Fabrication of TiO_2 Doped ZnO UV Detector by Pulse Laser Deposition

Samar Y.AlDabagh, Kadhim.A.Aadim, Thura tariq abbas

Abstract— **In this work TiO_2 doped with ZnO(5% , 7%) thin films were grown by pulse laser deposition technique on P-type (Si)substrate at RT under vacuum 10^{-2} mbar. The properties of the photovoltaic detector with the increase of ZnO concentration is studied. All the films display photovoltaic in the near visible region.**

It was observed that the responsivity increased to 3.39 at RT and to 3.82 after annealing at 500 ℃ with the increase of ZnO concentrations from (5% to 7%).The Specific efficiency increases with the increase of ZnO concentration at RT 10.9and after annealing to 12.3

Index Terms— **TiO_2, Nd:YAG, TiO_2:ZnO, UV detector**

I. INTRODUCTION

Ultraviolet (UV) photodetector has been a popular research issue for its potential applications in a wide range of field, such as remote control, chemical analysis, water purification, flame detection, early missile plume detection and secure space-to-space communications[1]. Titanium dioxide is a wide band semiconductor which exists in three crystallographic phases: rutile, anatase and brookite. Rutile and code anatase have a tetragonal symmetry and due to their strong photocatalytic properties and stability have become materials of high scientific interest[2]. Both oxides TiO_2 and ZnO have similar band-gap energies. Titania (TiO_2) and (ZnO) are the two semiconductors attracting the most attention for applications in photocatalysis, gas sensors and solar cells[3-5]. The wavelength selectivity and distinctive photoelectric properties make TiO_2 are very suitable for UV detection/photo-voltaic conversion[6,7]. Many deposition methods can be used to prepare TiO_2:ZnO thin films: arc ion plating, sputtering, pulsed laser deposition (PLD) and sol-gel method[8]. In the present work, preparation of nanostructures TiO_2:ZnO thin films using pulsed laser deposition on porous silicon (Psi) substrates and fabrication photovoltaic detectors.

II. EXPERIMENTAL WORK

Titanium oxide powder doped with different concentrations of ZnO with high purity (99.7%) pressed under 5 Ton for five minute to form a target with 2.5 cm diameter and 0.4 cm thickness. The deposition was carried out using by PLD technique using Nd:YAG (Huafei Tongda Technology DIAMOND-288 pattern EPLS) with λ = 1064 nm, the energy of laser beam at 700 mJ, 10 ns pulse width,vacuum up to 10^{-2} mbar and repetition rate 6 Hz for 600 laser pulses are incident on the target surface making an angle of 45° with it. The electrochemical method was used to etch silicon by put p-type Si wafer with (111) orientation in hydrofluoric acid diluted with distilled water by (1:1) for 10 minutes and the current flow was 20mA.The substrate is placed in front of the target with its surface parallel to that of the target. Sufficient gap is kept between the target and the substrate so that the substrate holder does not obstruct the incident laser beam. The scheme structure of deposited films on Si wafers to prepare TiO_2:ZnO/PSi heterojunctions photo detector is shown in figure (1).

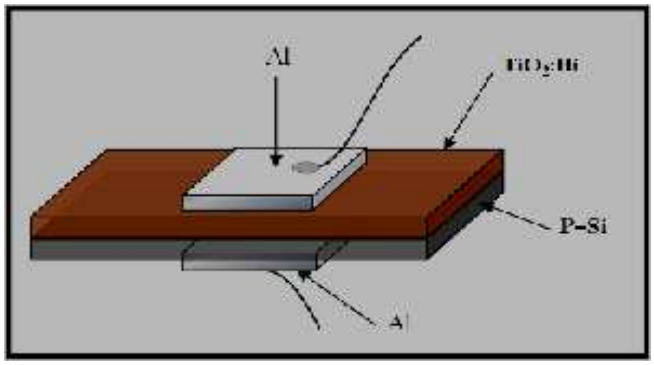

***Fig.(1): Schematic device structure of the* Al/TiO_2: ZnO /PSi/Al heterojunction ultraviolet photodetector.**

The Photovoltaic properties of TiO_2:ZnO thin films were investigated using the testing unit consists of : DC power supply (HY3003-3), variable resistance used to limit the detector bias current and PC-interfaced digital Multimeter as shown in figure (2). UV laser diode is used as a UV source for illumination the TiO_2:ZnO photovoltaic UV detector. The optical power of the UV laser is 103mw and the wavelength is about 385 nm. Figure (3) shows the operation circuit diagram for photovoltaic UV detector.

