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Research Article

Synthesis and Characterization of SnO_2 Nanoparticles UV-Photoconductive Detector

Abdulla. M. Suhail[Á], Asama. N. Naje[B*], Ghaida. S. Muhammed[B] and Azhar.S.Norry[B]

[Á]Dept of Optical techniques, Dijlah University College, Baghdad, Iraq
[B]Dept.of Physics , College of Science, University of Baghdad, Baghdad, Iraq

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Abstract

SnO_2 UV photoconductive detector was fabricated. The Tin Oxide nanopowder have been prepared by sol gel chemical method and deposited on porous silicon by dipping coating technique. The structural, morphological, optical properties and electrical properties of the prepared SnO_2nanopowder are studied. The X-ray analysis shows that the obtained powder is SnO_2 with tetragonal crystalline structure and the crystalline size is in the range 8-10nm.The Hall measurements show that the nanopowder are n-type with carrier concentration of about -1.273×10^{17} cm^{-3}. The surface functionalization of the SnO_2 deposited on porous silicon (PS) layer by polyamide nylon polymer has improved the photoresponsivity of the detector to 0.1A/W. The response time of fabricated detector was measured by illuminating the sample UV radiation and its values was 50µs. The specific detectivity of the fabricated detector is found to be 1.8×10^{10} cm $Hz^{1/2}$ W^{-1}.

Keywords: *SnO_2 nanoparticles, UV photodetector,I-V characteristic, response time .*

1. Introduction

[1]Nanomaterials have attracted great interest due to their intriguing properties, which are different from those of their corresponding bulk state (E. Ganesh *et al*,2012). Tin oxide (SnO_2) belongs to the important family of oxide materials that combines low electrical resistance with high optical transparency in the visible light (NocunMarek*et al*, 2008). SnO_2 is a n-type semiconductor with a wide band gap of 3.6-3.8 eV at room temperture , and one of most widely used semiconductor oxides due to its chemical and mechanical stabilities (Raman Mishra *et al*, 2010).

Many processes have been developed to the synthesis of SnO_2 nanostructures, e.g., spray pyrolysis, hydrothermal methods, chemical vapor deposition, thermal evaporation of oxide powders and sol–gel method (Paraguy .D *et al*, 2005, Rohana Adnan *et al*.2010 , ,Zhiwen Chen *et al* ,2003, M.M.Bagheri-Mohagheghi*et al* ,2008,Du. F *et al* ,2005, Liu, Y *et al*,2005) .

Research on tin dioxide (SnO_2) attracts a lot of interest because it has been widely used in many applications, such as transparent electrodes(Anima Johari*et al*, 2012), far-infrared detectors, high-efficiency solar cells, and gas sensors(Zhiwen Chen *et al* ,2003, K. Anandan*et al*,2010)
In this research SnO_2nano particle powder was deposited on porous silicon by dip coating technique to form UV photoconductive detector in order to improve the response time of the detector.

2. Experimental Work

Tin oxide nanopowders were prepared by means of dissolving of 2g (0.1 M) stannous chloride dehydrate (SnCl2.2H2O) in 100 ml distilled water.After complete dissolution, ammonia solution was added to the above solution by drop wise under stirring. The resulting gels were filtered and dried at 80ºC for 24 hours in order to remove water molecules. Finally, tin oxide nanopowders were formed at 550ºC for 2h.

N-type Si wafer of 0.05 Ω.cm resistivity was used as a starting material in the photochemical etching. The samples of 2 x 2 cm dimensions were cut from the wafer and rinsed with acetone and methanol to remove dirt. In order to remove the native oxide layer on the samples, they were etched in diluted (10 %) HF acid. After cleaning the samples they were immersed in HF acid of 50 % and ethanol (1:10) in a Teflon beaker.

Tungsten halogen lamp of 250 watts integrated with concave ellipsoidal mirror was used as the photon beam source. The photoetching irradiation time was10 minutes.

At the end of the photochemical etching process, the samples were rinsed with ethanol and stored in a glass containers filled with methanol to avoid the formation of oxide layer above the nanospikes film.

