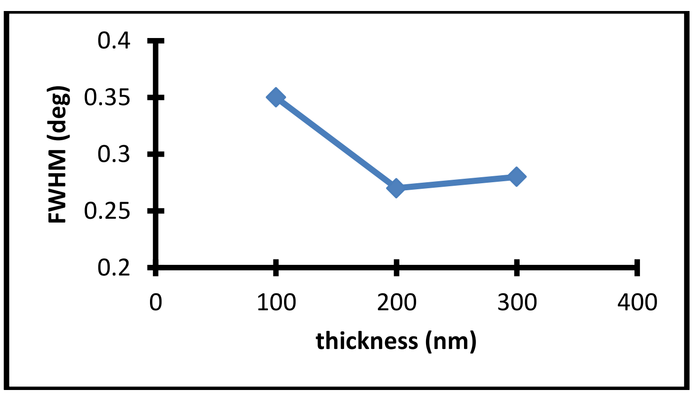


Figure (2): FWHM vs thickness on ZnO thin films.

The crystalline size of ZnO was determined by the X-ray line broadening method as shown in Table (1) using the Scherrer equation:

$$D = \frac{K\lambda}{\beta \cos\theta} \ldots\ldots.(1)$$

Where: D is the crystalline size

k: denote to scherre constant = 0.9
λ: is the wavelength of the incident Cu Kα radiation =1.5418 nm
β: is the full width at half maximum (FWHM) of the peak
And θ is the Bragg diffraction angle [8].

Table (1) indicates to the thickness and average crystalline size, notice when thickness increases the average crystalline size increase but at 300 nm notice slightly decreased.

Table (1): crystalline size and FWHM with a thickness of ZnO thin films.

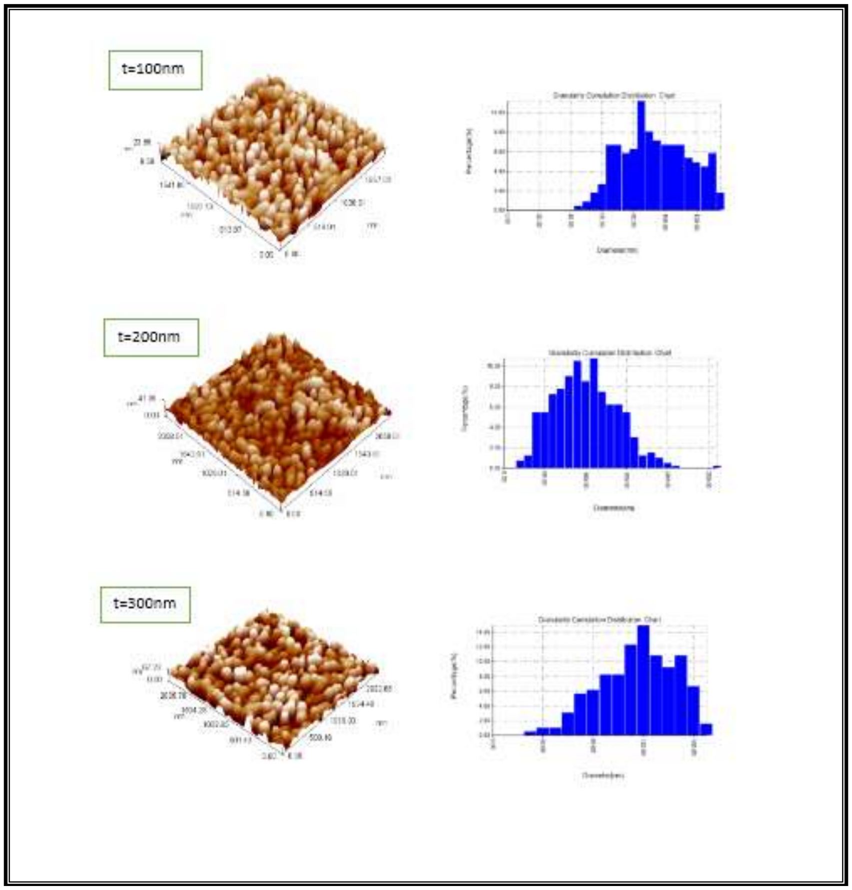
Thickness (nm)	D (nm)	FWHM (deg)
100	23.1	0.35
200	29.1	0.27
300	29.9	0.28

Atomic force microscopy (AFM) describes the surface morphology of ZnO thin films analyzed by AFM the surface of ZnO films observed that the grain is uniformly distributed within the scanning area. It is observed that the surface of the films exhibited roughness and ZnO films came rougher when thickness increase as shown in the table (2). This result refers to that the growth of larger grains with increased thickness leads to an increase in the surface roughness, it is observed that the average grain size increases with increasing of thickness and the value of the average grain size variable from 91nm to 110 nm depending on film thickness as shown in figure (3). The root means square of surface increase from 5 nm to 17 nm with increased thickness that indicates to high polycrystalline.

Table (2): Characterization of ZnO thin films.

Thickness (nm)	Average grain size (nm)	Root mean square (RMS) (nm)	Roughness density (nm)
100	91.29	5.69	4.83
200	94.82	7.38	6.04
300	110.11	17.5	14.9

The UV-visible spectrum of the ZnO films shows good optical transmission (90%) with wavelength (800-900) nm within infrared region shown in figure(4) with different thicknesses.The transmission stabilized when the wavelength increase.ZnO films are highly transparent and above the measured value of transmittance is due to loss of intensity as a result of reflection at the air- ZnO interface for normal incidence. The transmission of ZnO films decreased as the thickness increased because the atoms packed together. The high transmission makes ZnO films excellent elect for transparent window materials in solar cells [9].



Figure(3): AFM image of ZnO films with different thicknesses.