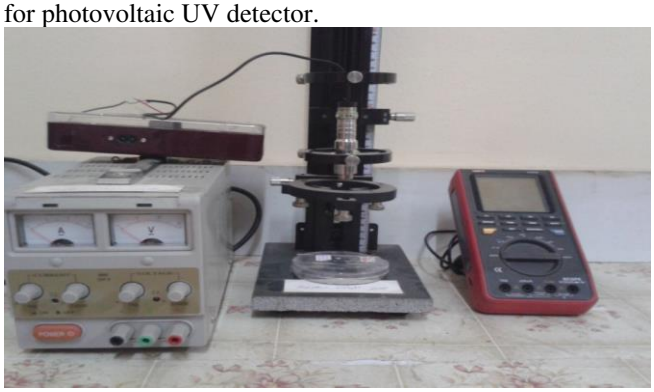

Figure (2): Image of the experimental setup.

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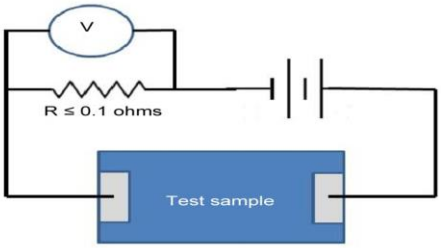


Figure (3): The operation circuit diagram of photovoltaic UV detector.

III. RESULTSAND DISCUSSION

A .Spectral Responsivity

The responsivity is a very important parameter. Responsivity of the detector at a given wavelength λ is the measured of output current Ioutput divided by the spectral radiant incident power on the detector. Can be expressed as[9]:

$$R(\lambda)=\frac{I_P}{P_{in}}=\frac{V}{P_{in}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where P_{in} is the incident optical power, I_p is the photo current. The responsivity increases with increasing of ZnO concentrations from (5% to 7%) reached to 3.39 at bias voltage 1.6 in concentration 7% at room temperature and this responsivity increased to 3.82 at the same bias voltage after annealing as shown in figure (2) and (3) respectively

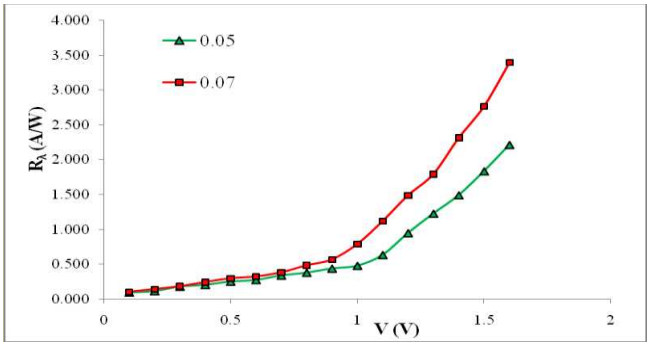


Figure (4): The responsivity as a function of bias voltage of TiO_2:ZnO at different concentrations at RT.

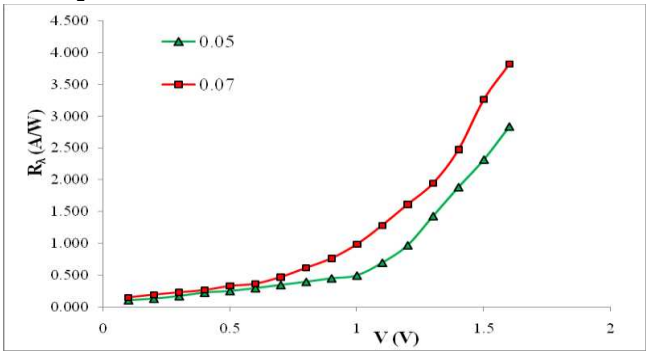


Figure (5): The responsivity as a function of bias voltage of TiO_2:ZnO at different concentrations at 500ºC.

