Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 4 Issue 5, May - 2017

Fabrication And Characterization Of Al/Zno/Si/Al Photodetector

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***Abstract*—In this research, ZnO nanostructure have been prepared from colloidal ZnO nanoparticles NPs utilizing chemical method. The structural, morphological and optical of ZnO thin film has been studied. XRD anaylsis assure that the ZnO thin film were of wurtzite hexagonal crystal structure. AFM investigations showed that the produced ZnO particles have ball-shape with good disposability. The optical energy band gap of ZnO thin film has been determined from optical properties and found to be in the range (3.2 eV). Al/ZnO/Si/Al photodetector heterojunction have two peaks of response located at 415 nm and 780 nm with max sensitivity of 0.6 A/W.**

Keywords—ZnO nanoparticle , optical properties, structural properties,

1- Introduction : Significant research efforts have been made in recent years for developing highly oriented and transparent ZnO thin films, because of their potential application in transparent electrode in display, window layers of solar cells, field emitters, ultraviolet laser emission, photodetectors, piezoelectricity, bio-sensors, short wavelength light emitting diode and information technology [1-8]. II-VI group semiconductor material ZnO has wide band gap (~3.3 eV at room temperature) and large excitonic binding energy of 60 meV. Due to their unique optical, electrical and semiconducting properties, ZnO thin films are extensively used in various applications. Despite several approaches adopted for making these ZnO thin films; controlling the size, shape, crystallinity and various parameters affecting the size and shape of these materials still need to be investigated. Therefore, it is essential to investigate optimum conditions for fabrication of highly oriented and transparent ZnO thin films. The main concern of researcher is to get better quality of material stoichiometry. ZnO thin films are grown by different techniques such as pulsed laser deposition (PLD), magnetron sputtering, MOCVD, spray pyrolysis etc [9-12].. In the present work, we report the growth of nano-structure ZnO thin films on glass and silicon substrates using zinc acetate precursor in order to study their structural, morphological , optical, and photo-detector properties

2-Experimental work:-

Thin films of Zinc oxide were prepared using the method of chemical method by using zinc chloride ($ZnCl_2$) and (0.1M) was dissolved in (100ml) of distilled water by using mixer glass under normal atmospheric pressure, Then the solution was centrifuged in order to maintain the collidal nanoparticle which was deposited on glass and silicon substrates using drop casting method , then the films subjected to heat at a temperature of (400° C) . Thickness of (300 ± 25) nm which was measured using ellipsometer (Angstrom sun Technologies Ins). Trans-mittance and absorbance spectra were recor-ded using a spectrophotometer type (Shim-adzu UV-1650 PC) in the wavelength range (400- 900) nm . All data were recorded at room temperature. X-ray diffractometer (XRD6000, Shimadzu, X-ray, diffract-ometer) with Cuka radiation at a wavelength of (λ=0.154056 nm) was used to investigate the structural properties of ZnO deposited on glass substrate. The morpholo-gy of the ZnO thin film was investigated by using AFM (AA 3000 Scanning Probe Microscope). The electrical characterization was carried out after making ohmic contacts on ZnO thin film deposited on silicon substrates by depositing a thick Al film through a special mask.

3-Results and discussion

To ascertain the crystalline nature and phase identification of pure and doped ZnO nanocrystalline thin films were subjected for X-ray diffraction analysis.The XRD patterns of ZnO, was compared with standard pattern from Joint Committee Powder Diffraction Standards (JCPDS) file no 36-1457. X-ray diffraction patterns of ZnO films. The XRD patterns of the samples were recorded in the 2θ range from 20^{o}-60^{o}.Figure 1 illustrates the diffraction patterns of undoped ZnO thin films .The XRD pattern shows the 2θ peaks at 32.2^{o} ,34.12^{o}, 35.83^{o}, and $47.24^{o}$are corresponds to the (100), (002), (101), and (102)) crystallographic planes of the ZnO wurtzite structure. The intensity of the XRD peaks related to the crystallization quality, density and thickness of the film. The crystallite size can be determined from line broadening of the peak by Debye-Schererr's. The estimated average grain size of the ZnO is 14.41 nm .

