Characterization of ZnO Thin Film/p-Si Fabricated by Vacuum Evaporation Method for Solar Cell Applications

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Abstract

Zinc oxide (ZnO)thin film (300nm) was successfully manufactured using thermal evaporation method. XRD, UV spectroscopy, AFM were used to study film characterization which was deposited on a glass substrate. Transmittance and reflection data of the film versus wavelength were investigated using UV-VIS Spectrophotometer. Over 50% transmittance values have been observed in the NIR region. Optical constants were calculated and the estimated energy gap (3.4 eV)of the prepared film. XRD results showed that films made from ZnO were crystalline with hexagonal wurtzitestructure. The measurements of (I-V) properties of the dark current and light I-V show that this variation has a high-voltage open circuit (Voc), which makes it suitable for application in highly efficient ZnO / p-Si solar cell.

Key Words: ZnO Thin Film, Photovoltaic Materials, Thermal evaporation, XRD, Optical Properties.

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Introduction

In recent decades, ZnO semiconductors became very important, especially in optoelectronic devices, like, photovoltaic devices, sensors, solar cells and biomedical fields [1-7]. ZnO features a direct gap in the range at 3.37eV at room temperature, large exciton binding capacity, high transparency, high conductivity and non-toxic materials [8-10].

Many methods were applied for the deposition of zinc oxidelike: Sol –Gel [11], PLD,CVD, sputtering [12-14], thermal evaporation [15,16]. Thermal evaporation is easy to control sedimentation parameters and shorter growth time.ZnO widescreen movies are very important for hardware applications [17]. The film thickness has a strong impact on the optical absorption of nanostructured thin films, generates defects in the crystalline network and increases recombination [18]. The goal is to prepare thin films from ZnO nanoparticles on the silicon glass type to study their physical properties and solar cell parameters.

Experimental Work

The Edward 306 thermal evaporation system was used to prepare thin films from ZnO on silicon and glass substrates. Wafer silicon was cleaned using HF(10%),eventually, ethanol and water dry up in hot dry. The vacuum compression system is used for 2×10^{-5}Torr.

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A film thickness 300 nm was measured using gravitational method. The film annelid at 350 °C. The transmittance and absorbance spectra were recorded using Shimadzu UV -Probe Japan in a wavelength range ranging from 250 nm to 900 nm. High-resolution X-Ray was used to measure the structural specifications of thin films. The AFM was used to introduce surface topography, SEM (Jeol JSM 6335F).

Results and Discussion

ZnO nanocrystalline thin film was subjected to XRD analysis. The patterns of ZnO were recorded in the 2θ range from 20°-80° and was compared with standard pattern from (JCPDS) file no 5-0664. Fig. 1 depicts the diffraction patterns of ZnO thin film. Two strong peaks at 30.02° and 34.82° corresponding to (100), (002) planes with hexagonal (wurtzite- structure).. The crystallite size (D)was evaluated utilizing Schererr's formula [19]:

$D = k\lambda/\beta \cos\theta$ (1)

where k is Schererr's constant and equal (0.9), λ is the wavelength of the X-ray (1.54060 Å), and θ is Bragg angle.

From the Schererr's formula, D was calculated to be 14.41 nm.

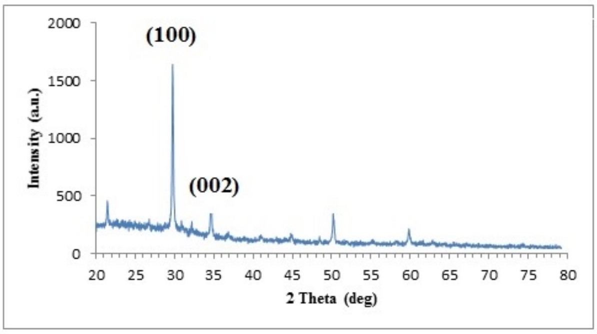

Fig.1. XRD spectra of ZnO thin film

Fig. 2 shows SEM image with amplification 1.00 Kx of ZnO thin film deposited by thermal evaporation method and annealed at350 ˚C. SEM image shows that these particles have different shapes. It has been observed that the molecules are not regular and consist of many small non-regular nanoparticles, and has different grain sizes ranging from 70 nm to 200 nm.

