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PERFORMANCE ANALYSIS OF PD/ZNO BASED FLEXIBLE UV MSM PHOTODETECTORS

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Abstract: Flexible electronics and optoelectronics devices attract further attention in recent years. In this paper, we present the fabrication and photodetection properties of a flexible metal-semiconductor-metal UV photodetector based on a thin ZnO film with Pd Schottky electrodes. The active ZnO layer was created using a hydrothermal method on ITO/PET flexible substrates. Palladium employed as back-to-back Schottky contacts. Metal masks are designed and used to deposit palladium via thermal evaporation. To demonstrate the impact of ZnO on flexible substrates, the structural, optical, and electrical characteristics of the produced films were examined and assessed. I-V characteristics under dark and illumination conditions for a device were measured using a voltage range of -2.8 V to 2.8 V. The measured data was used to calculate device parameters and photodetection properties. Such as ideality factor, barrier height, saturation current, detectivity, responsivity, contrast-ratio, and efficiency. The proposed device exhibited a gain (efficiency of 200%} caused by trapping hole carrier at ZnO-Pd interface

Keywords: *ZnO, Flexible substrate, Palladium, Hydrothermal method.*

1. Introduction

Novel flexible electronics research for building lightweight, low-cost, portable, and shock-resistant devices such as screens, solar cells, sensors, and radio frequency identification processes has gotten a lot of attention recently[1]. In optoelectronics applications, flexible sensors are becoming increasingly important[2]. It is a photodetector that converts ultraviolet light into electric current. Applications in the military (missile plume detection), medical field (sterilization), and environmental field (smoke detection)[3].Schottky contacts are a fundamental component of many electronic and photonic semiconductor devices. ZnO and its doping have received increased attention. They have been used in a range of technologies like as ultraviolet sensors, gas sensors, transistors, and so on in recent years due to their exceptional optical properties. With a 60-eV exciton binding energy and a 3.37 eV direct bandgap, zinc oxide, an II-VI semiconductor, has emerged as a key material for electrical and photonic devices in the short-wavelength range. n-type properties are inherent in this material Oxygen vacancies and/or zinc interstitials are formed due to donor deficiencies[4, 5]. Pt, Pd, and Au other metals with poor oxygen affinity have quite significant Schottky barriers on n-type ZnO, which range from 0.6 to 0.8 eV[6]. Chemical vapor deposition (CVD) is just one of a number of techniques,

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"physical vapor deposition (PVD)", "pulse laser deposition (PLD)", thermal evaporation, sol-gel, and sputtering, have been investigated in recent years to fabricate t nanostructures [7]. In this paper, we examine the interdigitated setup's performance of the Pd/ZnO photodetector. Hydrothermal deposition on ITO/PET of ZnO thin films. The topological, structural, and electrical features of thin films and devices were studied. Each device's optical reaction to UV illumination was tested and compared in terms of sensitivity, quantum efficiency, and detectability. Room temperature was used for the measurements.

2. Experiment

Hydrothermal processes were used to generate the nanostructured ZnO films. In order to create the ZnO thin films, ITO/PET substrates with a 1 inch ×1inch dimension. Before ZnO thin films growth process, the flexible ITO/PET substrates were cleaned. The flexible substrate immersed in an acetone on an ultrasonic bath for 2 minutes. Followed by the immersing in isopropanol (IPA) on ultrasonic also for 2 minutes, then, the substrate rinsed by deionized water (DI). Later, the dry step from DI is done by using sterilized paper, hence the flexible substrates are ready to spin coating[8].

The spin coater process was used to apply the seed layer to a flexible substrate. To make a composite solution, make a seed solution of 0.005 m zinc acetate in 20 mL isopropanol and dehydrate it. At 300 K, the solution was agitated for 3 hours to obtain a homogenous clear solution. At room temperature, a spin coater applies the solution to the substrate at 3000 rpm for 50 seconds.

