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Study of Oxide Semiconductor ZnO with Deposition Temperatures Effect of on the Structural, Optical and Electrical Properties

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Abstract:

The Zinc oxide (ZnO) thin films were deposited on a glass substrate by spray pneumatic technique; the elaborated substrates were heated by using a new of the solar cells method. The structural, optical and electrical properties of ZnO thin films were studied at various deposition temperatures (350, 400 and 450 °C). Polycrystalline ZnO films with a hexagonal wurtzite structure with a strong (101) preferred orientation were observed at all sprayed thin films with maximum crystallite size of 15.19 nm was attained of sprayed film at 450 °C. The ZnO thin films have good transparent is about 85% at 450 °C, the band gap energy varies from 3.28 to 3.31 eV was affected by deposition temperature, it is shown that the ZnO thin film sprayed at 450 °C has less disorder with few defects. The ZnO thin film deposited at a temperature of 450 °C have the lowest electrical resistivity was 0.064 $(\Omega.cm)^{-1}$.

Keywords

ZnO; Thin films; deposition temperature; Spray pneumatic technique;Organic solar cells

1. Introduction

Zinc oxide (ZnO) is one of the most II–IV semiconductors due to the direct band gap of 3.37 eV at room temperature and large exciton binding energy of 60 meV [1–3]. ZnO has wide applications in the optoelectronic and piezoelectric due to the high transparent with optimum refractive index (n ~ 2.0) and n-type semiconducting with low electrical resistivity (ρ) of $\sim 10^{-4}$ Ω-cm [4,5]. However, the best research, ZnO were fabricated to use in various fields such as solar cells, light emitting diodes (LED), laser diodes and acoustic–optical devices [6–9].

ZnO as thin films can be prepared by various physical and chemical methods such as magnetron sputtering technique, pulsed laser deposition (PLD), chemical vapor deposition, electrochemical deposition, sol-gel process and spray pyrolysis [10–14].

The aim of this work is to deposit ZnO thin films by the organic solar cells for economists the electrical energy. The organic solar cells consisted of a mirror layer inside (ITO glass) and a substrate holder. The ZnO thin films can be deposited by spray pneumatic technique on a glass substrate at various deposition temperatures are 350, 400 and 450 °C. The ZnO thin films were characterized by various methods likely X-ray diffraction, ultraviolet-visible spectrophotometer, and four point methods.

2. Experimental

In the experiment, the Zinc acetate dihydrate 0.1M (Zn(CH3COO)2, 2H2O) was used to prepare the ZnO solution in volume 100 ml of water. The solution was placed to the heater at 60 °C, in this setup can be added drops of HCl to the solution as a stabilizer with heating. After this setup, the solutions become transparent and clear. ZnO thin films were sprayed on the heated glass substrates at various temperatures of 350, 400 and 450°C by organic solar cells for 4 minutes of deposition time for the procedure see Figure 1.

The ZnO thin films have been characterized to find the crystalline structure, optical transmission and electrical conductivity by X-ray diffraction (XRD Bruker AXS-8D with λ = 0.15406 nm), spectrophotometer (UV, Lambda 35 with 300–900

nm wavelength), and four point methods, respectively.

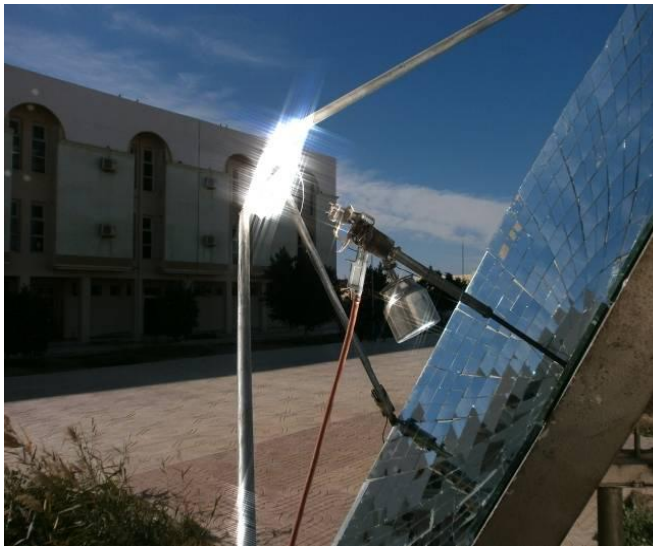


Figure 1: The procedure of elaborated of ZnO thin films at different deposition temperature.