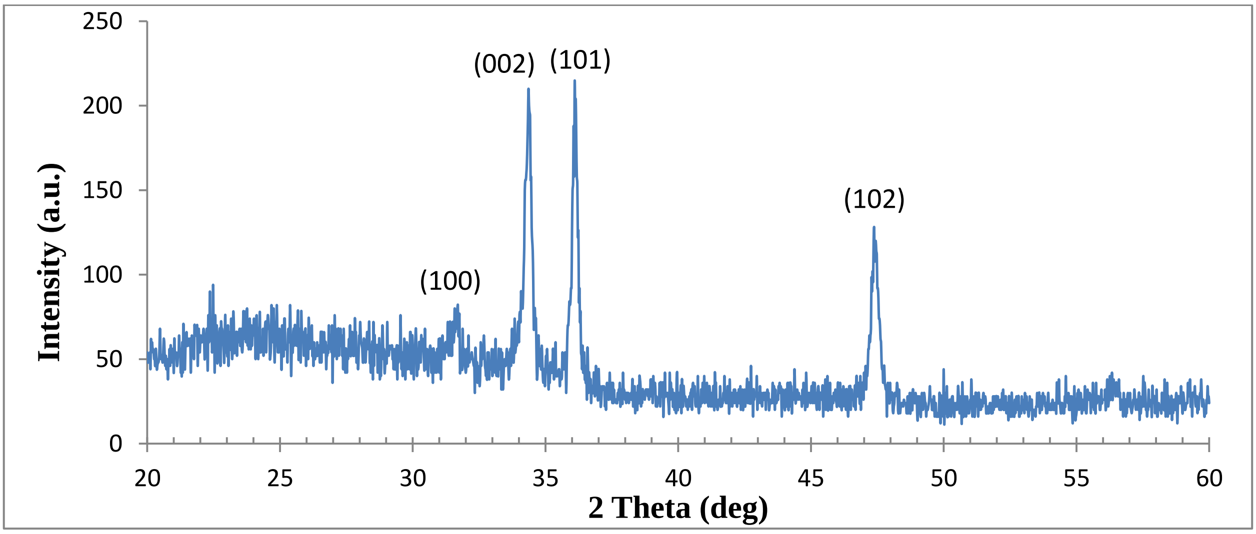

Figure 1: XRD patterns for the undoped ZnO

Surface morphology of ZnO thin films were studied using SEM image. Figure 2 shows SEM micrographs of the ZnO thin films, SEM micrographs show interconnected fibrous ZnO structure, which was uniformly grown throughout the film surface. The film deposited showed semispherical surface morphology.

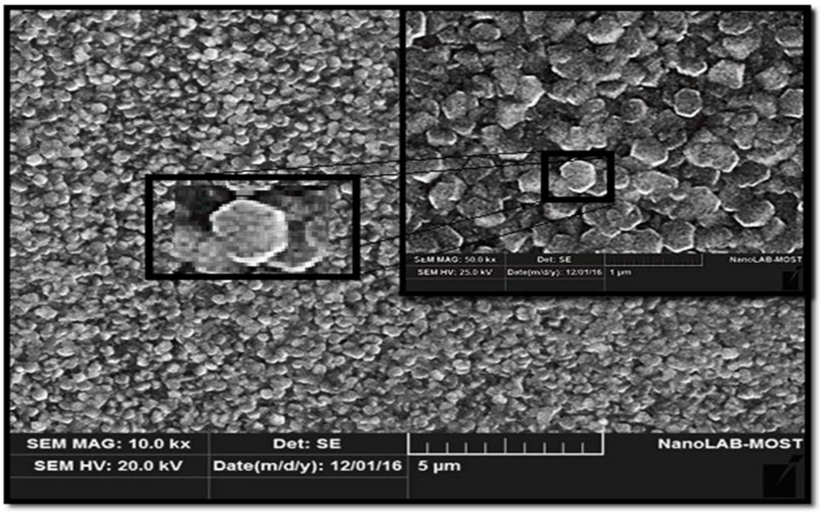

fig 2: sem image of ZnO thin film

Figure 3 depicts that the transmittance in the UV-Vis regions of ZnO films and it is clear that films exhibited a good transmittance (>80%) in the visible region. On the other word, we can say that there was almost low optical absorbance in the visible region. In the ultraviolet region, transmittance of the film decreases with an absorption edge at 380 nm wavelength. Such fundamental absorption edge is due to the inter-band transitions and it indicates a good structural quality of the film. This edge corresponds to electron transitions from valence band to conduction band[13] and can be used to determine the optical band gap of the ZnO film.