The morphology of the nanospikes surface produced by photochemical etching on Si wafer is studied using Scanning Probe Microscope. The nanospikes silicon layers were used as a substrate for the SnO_2 photoconductive detector elements.

In order to improve the response time of the SnO_2/PS photoconductive UV detector, kind of polymers that have

*Corresponding author: **Asama. N. Naje**

high UV absorption abilities are used in the experiment. The effect of the polymer type polyamide nylon on the enhancement of the UV response of the SnO_2 on porous silicon UV detector is tested.

The obtained samples were characterized by X-ray powder diffraction (XRD) using (XRD-6000),supplied by Shimadzu.The surface morphology of the samples was observed by Scanning probe Microscope (SPM) by using CSPMAA3000,supply by Angstrom Company.Optical absorption spectra of the samples were taken with OPTIMA SP-3000 UV-VIS Spectrometer.The room temperature photoluminescence(PL) spectra of SnO_2 were recorded with SL 174 Spectrfluormeter.

The variation of photoresponsivity of SnO_2 Photoconductive UV detector with the bias voltage was carried out under the illumination with UV diod. The measuring circuit is shown in Figure (1). The response time of the prepared detector was tested through illuminating the fabricated detector with.The SnO_2photocondutive detector output signal was displayed by digital oscilloscope of 200 MHz model TDS 202413 from Tektronix.

3. Results and Discussion

3.1 X-ray Characterization

The X-ray diffraction (XRD) patetern of SnO_2 nanoparticles powder is illustrated in Figure (2). In this diffraction pattern, the peaks at 2θ of 26.6°, 33.8°, 37.9°, 51.8°, and 54.7° can be associated with (110), (101), (200), (211) and (220) respectively. The SnO_2 product shows tetragonal structure, which are in a good agreement with other literutures. The average particles size was found to be in the range of (8-10) nm (L. C. Nehru *et al* ,2012).

3.2 Morphology of SnO_2 Nanoparticles

The SPM image of the surface morphology of the SnO_2 film gives a good indicator for formation of the SnO_2 nanoparticles. The average particle size determined from SPM, is about 73.65 nm, as shown in Figure (3).

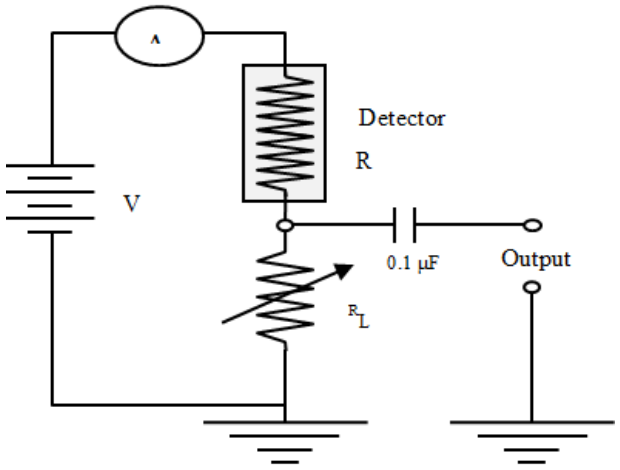

Fig.1 The operation circuit diagram of SnO_2 photoconductive detector

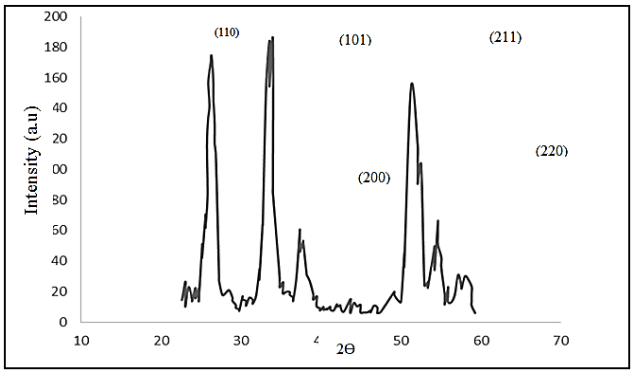

Fig.2 The XRD pattern of the SnO_2 nanoparticles

The results are obtained from the SPM of the SnO_2 nanoparticles show that the histogram of the percentage of SnO_2 as a function of the grain size as in the Figure (4).