B. Noise Equivalent Power (NEP)

Noise equivalent power (NEP) is defined as the root mean square (r.m.s) incident radiant power falling on the detector that is required to produce an (r.m.s) signal voltage or current equal to the (r.m.s) noise voltage or current at the detector output. It is expressed as[1]:

$$NEP=\frac{I_n}{R(\lambda)}=\frac{V_n}{R(\lambda)} \quad \ldots\ldots\ldots\ldots\ldots(2)$$

The noise equivalent power shown in figure (4), (5) as a function of bias voltage the figure show that the (NEP) decrease with increase the bias voltage and ZnO concentration also decrease after annealing at 500ºC.

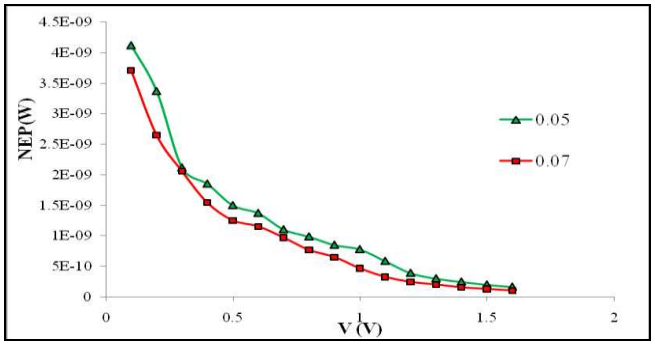


Figure (6): The noise equivalent power as a function of bias voltage of TiO_2:ZnO at concentrations (5%, 7%) at RT.

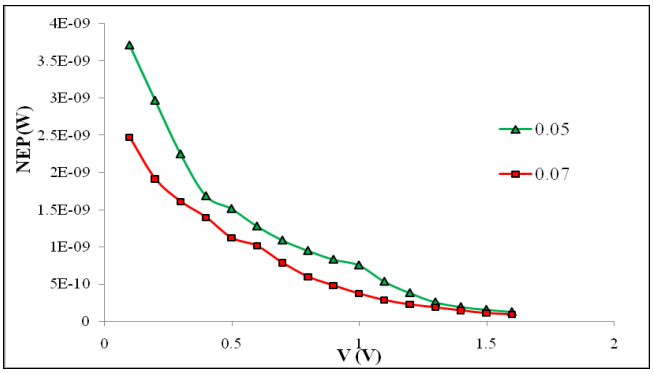


Figure (7): The noise equivalent power as a function of bias voltage of TiO_2:ZnO at concentrations (5%, 7%) at 500ºCC.

Specific Detectivity (D)*

The detectivity (D) is defined as the signal to noise ratio per unit incident radiation power and it is defined as[1]:

D = 1/NEP ……(3)

The specific detectivity (D*) as a function of bias voltage for concentrations 5% and 7% at room temperature and annealing at 500 ºC are shown in figure (6), (7) respectively. From the figure can see that the D* increases with increase the bias voltage reach to 8.17×10^9 at concentration 7% at room temperature and increase to 9.21×10^9 after annealing