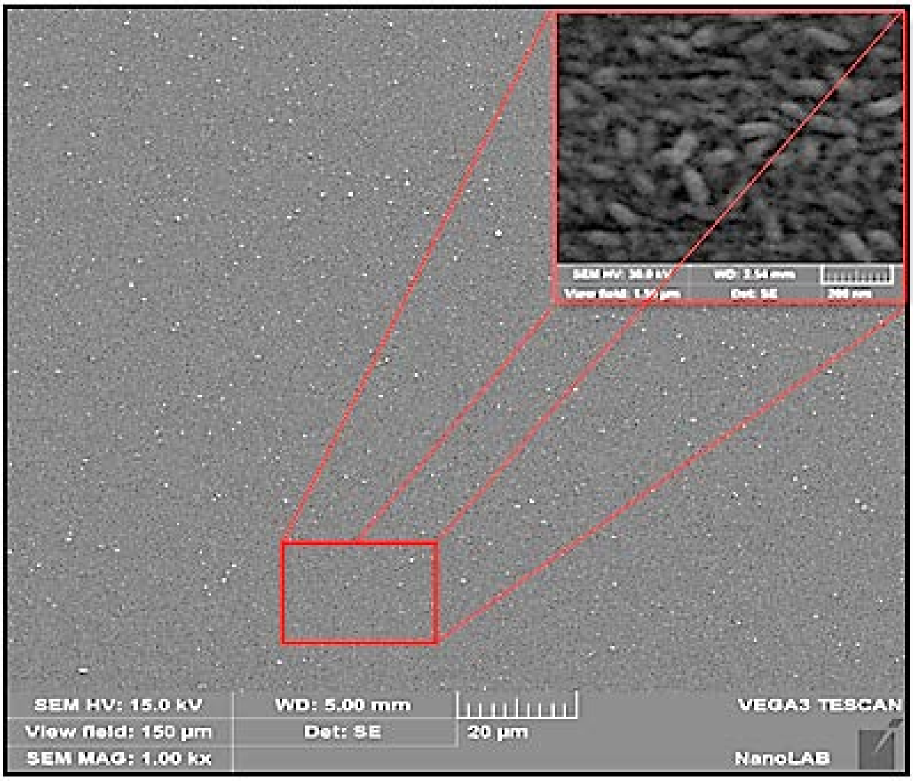

Fig. 2. SEM image of ZnOthin film

Transmittance spectra of ZnOhavea thickness of 300 nm. Increases (T) with low wavelength as shown in fig.3. The sample provides a very sharp absorption edge in the ultraviolet (UV) area about 310 nm because of the basic absorption of the appearance. The increase in optical transmittance due to increased optical scattering happened by grain boundaries.

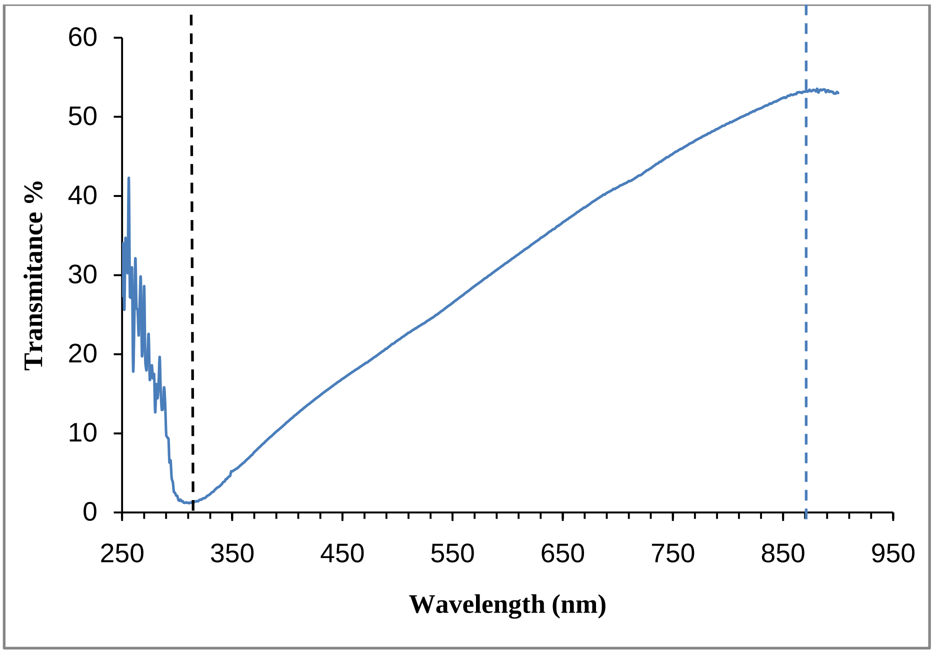

Fig.3. Optical transmittance of ZnO thin film

Fig.5 shows a relation between $(\alpha h\nu)^2$ vs. hν. Assuming direct transmission between the conduction and valence bands, the bandgap is calculated by Tauc equation [20,21]:

$\alpha h\nu = B(h\nu - Eg)^n$ (4)

Where(α) absorption coefficient using the (2.303*A/t) relationship, t is the ZnO thin film thickness and A is the absorption. The calculated α values were used to calculate the energy gap E_g. n= 1/2 corresponds to direct band, also, Fig. 3 shows that $E_g$of ZnO. The measurement was from the square plot $(\alpha h\nu)^2$versus hν by extrapolating the linear part against the photon energy. The E_g of ZnO is found to be 3.4eV as shown in fig.4.

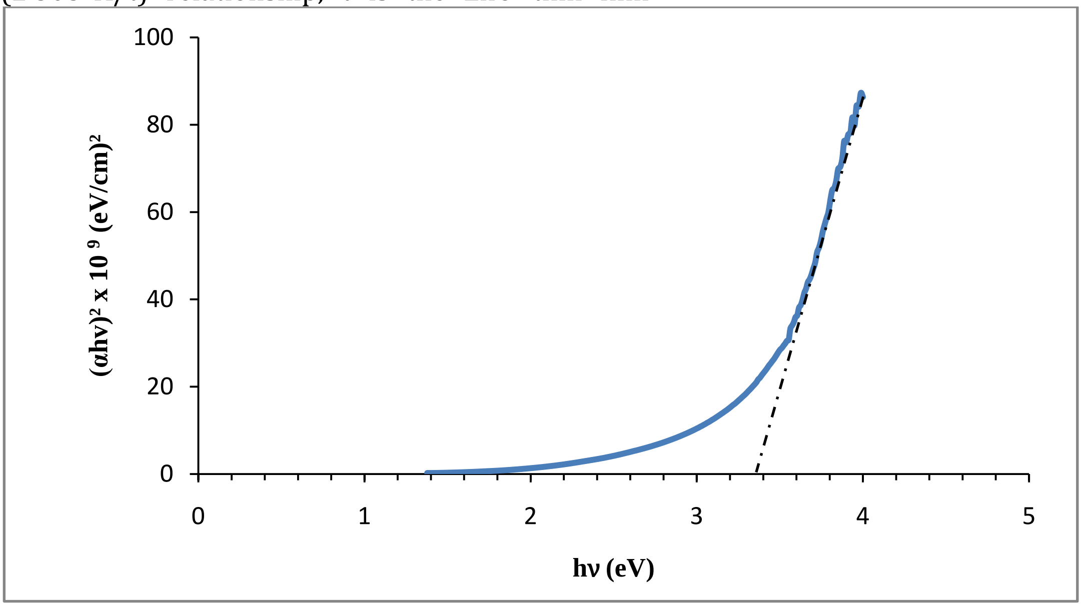

Fig.4. Plot of $(\alpha h\nu)^2$ vs.hν curve of ZnO thin film

Fig. (5) Shows3D AFM image of the ZnO. They are fully wrapped with ZnO nanoparticles. Spread regularly on the surface. Table (1) shows that average grain size, root means square and surface average roughness.

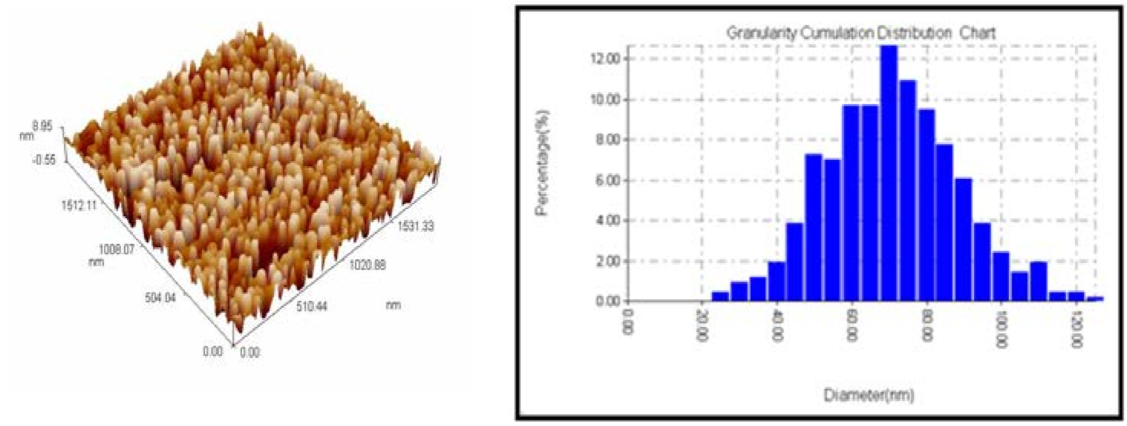

Fig.5. 3DAFM Image and chart distribution of average grain size for ZnO thin film.