3. Results and discussion

3.1. The crystalline structure of ZnO thin films

The spectra's of X-ray diffraction of the deposited ZnO thin films with various temperatures are shown in Figure 2. Vertical lines show the peak positions and relative peak intensities of a ZnO powder reference (ICSD-26170) [15]. As first result, the structure property enhanced with the increase in deposition temperature up to 450°C. It was has a good crystallinity as well as for the peaks presences, which are (100), (002), (101), (102), (110), (103), (200) and (112) planes. It shows that the sprayed ZnO at 450°C was polycrystalline hexagonal wurtzite structure. The diffraction peak at 2θ = 36° related to (101) plan is the highest one with comparing of others of (100) and (002), indicate that the preferred orientation with the (101) plan. However, the crystalline quality of ZnO thin films was affected by deposition temperature to enhance at 450°C. However, the crystallite size of ZnO thin films the (101) plan was estimated using the Debye-Scherrer formula [16]:

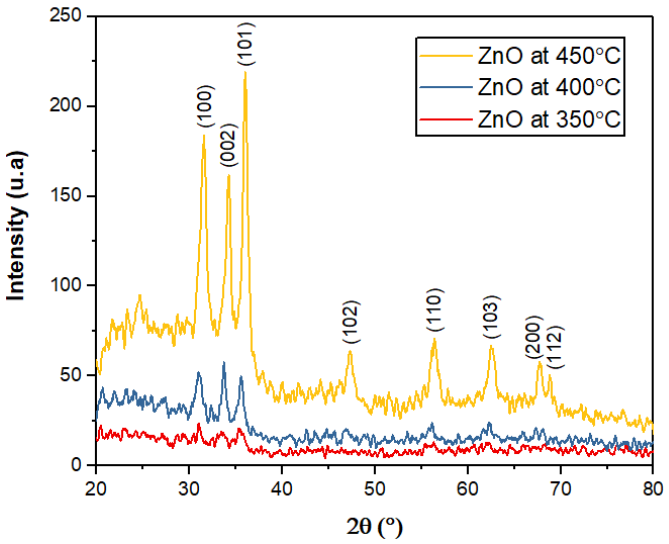


Figure 2: X-ray diffraction spectra of ZnO thin films at different deposition temperature.

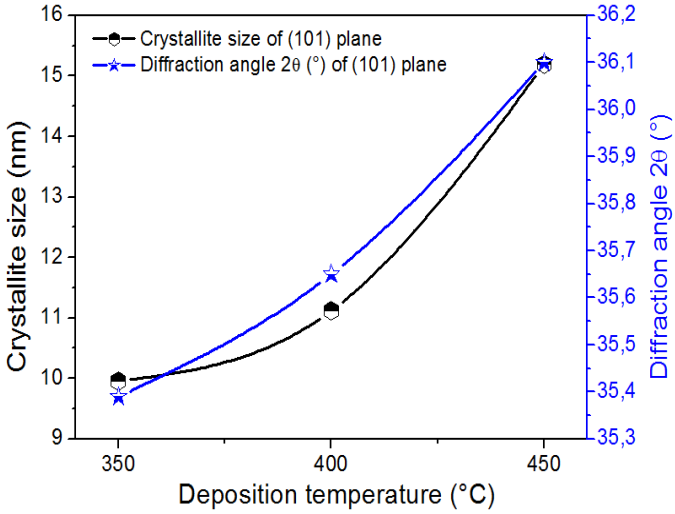


Figure 3: The variation of crystallite size and lattice parameter c as a function of deposition temperature in ZnO thin films.

$$G = \frac{0.9\lambda}{\beta \cos\theta} \qquad (1)$$

where G is the crystallite size, λ is the wavelength of X-ray (λ = 1.5406 A°), β is the full width at half-maximum (FWHM), and θ is the half diffraction angle of the centroid of the peak.

Figure 3 shows the variation of the crystallite size and diffraction angle of (101) diffraction peak as a function of deposition temperature. It can be seen from Figure 3 that the crystallite size increased greatly from 9.96 to 15.19 nm by increasing of deposition temperature from 350 to 450°C. This phenomenon can be explained by the improvement of the crystal structure of ZnO thin films at 450 °C. As can be seen, an increase in the deposition temperature shown that the diffraction angle also was increased due to the existence of sufficiently

thicker films in less strained (or more relaxed) state, or by decrease of the defects in the films.