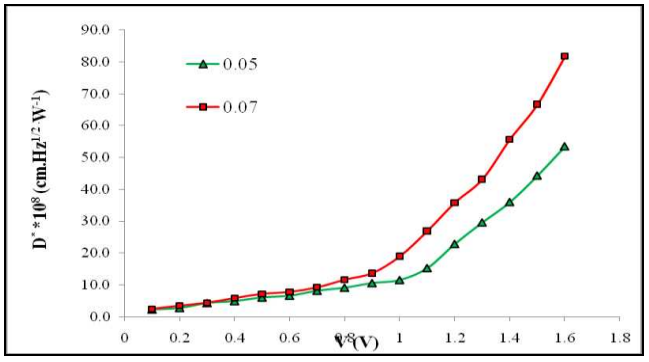
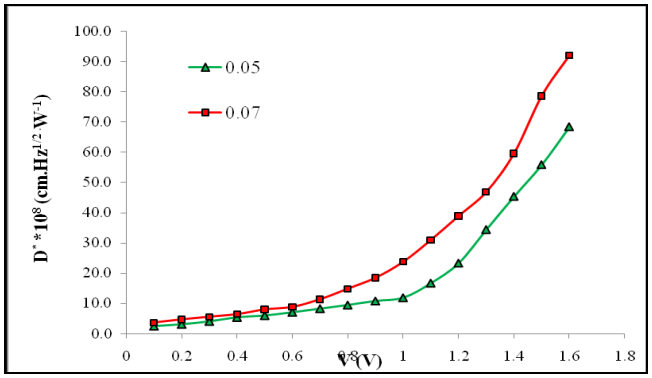


Figure (8): The specific detectivity (D)as a function of bias voltage of TiO_2:ZnO at concentrations (5%, 7%) at RT*



Figure(9): The specific detectivity (D*)as a function of bias voltage of TiO_2:ZnO at concentrations (5%, 7%) at 500ºC

D. Specific efficiency (η)

Specific efficiency η is the number of photoelectrons generated per incident photon**.** The quantum efficiency is given by[10]:

$$\eta = \frac{I_P/q}{P_{in}/h\nu} = \frac{1.24\ I_P}{P_{in}\ \lambda(\mu m)} \quad \ldots\ldots\ldots\ldots (4)$$

The Specific efficiency (η) for (5%,7%) at RT and annealing at 500 ºC shown in figures (8), (9) respectively. Note that the Specific efficiency increase with increase ZnO concentration and with annealing reached to $1.23x10^{+1}$ after annealing at concentration 7% as shown in table (1).

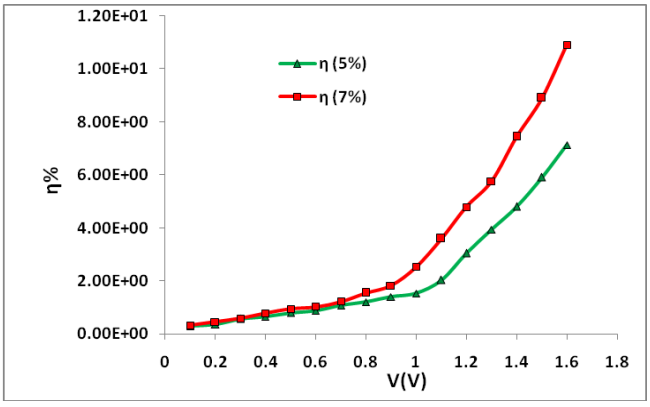


Figure (10): The quantum efficiency (η) as a function of bias voltage of TiO_2:ZnO at concentrations (5%, 7%) at RT.

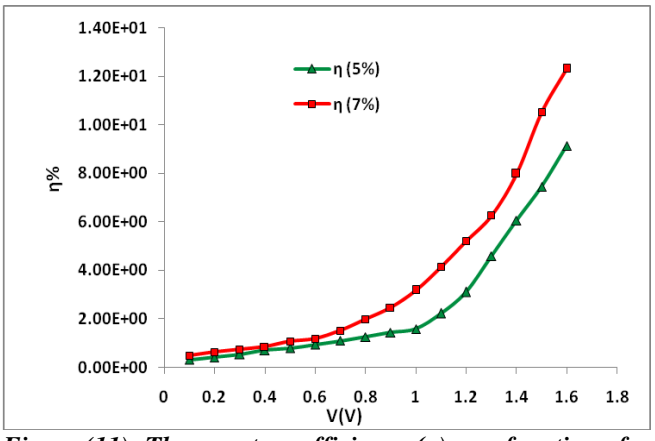


Figure (11): The quantum efficiency (η) as a function of bias voltage of TiO_2:ZnO at concentrations (5%, 7%) at 500ºC