Hydrothermal deposition technique was applied to form ZnO nanostructured thin films. The solution used to formation the nanostructured was constituted of two mixed solutions, Solution first contained 0.05M Zinc nitrate Hexahydrate in 20 mL deionized water and was agitated for 30 minutes. Both contain 0.05M Hexamethylenetetramine (HMTA) in deionized water and are whirled in the same way. After that, the two solvent solutions are blended and agitated for 20 minutes to ensure homogeneity. The pieces of flexible substrates which seed layer was the formation on it are dipped in a homogeneous solution and placed in an "autoclave" and heated for 5 h at 90°C [9].

For electrodes, ZnO thin films were metalized. Metallization is a gas phase deposition procedure that is carried out in a confined vacuumed chamber. Palladium powder (99.99 %) was used by using a tungsten boat in the vacuum vapor deposition process as the source material in the vacuum coating unit. The following are the deposition conditions: The chamber pressure was evacuated to $2*10^{-4}$ mbar, with a 6 cm spacing between the substrates and the boat in the vacuum unit.

A Keithley semiconductor characterization system (Keithley, SCS-4200) was used to measure current versus voltage curves in the dark and under UV illumination (254nm wavelength with optical power of 163.2µm–171.8µm) when a bias voltage was supplied in the range of -2.8 to 2.8 V.

3. Result and Discussion

A I–V characteristics from ZnO films and nanorod photodetectors were measured in the dark condition (for saturation current, ideality factor, barrier height) and under UV light of 254 nm light (for photocurrent, contrast ratio, responsivity, quantum efficiency and detectivity) The voltage used for this experiment ranges from -2.8V to 2.8V at a wide range of optical power densities from (163.2 µw to 171.8 µW). A metal-semiconductor-metal (MSM) structure is made up a semiconductor layer separates two Schottky connections.

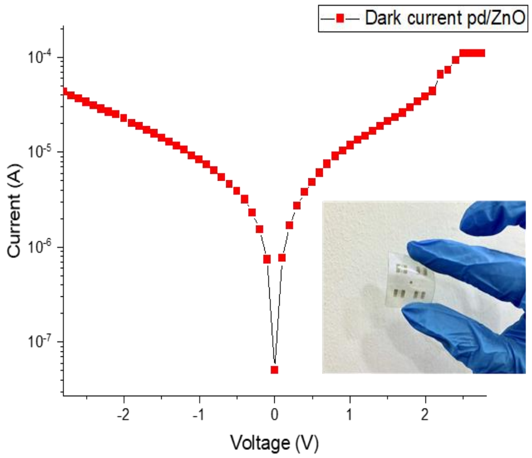


Figure 1. Shows the I-V characteristics under dark condition

A Pd/ZnO Schottky MSM photodetector was used to take the I–V measurements. This Eq. (1) describes the thermionic emission theory that governs the flow of current via a diode (1) [10].

$$I = \left[AA^{*}T^{2}\exp\left(\frac{-q\varphi_B}{KT}\right)\right]\left[\exp\left(\frac{qV}{nKT}\right)-1\right] \quad (1)$$

n is the ideality factor , q has a positive or negative charge on an electron, K is the Boltzmann's constant, T is the actual temperature, in degrees Fahrenheit., φ_B is the height of the barrier, A is the location where the Schottky contact points are located (6mm*4 mm) and A* Is the actual "Richardson Coefficient effective~32 A/cm²K²"[11]. A parameters barriers, ideality factor, saturation current and turn-on voltage for the saturant current Pd/ZnO contact were retrieved from the I –V characterization data and agreement with others[12]. The ideality factor's value was derived using the Eq.(2)[13]:

$$n = \frac{qV}{KT}\left\{\frac{1}{\ln(I/I_o)+1}\right\} \quad (2)$$

Where I_0 denotes the saturation current. The ideality factor value was calculated to be 3.19. the high ideality factor is often attributed to barrier inhomogeneity at the Pd/ZnO contact[14]. At room temperature (300 K), the barrier height calculated from Eq.(3) [10]was determined to be 0.73 eV.

$$\varphi_B = \frac{KT}{q}\ln\left(\frac{AA^{*}T^{2}}{I_0}\right) \quad (3)$$

Depletion widths for Pd/ZnO were calculated from Eq.(4) [15] to be 8.25*10^{-6} m

$$w = \sqrt{\frac{2\varepsilon_s}{qN_D}V_{bi}} \quad (4)$$

where ε_s is the relative permittivity of ZnO, which is 8.2[13].

