Fabrication of a Photodetector Using Zinc Oxide Nanoparticles (Zno Nps) Prepared by Plant Synthesis

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Abstract
The performance of the (ZnO/PSi) photo detector was improved by preparing zinc oxide nanoparticles (ZnO NPs) as colloidal nanoparticles utilising plant synthesis. These ZnO NPs were then coated using the drop casting method on p-type porous silicon (PSi) substrates as well as glass substrates to make thin films. The structural and morphological properties for zinc oxide nanostructure (ZnO NPs) deposited on glass substrate have been studied by using X-ray diffraction (XRD) and Atomic Force Microscope (AFM) and ultraviolet-visible radiation(UV-VIS) were carried out to find out the properties of nanoparticles and then zinc oxide nanoparticles were deposited on porous silicon wafers of the P-type using drop casting technique to create a Photodetector and then study its properties. The photovoltaic properties of the ZnO NPs/ Psi/ Si/Ag Photodetector have been published, as have the quantum efficiencies of the device.
Keywords: ZnO NPS, XRD, AFM, UV-visible spectroscopy, Photodetector, quantum efficiency

1. Introduction

The detector takes in electromagnetic radiation and then releases an electrical signal that is typically proportionate to the amount of electromagnetic radiation that was taken in. The type of detector and the mechanism by which it operated determined whether the signal released was a voltage or a current, and the output signal might be either. [1]. Photonic and thermal detectors are the two primary types of detectors, each of which is distinguished by the type of detection mechanism they employ. Initially, there are Thermal Detectors. These reagents are dependent on the thermal effect because the absorption of a thermal ray causes an increase in the temperature of the absorbent material, which in turn causes a change in the reagent's physicochemical properties [2]. The thermal detectors have a distinguishing feature that allows them to respond uniformly to all wavelengths. Thermal detectors have the advantage of being able to respond to long wavelengths even when the temperature is at room temperature [3]. Optical detectors come in second place. When light hits this detector, the photons excite the electrons to higher energy levels, which results in the formation of electrical charge carriers (e or h) that remain within the detector material [4]. This detector converts photons directly into free current carriers. In order to excite valence electrons, the photon that causes the incident must have an energy that is equivalent to or greater than the band gap energy.

2. Experimental

Nanoparticles of zinc oxide (ZnO NPs) were prepared by the method of plant synthesis. The Nano zinc oxide was prepared by the method of plant synthesis using zinc nitrate and henna plant extract. First, one gramme of henna plant was mixed with one hundred millilitres of distilled water in a glass beaker. Then, the solutions were placed on a magnetic stirrer and kept under continuous stirring at seventy degrees Celsius for thirty minutes. After that, the heterojunction (p-ZnO/Si) Photodetector is produced by depositing the nano-solution, which contains the ZnO NPs, onto cationic porous silicon wafers using a droplet casting technique.

3. Results and Discussion

The following figure (1) represents the X-ray diffraction spectrum of ZnO prepared by plant synthesis using zinc nitrate and henna plant extract and deposited on the glass by droplet casting in air.) For a range of angles (20-80 degrees) in which it is noted that there are two sharp peaks at the angles (29.76, 31.89) and they represent Miller coefficients(100), (002) which apply to international specifications (96-230-0451) in addition to that were calculated each crystalline size and interfacial distances, as shown in Table (1)[5].

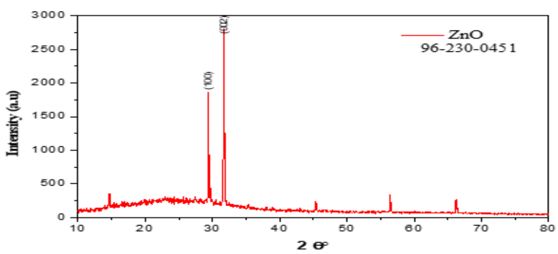

Figure (1) shows the X-ray diffraction (XRD) of zinc oxide Nano films (ZnO) prepared by plant synthesis

Table (1) Structural properties of ZnO NPs prepared by the plant synthesis method					
2θ (Deg.)	FWHM (Deg.)	dhkl Std.(Å)	dhkl Exp.(Å)	Crystallite size (nm)	Average Crystallite size (nm)
29.76	0.38	2.92	3.00	21.63	21.25
31.89	0.34	2.67	2.80	20.86	

The following figure (2) represents an atomic force microscope image in two dimensions (1μm,1μm) of zinc oxide nanomaterial prepared by a plant synthesis method using both zinc nitrate and henna extract and deposited on the glass by drop casting at a temperature of (70C) where we notice ripples distributed in a homogeneous and regular manner on The surface of the glass which indicates the absence of voids and that the deposited thin film is regular and the meanders of the material particles that describe horizontally towards the peaks upwards where the highest peak represents a rise in the roughness rate and reaches (24.57nm), and the distances separating those peaks which represent the free path rate (2.14nm), which indicates that the method of preparing the film by drop casting method is suitable for this purpose and that increasing the roughness leads to an increase in the surface distances which leads to an increase in the Surface distances per unit volume which increases the absorption of the film which describes the work of the Photodetector.