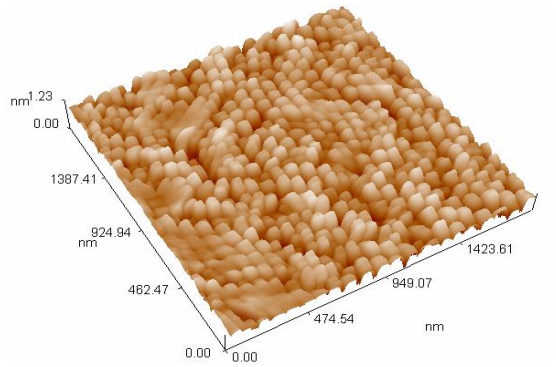

Fig.3 The SPM of SnO_2 nanoparticles

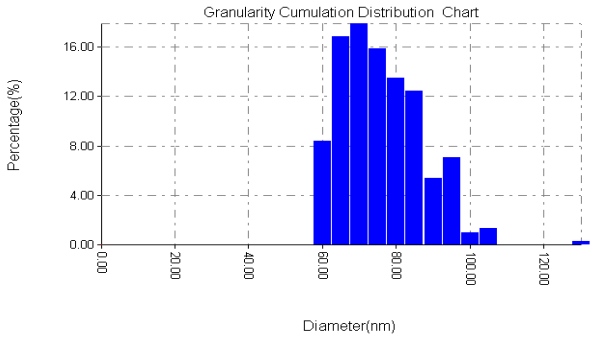

Fig. 4 Granularity Cumulation distribution Chart

3.3. Optical properties

The absorption spectrum of SnO_2 deposited on glass substrate is shown in Figure (5). The figure shows high absorption coefficient in the UV region, whereas it is transparent in the visible region.

The optical band gap energy (E_g) of thesemiconductor is calculated from Tauc relation (Pankov JI, 1971). A plot of $(\alpha h\nu)^2$ versus hυ shows intermediate linear region, the extrapolation of the linear part can be used to calculate the E_g from intersect with hν axis as shown in Figure(6). The resultant values of E_g for SnO_2 is found to be about 3.78eV and 4.3 eV(SmritimalaSarmah*et al*, 2010) , The above

two values may be related to the formation of nanostructures of SnO_2 and the bulk SnO_2, these values show a good agreement with the values presented by other workers(S. GNANAM *et al*,2010, M. M. Bagheri-Mohagheghia*et al* ,2008

