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

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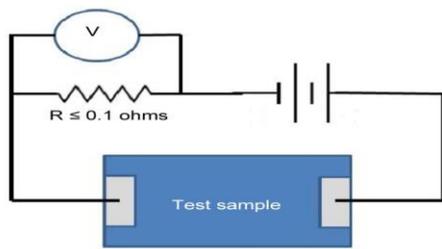**Thura tariq abbas,** Department of Physics, College of Science for Women University of Baghdad. Baghdad -Iraq

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).
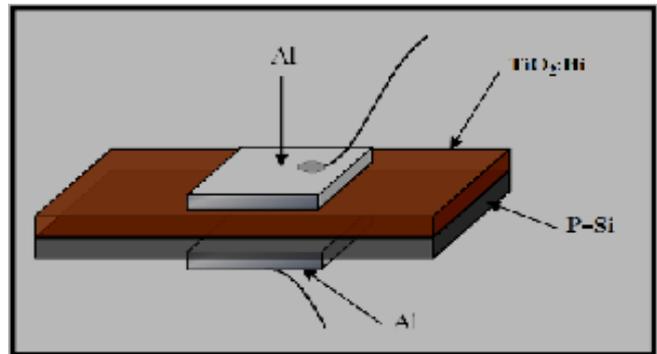
***Fig.(1): Schematic device structure of the* Al/TiO$_2$: ZnO /PSi/Al heterojunction ultraviolet photodetector.**

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.
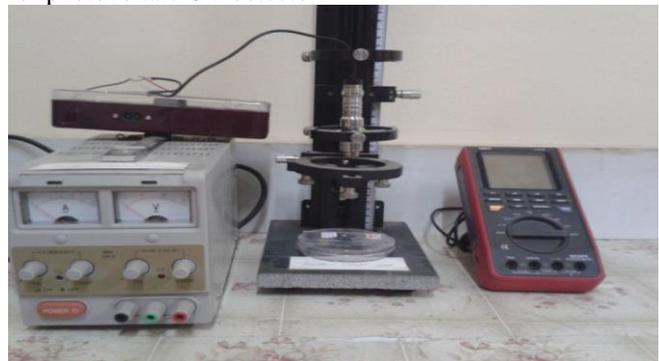
Figure (2): Image of the experimental setup.

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

III. RESULTS AND 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
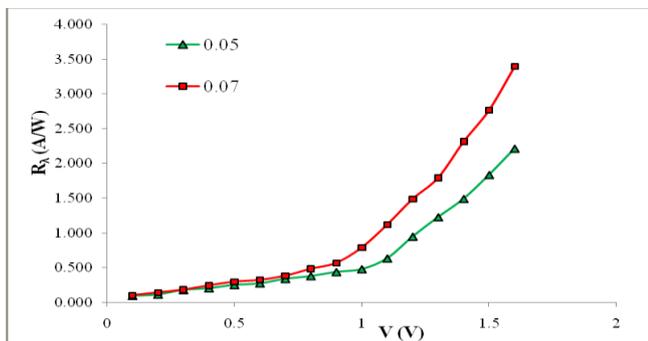

Figure (4): The responsivity as a function of bias voltage of TiO₂:ZnO at different concentrations at RT.
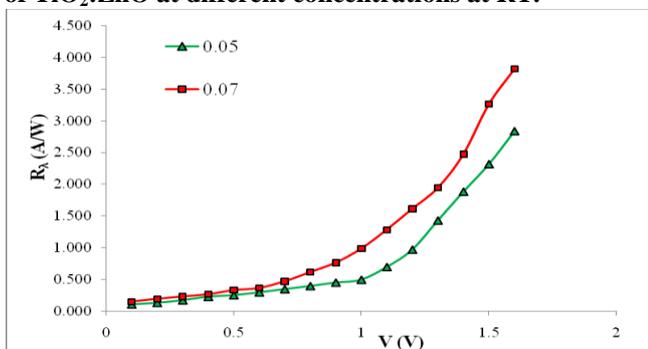

Figure (5): The responsivity as a function of bias voltage of TiO₂:ZnO at different concentrations at 500ºC.

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.
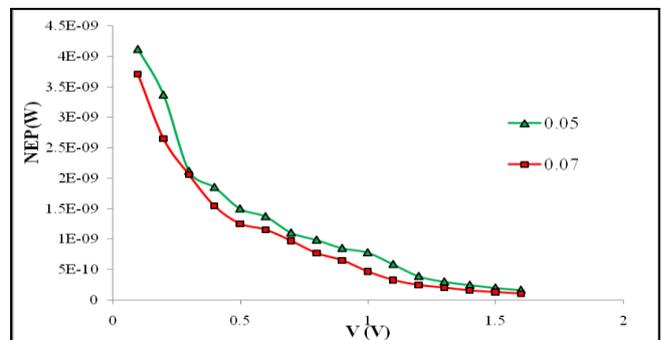