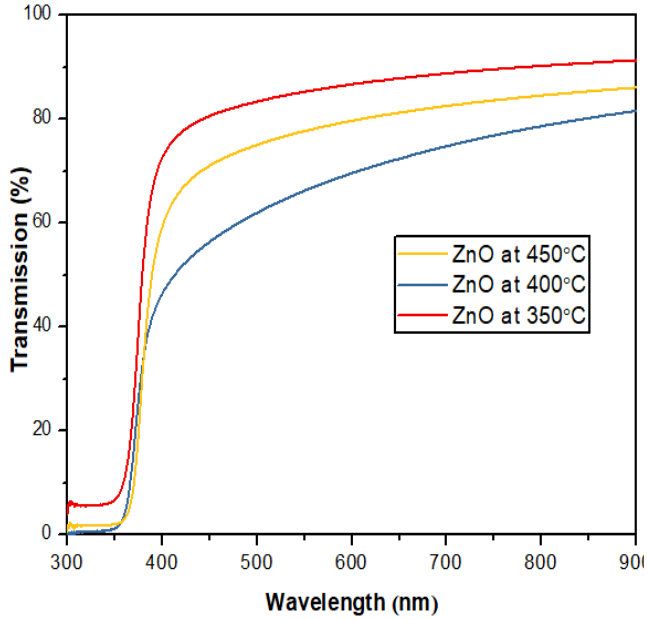


Figure 4: Transmission spectra T(λ) of ZnO thin films as a function of deposition temperature.

3.2. The optical properties of ZnO thin films

The optical transmission of ZnO thin films deposited at various temperatures is shown in Figure 4. From Figures 3 the optical transmission was enhanced at 450 °C, this film exhibits an average transmission of about 85% in the visible region. The transmission was decreased greatly in the wavelength varied between 300-400 nm due to the absorption edge. We have found at 300 nm the transmission is higher of others caused by the increase crystallite size (see Figure 3). It can be noted that the transmission of ZnO thin films is affected by crysatalinity. The information on optical properties was investigated by measuring the optical band gap energy and Urbach energy. The optical band gap was calculated from the relations [17]:

$$A = \alpha\, d = -\ln T \qquad (2)$$

$$(\alpha h\upsilon)^2 = C(h\upsilon - E_g) \qquad (3)$$

where α is the absorption coefficient, A is the absorbance, d is the film thickness; T is the transmission spectra of thin films; C is a constant, $h\nu$ is the photon energy $\left(h\nu = \frac{1240}{\lambda(nm)}(eV)\right)$ and E_g the band gap energy of ZnO thin films. Figure 5 shows the variation of $(\alpha h\nu)^2$ as a function of photon energy ($h\nu$), which was used for determine the optical band gap E_g. The determination is preceded by the extrapolation of the straight-line portion to zero absorption ($\alpha = 0$) [17]. However, Urbach tail energy (E_u) also was estimated by following equation [18]:

$$\alpha = \alpha_0 \exp\left(\frac{h\upsilon}{E_u}\right) \qquad (4)$$

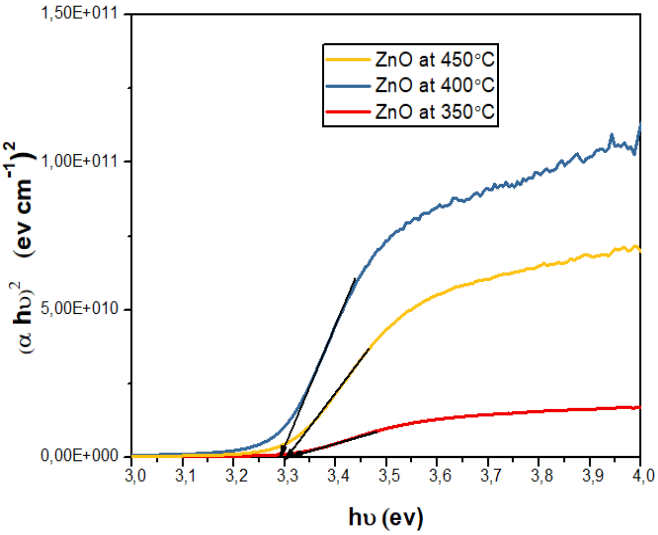


Figure 5: The typical variation of $(\alpha h\nu)^2$ vs. photon energy all deposited ZnO thin film as a function of deposition temperature.

where α_0 is a constant $h\nu$ is the photon energy and E_u is the Urbach energy. In the draw the curve of variation of $(Ln\alpha$ as a function of photon energy ($h\nu$) can be determine the Urbach energy. Figure 6 shows the variation of the optical gap energy and the Urbach energy of ZnO thin films at various deposition temperatures. The change is inverses to other due to the conduction band and valence band, with the increase of deposition temperature the optical band gap energy decrease at 400 °C then increase at 450 °C. The increase was affected by the increase of crystallite size (see Figure 3). however, the minimum value of Urbach energy was observed at 450 °C it is 0.328 eV, it is shown that the ZnO thin film prepared at 450 °C has less disorder with few defects, which may be attributed to the decrease of crystallite boundary for an increase of deposition temperature; similar observation was found for optical transmission.