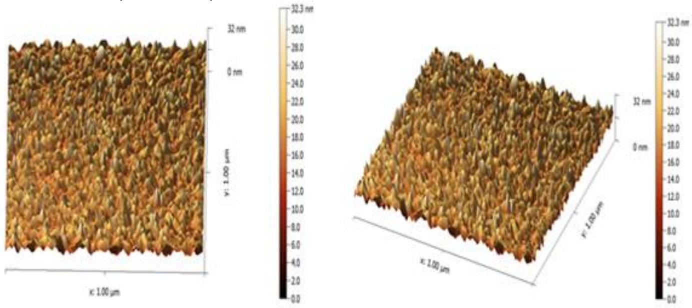

Figure (2) 2D and 3D AFM images of ZnO prepared by plant s ynthesis

Table (2) shows the surface roughness average values, root mean square roughness values, and particle size average values according to (AFM) measurements of ZnO prepared by plant synthesis			
Sample	Average Grain size (nm)	Roughness average (nm)	Root mean square (nm)
ZnO	14.37	24.57	2.14

The small dimensions on the electronic structure are more pronounced in nanoclusters and have the most important effect on the energies of the highest occupied molecular orbital which is mainly the valence band and the lowest unoccupied molecular orbital which is the conduction band. The emission of materials and their visual absorption takes into account the transformations between these cases, semiconductor and minerals appear in particular significant changes in the optical characteristics such as color as a sign of particles, the form (3) clarifies the good absorption of the rays on the superiority of (Zno Nps). For the wavelength (300-250nm) and an increase in the absorption band towards the red wavelength is observed after using the plant extract, and this phenomenon is called the redshift. This phenomenon can be seen clearly in Figure (3), which shows the improvement in the sensitivity of the resulting material from adding the plant extract to zinc oxide by improving the extent of absorption in the sample mentioned above. The optical band gap can be determined using the Tauc formula [6], $(\alpha h\nu)^2 = B(h\nu - E_g)$ Where; α is the absorption coefficient, h = 6.626×10^{-34} m^2 kg/s is Planck's constant, ν is the frequency of photon, B is the constant and Eg is the band gap energy. When $(\alpha h\nu)^2 = 0$ then $E_g = h\nu$ Hence, extrapolating the linear portion of the graph $(\alpha h\nu)^2$ Vs hν having intercepted on energy axis gives the optical band gap of the sample. The Tauc plot of as - synthesized ZnO sample is given in the fig.(3). From the Tauc plot, the optical band gap of the as-prepared ZnO sample was found to be (5.30 eV). Since bulk ZnO has a band gap of (3.37 eV) [7], there is band widening in our prepared ZnO sample. This band widening may be attributed to the quantum quenching effect[8]. This confirms the formation of ZnO nanoparticles in our prepared sample.

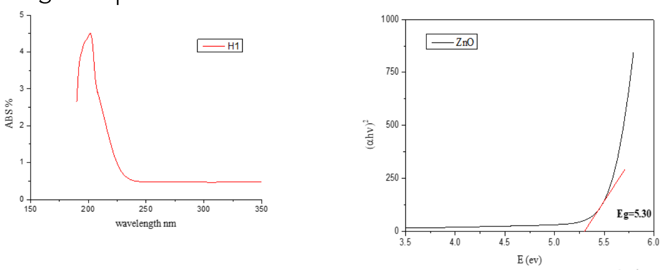

Figure (3) shows the energy gap and absorption coefficient of (ZnO NPs) prepared by plant synthesis.

Spectral response (Rλ) is one of the important parameters in photodetectors. It is possible to specify the spectral range in which the detector operates. Figure (4) shows the spectral response diagram of the photodetector (Ag/ZnO/PSi/Si/Ag) prepared by the plant synthesis method. The spectral response of the structures was examined in the wavelength range (350-900nm) with a potential difference (5V) and is calculated by Equation (1-1). The maximum spectral response was observed (Rλ= 0.5654A/W) at a wavelength of (800nm).

$$R_\lambda = \frac{I_{ph}}{P_o} \text{ or } \frac{V_{ph}}{P_o} \dots\dots\dots \dots\dots (1-1)$$