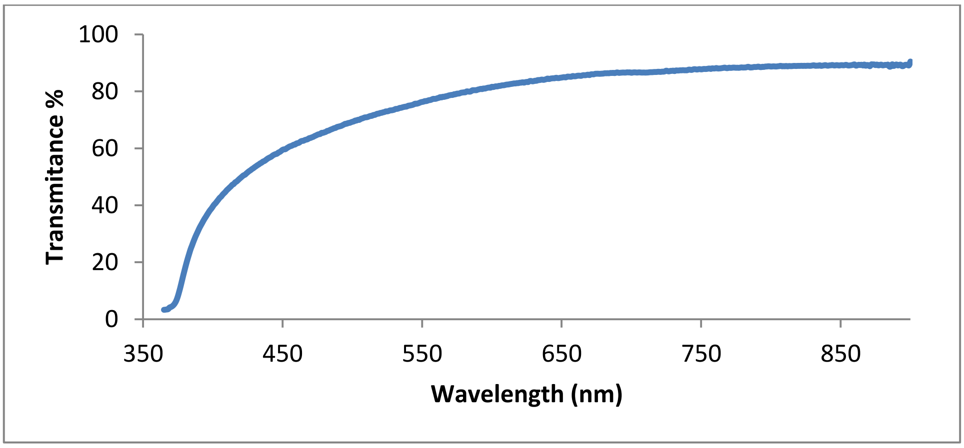

Fig. 3 :UV-Visible transmission spectrum of ZnO thin film.

The optical band gap energy (Eg) of the ZnO can be determined by Tauc's relation of $(\alpha h\nu)^2$ versus photon energy hυ (eV), by using the following equation [14]

$$(\alpha h\nu)^2 = A(h\nu - E_g)^n \;\ldots\ldots \quad (1)$$

where n is 0.5 for direct allowed transition, α is the absorption coefficient, A is the band edge sharpens constant, h is the Plank's constant and hυ is the photon energy.By plotting$(\alpha h\nu)^2$, the optical band gap energy was determined by extrapolating the linear portion of the plot to hυ = 0.

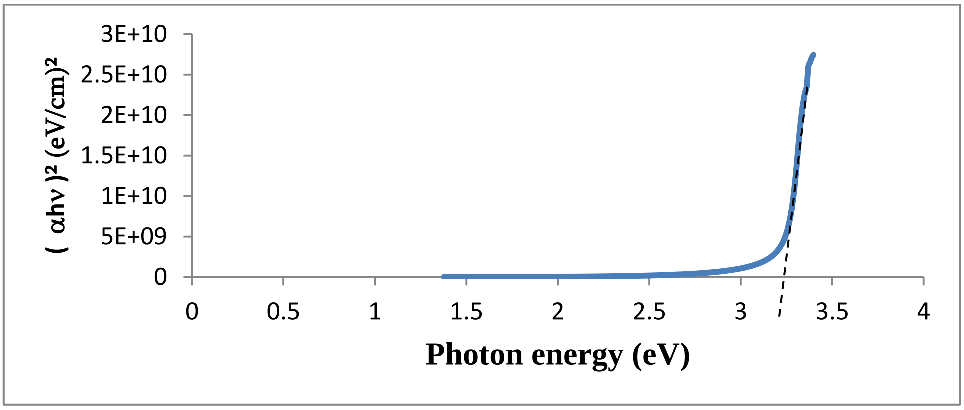

Fig4:$(\alpha h\nu)^2$ versus photon energy gap of CdO thin film continuously

The values of band gap of ZnO thin film was 3.2 eV. AFM image of ZnO thin film was shown in Fig. 5. The film was highly dispersed ball_shaped and the grains are homogenous and aligned vertically. By using special software, the average grain size was estimated by imager software and it is found to be around 98nm