Table 1. Topographical parameters of ZnO thin film.

Thin film	Average grain size (nm)	Surface Roughness (nm)	RMS (nm)
ZnO	65.62	1.33	1.57

Figure 6 shows the dark properties of (current-voltage) in the front and back direction of the ZnO / p-Si Photo detector. The front of the detector is small at voltages below 1 volt. This current which occurs only at very low voltages is called recombination. It is created when each electron is stimulated by the valence bar to restore balance. The second high-voltage zone represents the area of propagation or bending, which depends on the chain resistance. The electron bias effort may provide sufficient energy to break the barrier between the sides of intersection in this region. These results are consistent with other workers [22].

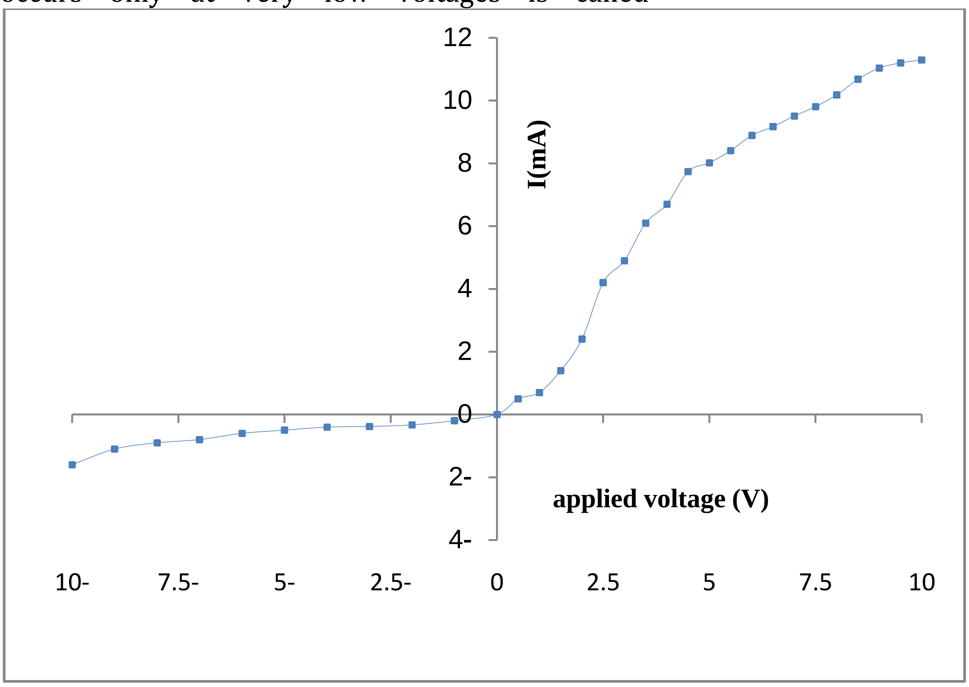

Fig.6. (current-voltage) properties under forward reverse bias of the ZnO/ p-Si

Figure 7displays the characteristics of reverse current in dark and light under a 40 W×10^{-6} / Tungsten lamp bright. It can be observed that current inverse value at a particular voltage of the ZnO / p-Si reflector under bright is higher than the dark, indicating that light-emitting vector contributes to the current photon due to (e-h) production. This manner gives helpful acquaintance about electron-hole pairs, which are created in the intersection by accident photons.