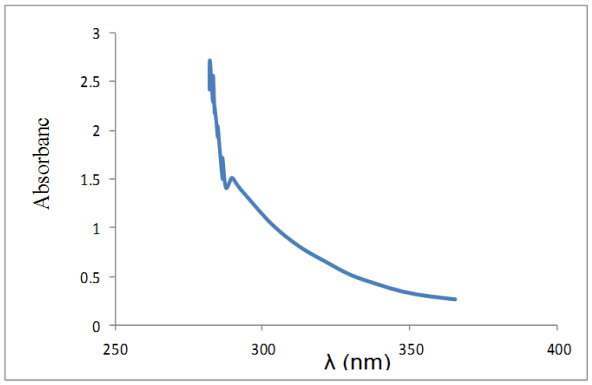

Fig. 5 The absorption spectrum of SnO_2 nanoparticles

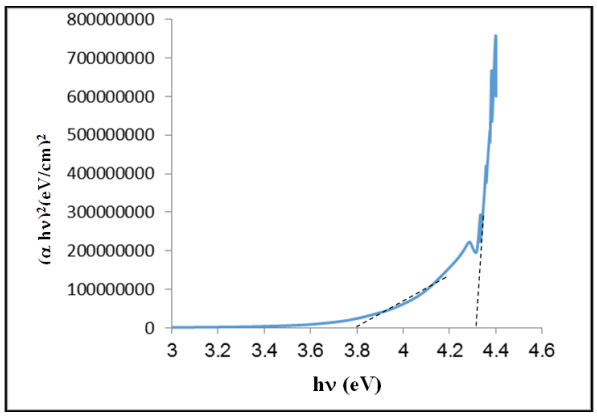

Fig. 6 Plot of $(\alpha h\upsilon)^2$ vs. photon energy ($h\upsilon$) for SnO_2

Figure (7) shows the photoluminescence emission spectra of SnO_2 nanoparticles at 280nm excitation, SnO_2 nanoparticles exhibit emission at 437nm. The emission maximum of 437 nm is lower than the band gap of the SnO_2 bulk; this peak can be attributed to the contribution of oxygen vacancies and defect in the SnO_2 nanoparticles (FengGu*et al*, 2003, S. GNANAM *et al*,2010).

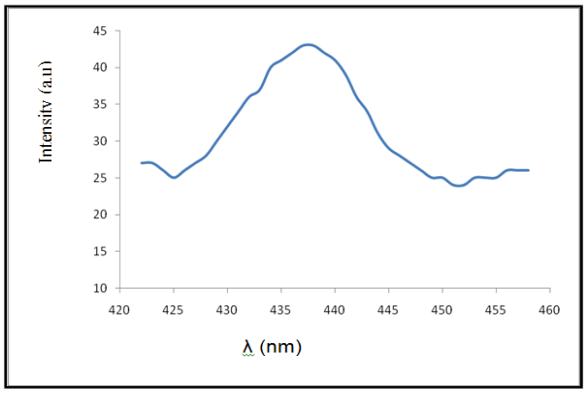

Fig.7 The Photoluminescence emission spectra of SnO_2.

3.4 Hall measurements

The Hall measurements show that the SnO_2 nanoparticles deposited on silicon substrate by dip coating technique is n- type semiconductor. The Hall parameters for n- type nanoparticles which are included (resistivity, conductivity, and Hall coefficient)) were illustrated in Table (1).

Table 1 Hall Effect parameters for SnO_2deposited on porous silicon

Resistivity (ρ) (Ω.cm)	3.033E+0
Conductivity (1/ Ω. cm)	3.297E-1
Average Hall (m^2/c)	-4.903E+1
Bulk Concentration (1/cm^3)	-1.273E+17
Mobility(cm^2/Vs)	1.616E+1

3.5 Electrical properties

I-V characteristics of the fabricated device are illustrated in Figure (8). The dark (I_d) and photo (I_p) currents are increased with increasing in the bias voltage. All samples used in the experiments of the photoresponsivity measurements of the prepared detectors are carried out under identical experimental conditions.

From Figure (8), it can be observed that the photocurrent is very low in dark (there is no light), and the photocurrent is highly increased under the illumination by UV source with wavelength 385nm and 2.5 mW incident power.

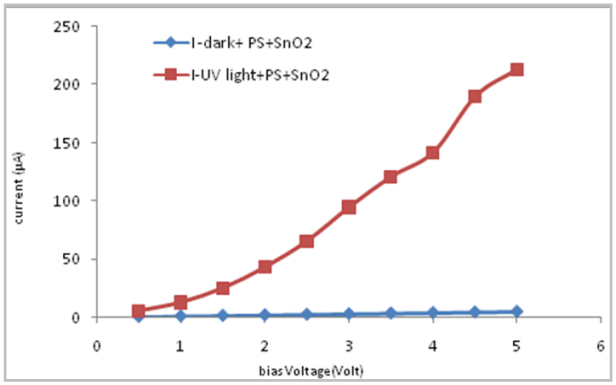

Fig.8 The variation of the photocurrent of the fabricated SnO_2 UV detector on porous silicon layer as a function of the bias voltage

The increase of the photocurrent of the polymer coated SnO_2/PS photoconductive UV detector samples are higher than that of the uncoated detectors samples as shown in Figure (9). This figure shows the variation of the photocurrent of the fabricated SnO_2 UV detector on PS layers as a function of the bias voltage. The photocurrent in dark is found to be about 95μA at 5Vbias whereas the photocurrent is 251μA under the illumination source by UV. This result reflects a good UV radiation sensitivity with photoconductive gain (G) of more than 2.64.