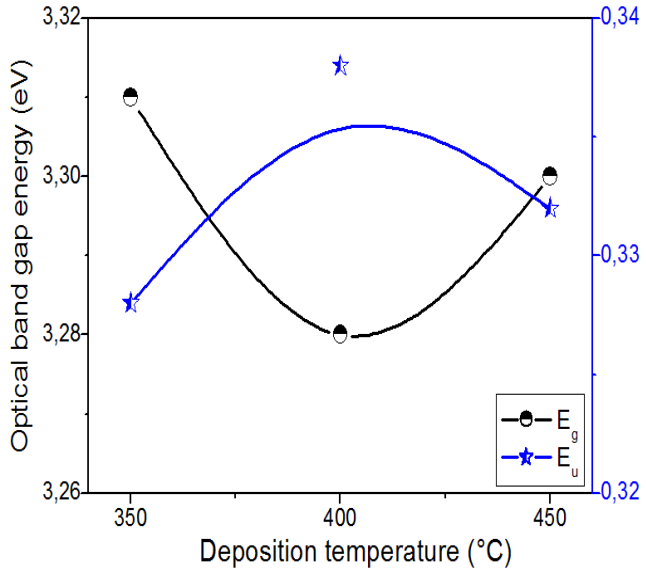


Figure 6: The variation of optical band gap E_g and Urbach energy E_u of ZnO thin films with deposition temperature.

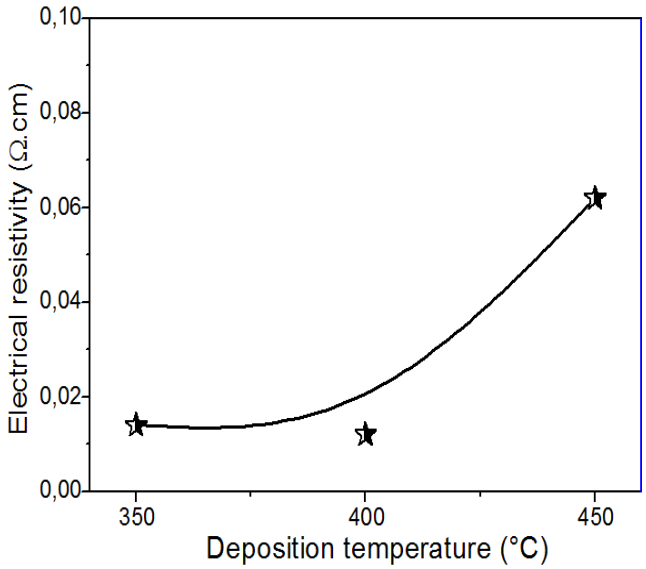


Figure 7: Electrical resistivity of ZnO thin films at different deposition temperature.

3.3. The electrical resistivity of ZnO thin films

Figure 7 shows the variation of the electrical resistivity ρ of ZnO thin films as a function of deposition temperature. As result, the electrical resistivity decreased from 0.014 to 0.012 $(\Omega.cm)^{-1}$ for the increase of deposition temperature from 350 to 400 °C, and then increased up to 0.064 $(\Omega.cm)^{-1}$ for 450 °C. The increase in the resistivity of can be explained by the increase of crystallite size (see Figure 3).

4. Conclusions

In summary, the ZnO thin films were deposited on glass substrate by spray pneumatic technique on a glass substrate. The effect deposition temperature (350, 400 and 450 °C) on structural, optical and electrical properties was investigated. Polycrystalline ZnO films with a hexagonal wurtzite structure with a strong (101) preferred orientation were observed at all sprayed films with maximum crystallite size of 15.19 nm was attained of sprayed film at 450 °C. The ZnO thin films have good transparent is about 85% at 450 °C, the band gap energy varies from 3.28 to 3.31 eV was affected by deposition temperature, it is shown that the ZnO thin film prepared at 450 °C has less disorder with few defects. The ZnO film deposited at 450 °C have a lowest electrical resistivity was 0.064 $(\Omega.cm)^{-1}$.

Ethical considerations

The submitted manuscript contains original and new results which are not submitted for publishing to other publications or published elsewhere.

All research was conducted to the highest possible ethical standards.

All authors are involved in the work. Authors and co-authors reviewed and ensured the accuracy and validity of all the results prior to submission.

All authors guarantee that the research findings have not been previously published.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Declaration of conflicting interests

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Data availability statement

Data supporting this study are included within the article and supporting materials.

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