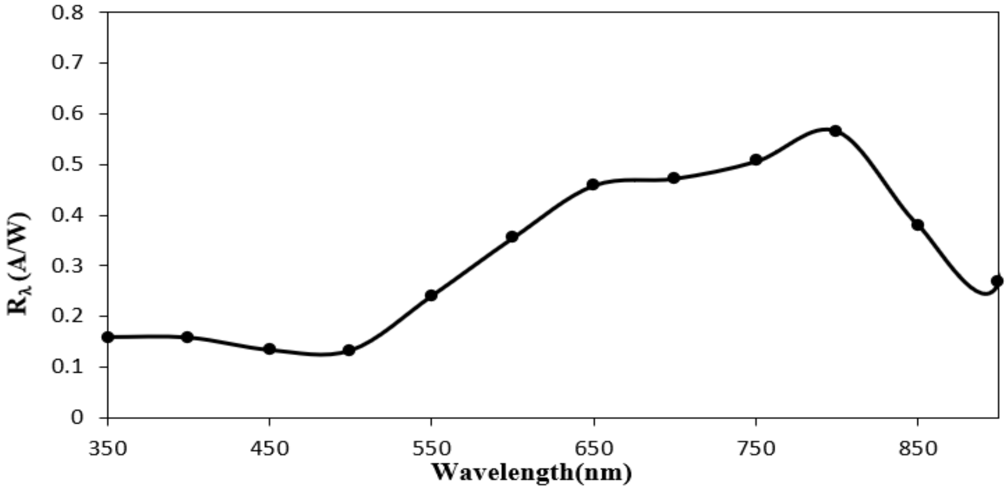

Figure (4) shows the spectral response of the photodetector

4. Specific Detectivity(D*)

Specific detection is an important feature of photodetectors as it represents the minimum detectable power. As a result the detector performance is related to this parameter. Figure (5) shows the specific detection as wavelength of the photodetector (Ag/ZnO/PSi/Si/Ag). Prepared by the method of plant synthesis. Figure (5) shows that the detection depends directly on the spectral response (Rλ) through equation (1-2). The maximum specific detection limit was found to be (D*= 8.0850*10^{12}cmHz1/2) W^{-1} at a wavelength of (800nm).

$$D^* = \frac{R_{(\lambda)}(A \cdot \Delta f)^{1/2}}{I_n} \dots\dots\dots\dots (1-2)$$

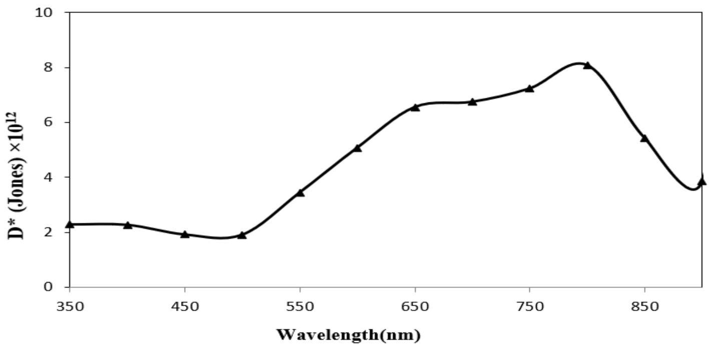

Figure (5) shows the Specific Detectivity of the photodetector

Figure (6) indicates that the quantum efficiency (η) as a function of wavelength (λ) of the hybrid scattering detector (Ag/ZnO/PSi/Si/Ag) prepared by plant synthesis method.) with a potential difference (5V) and is calculated by equation (1-3), then Figure (3-16) shows that the highest peak of quantum efficiency is (η=87.6488%) at a wavelength (800nm).

$$\eta(\lambda)\frac{R(\lambda)hc}{q\lambda} \dots\dots\dots\dots\dots\dots\dots (1-3)$$

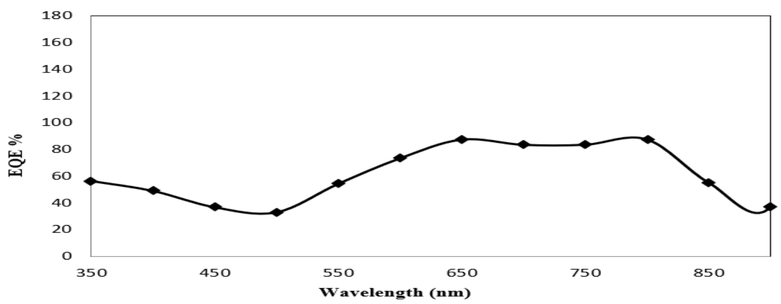

Figure (6) shows the Quantitative efficiency of the photodetector

5. Conclusions

The process of preparing (ZnO NPs) using the vegetable synthesis method is a good process by determining the most important structural and optical properties of the thin film prepared by the vegetable synthesis method by means of X-ray diffraction tests, atomic force microscopy and UV-visible spectroscopy. Then this film is deposited using the drop casting technique. Where a photodetector with distinctive optical properties was obtained.

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