Demonstrates the relationship between applied bias V and the photocurrent and contrast ratio (sensitivity) in the air, measured both in the dark and with UV light in Fig.(2a). Difference between light and dark current is what we mean by "photocurrent"[10]. It is important to consider the contrast ratio of a UV detector in Fig. (2 b). The ratio of the irradiation current to the dark current is known as the contrast ratio (sensitivity)[16].

Table 1. The parameters for ZnO thin film

parameters	Saturation Current(A)	Barrier Height(eV)	Ideality Factor
Value	4.06*10^{-7}	0.73	3.19

parameters	Contact Potential (Vbi)(eV)	Turn on voltage (V)	Depletion widths(m)
Value	0.72	0.489	8.25*10^{-6}

The responsivity and detectivity are critical properties that are mostly determined by electron-hole pair formation and transit across the junction[17]. The responsivity and detectivity are shown in Fig. (3). The MSM detector's sensitivity requirements are stated by [18]

$$\text{Rcrt}=\frac{q}{hv}\times\frac{s}{s+w} \quad (5)$$

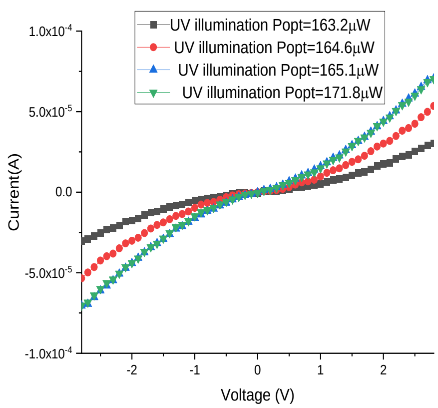
Where Rcrt is the photodetector responsivity criterion, v is the frequency, s is the electrode spacing, and w is the electrode width. In the current investigation, the responsivity was discovered to be substantially more than the responsivity criteria, resulting in a large gain.

The device's voltage-dependent detectivity D is denoted by[5].

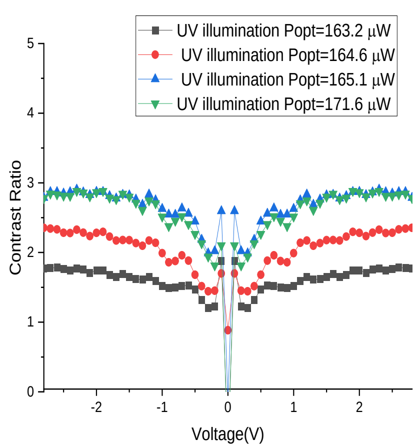
$$D=\frac{\lambda\eta q}{hc}\sqrt{\frac{RA}{4KT}} \quad (6)$$

Where "ɳ is the external quantum efficiency", k is the Boltzmann constant, T is the temperature, and RA is the device's resistance-area-product and may be calculated from J –V characteristics as[5].

$$RA = \left(\frac{\partial J}{\partial V}\right)^{-1} \quad (7)$$



(a)



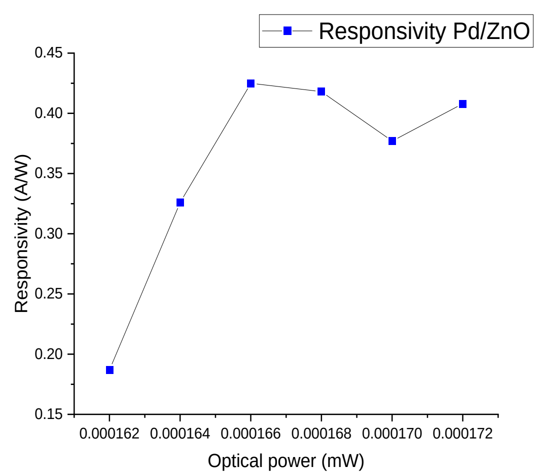
(b)