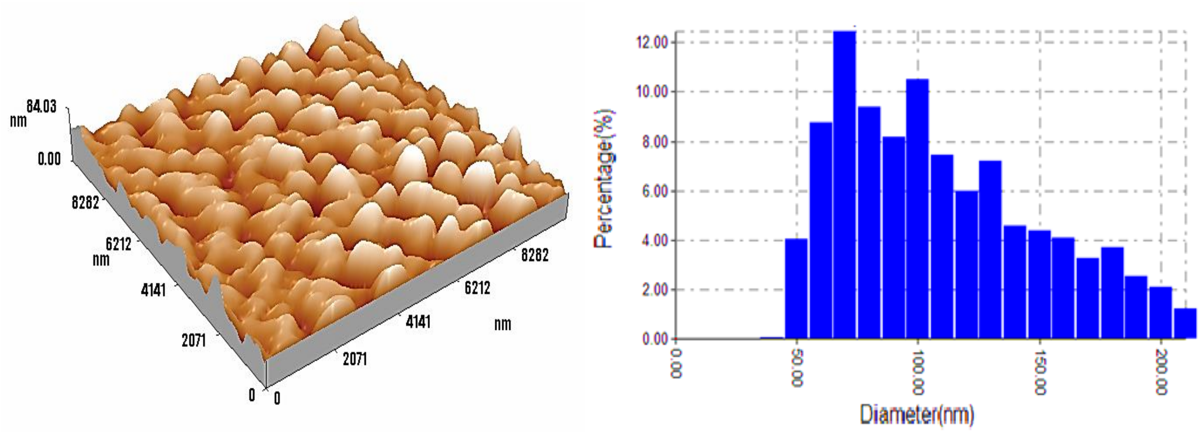

fig 5: AFM image of ZnO thin film

Figure 5 shows the I-V dark characteristics in forward and reverse direction of Al/ZnO/ p-Si/Al heterojunction. The forward current of heterojunction is very small at voltages less than 2 V. This current is known as recombination current which occurs at low voltages only. It is generated when each electron excited form valence band to conduction band. The second region at high voltage represented the diffusion or bending region ,which depending on serried resistance .In this region; the bias voltage can deliver electrons with enough energy to penetrate the barrier between the two sides of the junction.

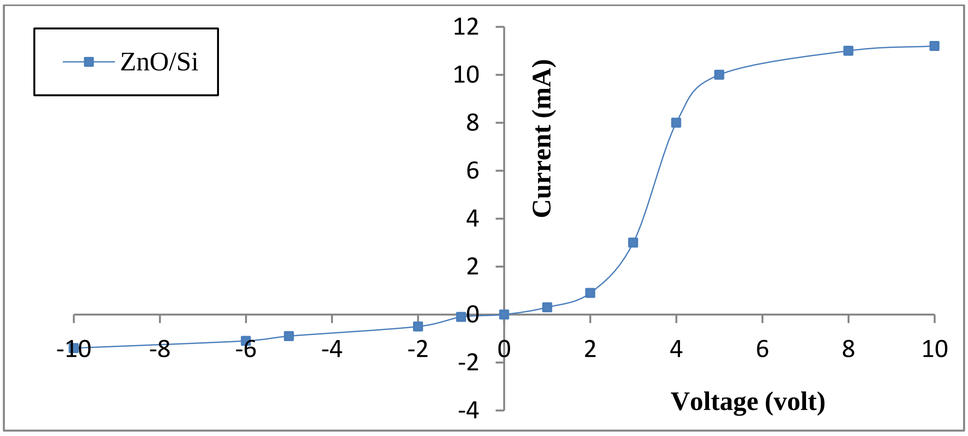

Fig. 6 I-V characteristic under forward reverse bias of the ZnO/p-Si hetetrojunction

Figure 7 shows that the reversed current-voltage characteristics of the device measured in dark and the photocurrent under a 40 W/ tungsten lamp illumination.It can be seen that the reverse current value at a given voltage for ZnO/p-Si hetetrojunction under illumination is higher than that in the dark and it can be seen from this figure that the current value at a given voltage for ZnO/p-Si under illumination is higher than that in ZnO/Si in dark, this indicate that the light generated carrier – contributing photocurrent due to the production of electron –hole as a result of the light absorption. This behavior yields useful information on the electron-hole pairs, which are effectively generated in the junction by incident photons.