The carrier life time (τ) was calculated after calculate T_r (transit time), using the values of G=2.64, μ=1.616*10 cm^2/V.s as found from Hallmeasurements, L=0.04 cm and

V=5Vthe carriers life time(response time) (τ) was found to be about 50μs.

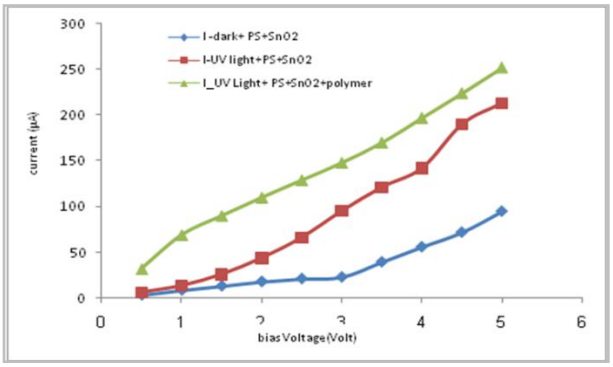

Fig.9 The variation of the photocurrent of the fabricated SnO_2 UV detector on porous silicon layer as a function of the bias voltage with coated polymer

The specific detectivity (D^*) is the reciprocal of the Noise Equivalent Power (NEP) normalized to the deteceor area of 1 cm^2 and a noise electrical band width Δf of 1 Hz. This detector parameter is calculated for the fabricated photodetector elements, and using the values of I_d=95μm at the bias voltage of V, Δf= 1Hz, photoresponsivity R_λ=0.1 A/W at λ= 385nm,A=1cm^2 and $I_n=5.56*10^{-12}$A, the specificdetectivity of the fabricated SnO_2 UV detector deposited on porous silicon layer is found to be 1.8×10^{10} $cm.Hz^{1/2}.W^{-1}$.

The photocurrent gain is calculated for the polymer coated and uncoated SnO_2 UV photoconductive sample. The average value of the gain registered for the polymer coated UV SnO_2 photoconductive detectorsunder the same measurement conditions is found to be about 2.64, whereas the gain without polymer ≈2.2.

The above value reflects the effect of the nylon polymer coating on the improvement of the gain of the fabricated detector.

The response time of the fabricated SnO_2 UV detector on PS layer is tested by UV source. The trace of the output pulse on the digital oscilloscope of 200 MHz band width is illustrated in Figure (10). It can be noticed from the output detector signal traced by the oscilloscope that the rise time (10%-90%) is inthe order of 1.5ms and the fall time (1-1/e) is 1.5ms.

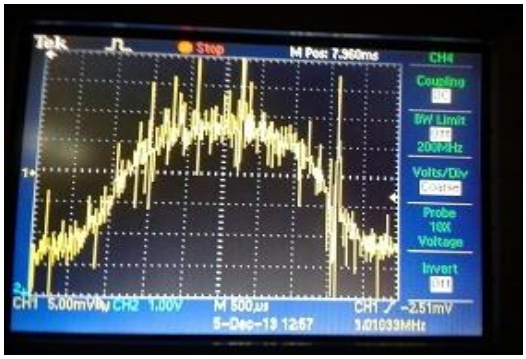

Fig.10: The photoresponse time of fabricated SnO_2 UV detector.The time base on x-axis is 500 μs/div

Conclusions

The SnO_2 UV photoconductive detector samples prepared by Sol gel method are fabricated, which indicate that Sol gel method can be considered as a good method to prepare SnO_2Nnopowder for the UV detectors.

The PL spectrum of SnO_2 shows that exitation at 280nm, SnO_2 nanoparticles exhibit emission at 437nm. Emmision maximum of 437nm is lower than the band gap of the SnO_2 bulk; this peak can be attributed to the contribution of Oxygen vacancies and defect in the SnO_2 nanoparticles. The functionalization of the SnO_2 samples surface by polymers shows giant enhancement in the responsivity. The maximum responsivity was observed by the samples coated with the Polyamide nylon and it is about 0.1 A/W and response time was about 50μs.

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