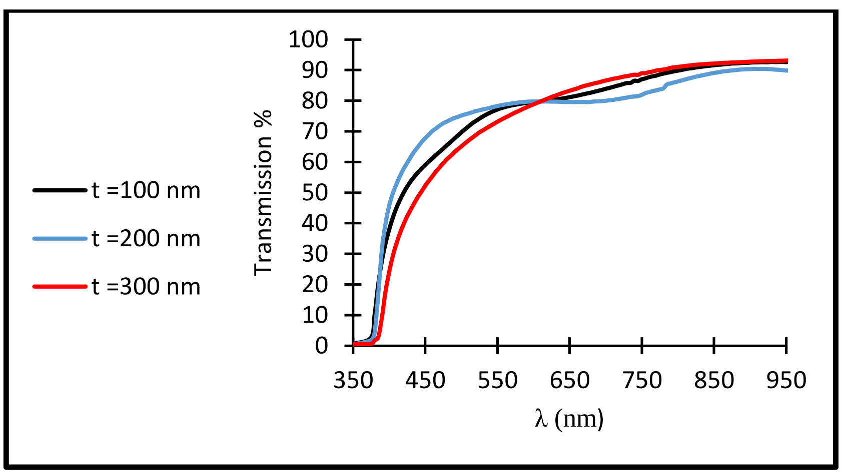


Figure (4): Transmission of ZnO thin films with different thicknesses.

The band gap of ZnO films was calculated by drawing the curve between (hν) and $(\alpha h\nu)^2$ shown in figure (5).

$\alpha h\nu = B(h\nu - Eg)^{1/2}$ ……… (2)

where (ν) is the frequency (α) are the optical absorption coefficient and (h) Planck's constant where [10].

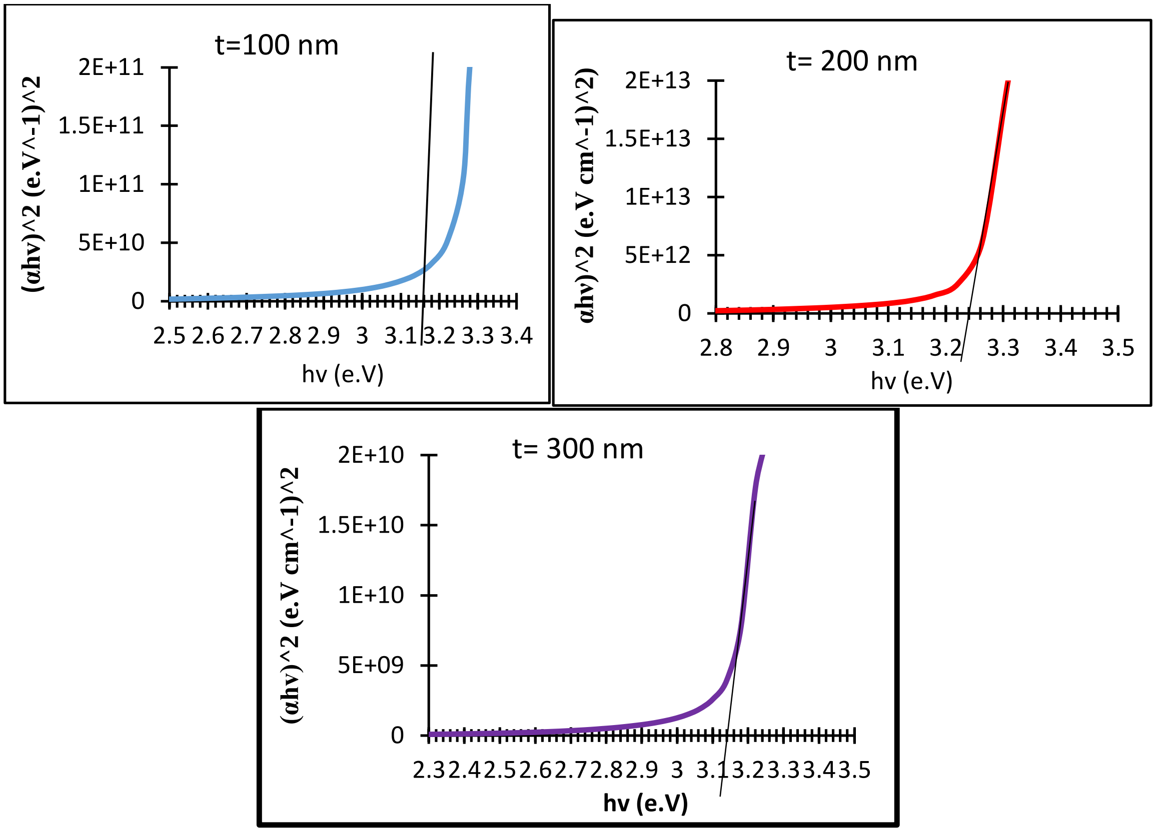


Figure (5): A plot of (αhv)² as function of photon energy for ZnO films with different thicknesses.

the band gap energy obtained the thickness of ZnO films dearease from 100 nm to 300 nm. The value of optical band gap decreases from (3.26, 3.24, and 3.14) eV respectively. This behaviour is back to the increase in average grain size [11].

Conclusions

ZnO thin films have been deposed by thermal evaporation on a glass substrate at different thicknesses. The samples have a good quality onto a glass substrate using Zn metal. The XRD of the thin film has good polycrystalline and hexagonal wurtzite structure. The UV-Vis measurement, optical transmittance spectra, showed high transmission about 90% within visible and infrared range.The value of energy gap decreases from 3.26 to 3.14 e.V with increase thickness. Atomic Force Microscope AFM (topographic image) shows the grain size increased in the range (91.29 -110.11)nm with respect to increase thickness.

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