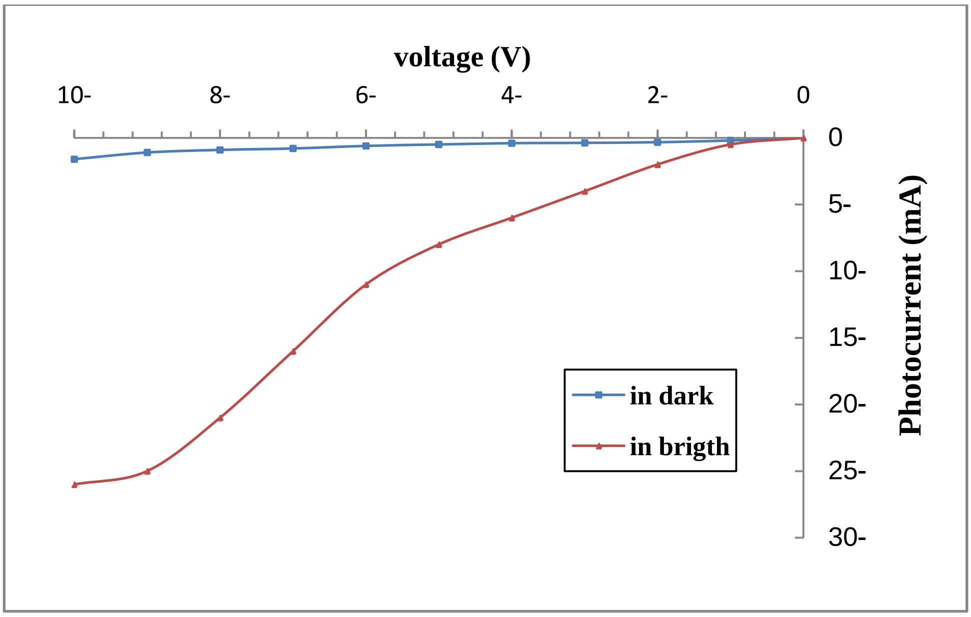

Fig.7. Bright (I-V) characteristic of ZnO/ Si heterojunction for solar cell applications

Figure (8) shows the (current-voltage) characteristics for ZnO/p-Si heterojunction. Short-circuit current(I_{sc}), open –circuit voltage(V_{oc}), fill factor (F.F) and Efficiency (η)have been measured were 50 mA, 0.45 V, 36% and 6% respectively. All the results relieve that the heterojunction ZnO/p-Si could be used for solar cell applications.

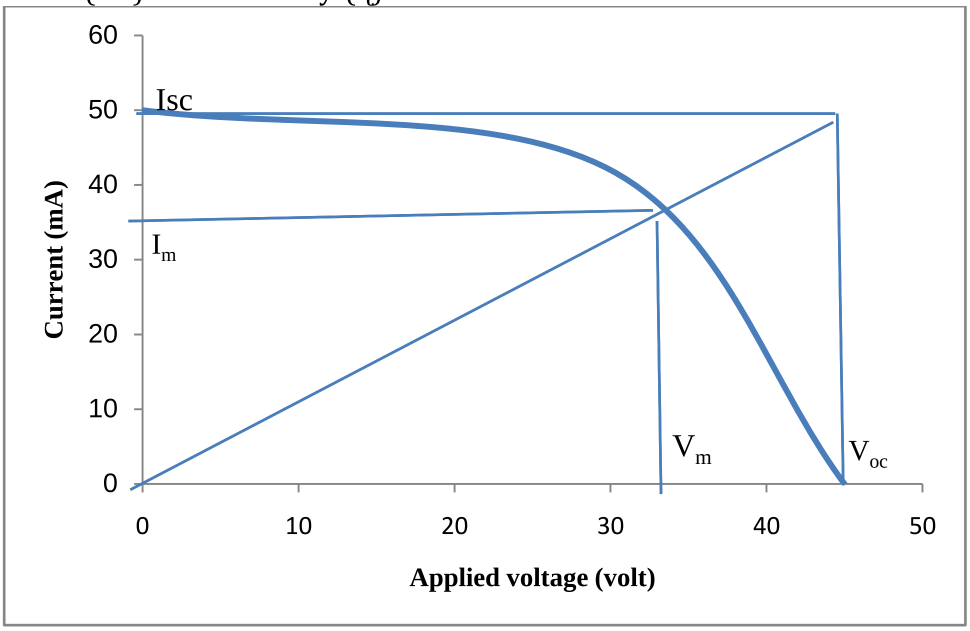

Fig.8. I-V characteristics of solar cell applications at illumination of ZnO/p-Si for solar cell applications

Conclusions

The thin film of ZnO nanostructure with average crystallite size about 14.41 nm, prepared by vacuum thermal evaporation technique. Optical properties revealed that the band gap of ZnO film is direct. X-ray diffraction detection (XRD) reveals that ZnO was polycrystalline with a hexagonal crystalline structure. SEM showed that the ZnO particle was a semispherical deposition of ZnO/Si.

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