(%)	Annea-ling	Max (R_λ) (A/W)	λ (nm)	Max(D*) $\times 10^9$ (cm.$Hz^{1/2}$ .W^{-1})	Min(NEP) (W)	Max (η) (%)
5	RT	2.215	385	5.34	1.67×10^{-10}	7.13
7	RT	3.39	385	8.17	1.09×10^{-10}	10.9
5	500 ºC	2.835	385	6.84	1.31×10^{-10}	9.1
7	500 ºC	3.82	385	9.21	9.71×10^{-11}	12.3

Table (1): The TiO_2:ZnO/PSi detector parameters at 1.6 bias voltage with different ZnO doping ratio and annealing temperatures

IV. CONCLUSION

TiO_2 a photovoltaic UV detector was developed using different concentration of ZnO prepared by pulse laser deposition technique. This device shows a prominent performance for UV light detection. The responsivity, quantum efficiency and the specific detectivity for TiO_2:ZnO/PSi detector increased with the increase of ZnO concentration from 5% to 7% at room temperature and after annealing, while the NEP has inverse behavior. The responsivity reached to (3.39) A/W in concentration 7% at room temperature and this responsivity increased to (3.82) A/W after annealing.

REFERENCES

[1] Sabah N. Mazhir, Ghuson H. Mohamed, Abdullah A. Abdullah, Maysoon D. Radhi "UV Photovoltaic detector based on Bi doped TiO2 Fabricated by Pulse Laser Deposition" International Journal of Advanced Research, Vol. 3, 2015, PP. 1060.

[2] Adawiya J. Haide\, Samar Y.Al-Dabagh and Mirvat D. Majed, " Effect of Oxygen Pressure on the Optical, Morphology and Structural Properties of TiO2: Cr Thin Films Prepared by Pulsed Laser Deposition"Journal of Materials Science and Engineering,Vol.A2(3), 2012,pp.346-351.

[3] Saja H.Rashed Adawiya J. Haider Samar Younis ,"Preparation and Characterization of (Tio2-Sno2) Thin Films by Pulsed Laser Deposition"E Tech.Journal, Vol. 32,Part (B), No.4, 2014ng. & Vol. 32,Part (B), No.4, 2014

[4] Ru-Hua Tao, Jin-Ming Wu, Jing-Zhong Xiao, Yi-Ping Zhao, Wei-Wei Dong,Xiao-Dong Fang" Conformal growth of ZnO on TiO2 nanowire array for enhanced photocatalytic activity" Applied Surface Science Journal, Vol. 279, 2013,pp. 324

[5] Abood, M.A. Mustafa, F.I. Fraih, M.R. and Abduligabar, M.D. 2014 Fabrication of multi-junction solar cells. J. Baghdad for Science. Vol.11, Nov. 2014,Pp.614

[6] M. Ouyang, R. Bai, L. Yang, Q. Chen, Y. Han, M. Wang, Y. Yang, H. Chen, High photoconductive vertically oriented TiO2 nanotube arrays and their composites with copper phthalocyanine, Journal of Physical Chemistry , VOL.112,2008,pp.2343-2348.

[7] Kewei Liu,* Makoto Sakurai,* and Masakazu Aono ,"ZnO-Based Ultraviolet Photodetectors,Sensors (Basel),VOL. 10(9), 2010, PP.8604–8634.

[8] Zainab N. Jameel, Adawiya j. Haider, Samar y. Taha" Synthesis of TiO2 Nan particles by Using Sol-Gel Method and its Applications as Antibacterial Agents", Eng. &Tech.Journal,vol. 32 (No.3), ,2014,pp.418-426

[9] R.K.Willardson , — Semiconductor and Semimetals, Academic Press , NewYork , London , Vol .12 , 1977 ,Chapter 11.

[10]Z.Jiang and Y.Chang , "Fabrication of Ge P-i-n and GaAs M-S-M Photodetectors on Si Substrate " M.Sc. Thesis , NCTU , Taiwan , R.O.C, 2009.