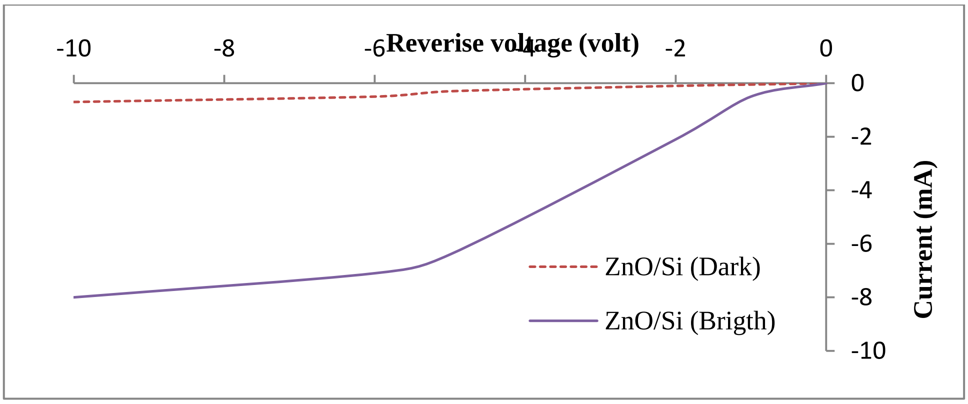

Fig. 7. Illuminated (I-V) characteristic of for ZnO/p-Si photodetectors.

Figure 8 displays the responsivity as a function of wavelength for ZnO/p-Si hetetrojunction It is clear from the figure that the maximum responsivity is located at visible region and the other NIR region, the spectral responsivity curve of ZnO/p-Si hetetrojunction consists of two peaks of response; the first peak is located at 415 nm due to the absorption edge of ZnO thin film, while the second region is located at 780 nm due to the absorption edge of silicon.

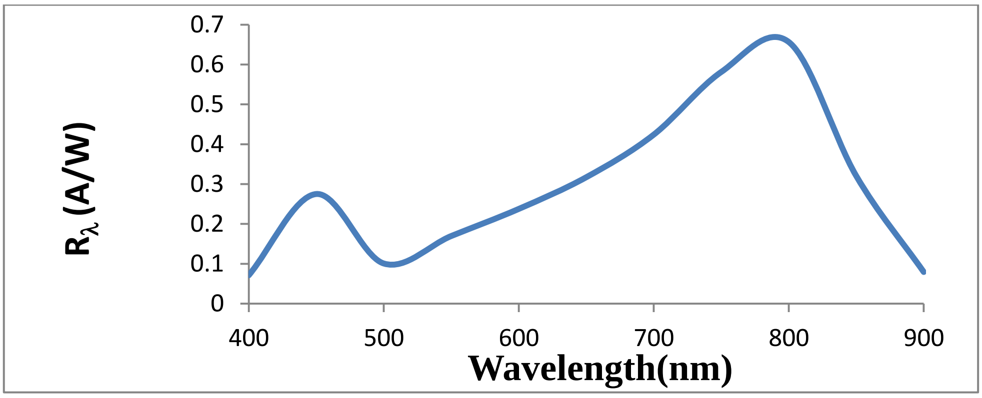

Fig. 8:Spectral Responsivity plots for ZnO/p-Si hetetrojunction as a function of wavelength.

4. CONCLUSIONS

The synthesised ZnO thin film was in nanosized 98 nmwhich prepared by chemical method. The optical properties revealed that the direct band gap ZnO thin film was 3.2 eV . X-ray diffraction (XRD) measurement disclosed that the ZnO particle was polycrystalline with hexagonal crystal structure and no other phases were noticed, (SEM) demonstrated that the ZnO particle was semisperical Deposition of ZnO/ Si) gave suspensions photodetector characteristics enhanced the properties of photodetectors. The spectral responsivity (R_λ) of Al/ZnO/Si/Al photodetector was around 0.5 A/W at λ= 780 nm wavelength due to the absorption edge of silicon and around 0.6 A/W at λ = 415 nm wavelength due to the absorption edge of ZnO NPS .

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