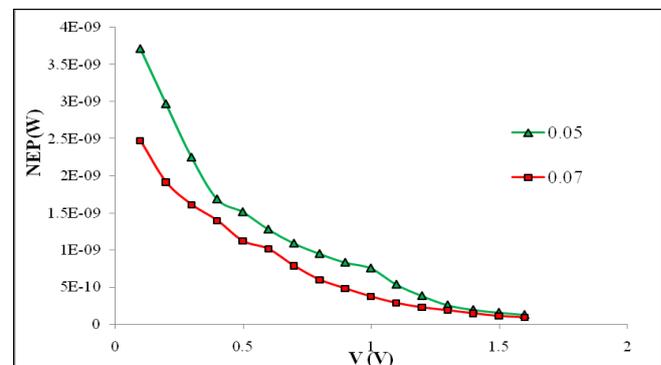*Figure (6): The noise equivalent power as a function of bias voltage of TiO₂:ZnO at concentrations (5%, 7%) at RT.*

Figure (7): The noise equivalent power as a function of bias voltage of TiO₂: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

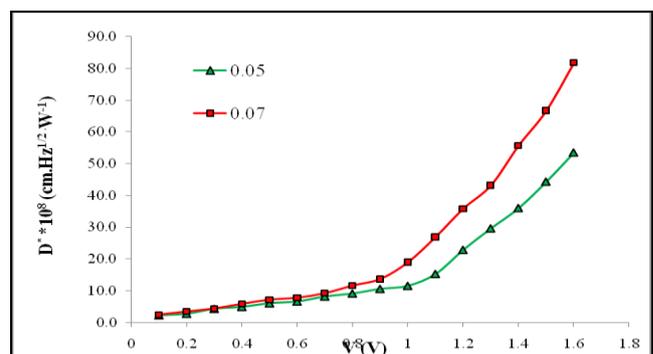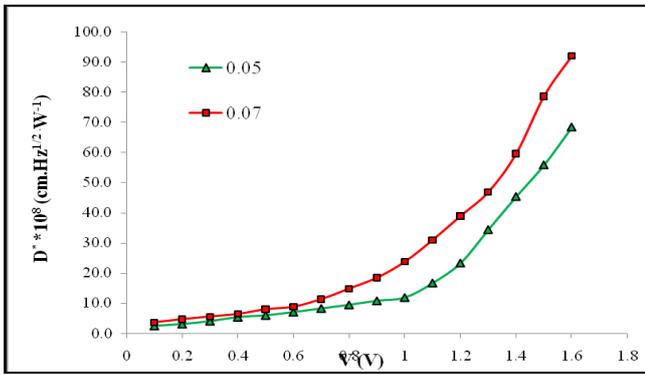*Figure (8): The specific detectivity (D*)as a function of bias voltage of TiO₂:ZnO at concentrations (5%, 7%) at RT*

Figure(9): The specific detectivity (D*)as a function of bias voltage of TiO$_2$:ZnO at concentrations (5%, 7%) at 500ºC

(%)	Annealing	Max (R$_\lambda$) (A/W)	λ (nm)	Max(D*) ×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

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 $1.23 \times 10^{+1}$ after annealing at concentration 7% as shown in table (1).
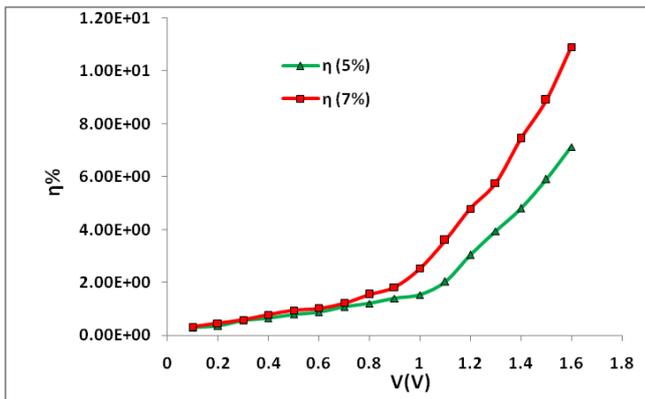

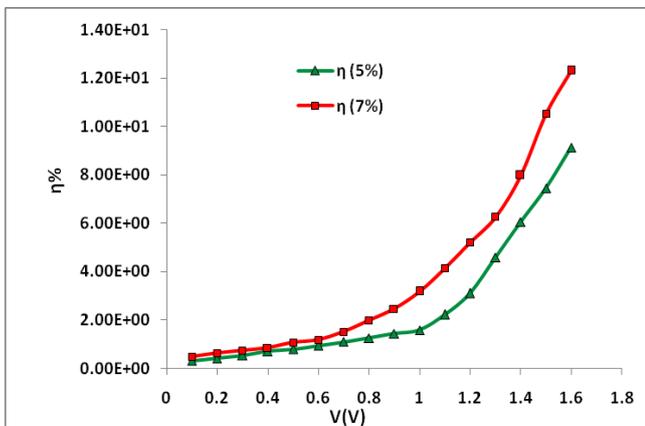*Figure (10): The quantum efficiency (η) as a function of bias voltage of TiO$_2$:ZnO at concentrations (5%, 7%) at RT.*

Figure (11): The quantum efficiency (η) as a function of bias voltage of TiO$_2$:ZnO at concentrations (5%, 7%) at 500ºC

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.

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