Figure 2. (a) photocurrent vs. Voltage of pd/ZnO. (b) contrast ratio vs. Voltage of pd/ZnO

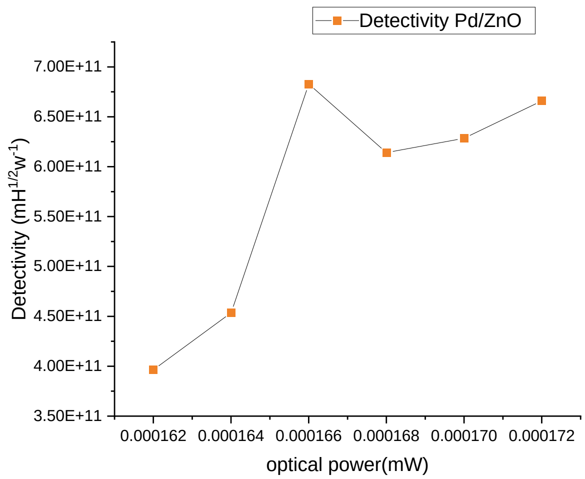
The detectivity of the devices improved with increasing optical power, peaking at 0.000166 W before falling to $6.14*10^{11}$ $mHz^{1/2}w^{-1}$ due to the formation of additional electrons and holes as a consequence of the new defect chemistry as a result of doping[17].

Another key statistic shown in Fig. (4) is external quantum efficiency, which provides critical information on the collection of photogenerated charge carriers following the incident of one photon[19]. The quantum efficiency is used to calculate the O/E conversion efficiency, which is presented below[20]. Schottky MSM PDs, On the other hand, the Schottky contact, which prevents secondary charge carriers, does not anticipate a gain. The photodetector occasionally experiences a gain. This study found that Pd/ZnO had a boost in performance. As the optical power increased, so did the quantum efficiencies (or gains).

$$\eta = \frac{Iph}{Popt} \times \frac{hf}{q} \quad (8)$$



(a)



(b)

Figure 3. (a) Pd/ZnO optical power vs. Responsiveness. (b) Pd/ZnO Detectivity vs. optical Power.

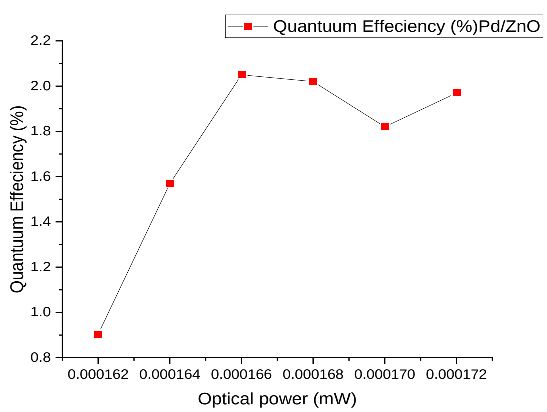


Figure 4. Pd/ZnO Optical Power vs. External Quantum Efficiency

4. Conclusion

In this paper, we have successfully built a flexible Pd/ZnO MSM photodetector Hydrothermal ZnO thin films are used in this design. Saturation current, ideality factor, and barrier height are all examples of device parameters found to be 4.06×10^{-7} A, 3.9 and 0.73 eV, respectively. The ideality factor found to be larger than theoretical value because barrier inhomogeneity at the Pd/ZnO contact. The performance characteristics responsibility 0.408 A/W, detectivity 6.66033×10^{11} mHz$^{1/2}$ W^{-1}. The photodetector revealed a gain about 2 9 efficiency 200%) at Popt = 0.166 mW and V=2.8 V, that initiates from the existence of hole trap at the ZnO surface**.**

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Conflict of interest

The authors confirm that the publication of this article causes no conflict of interest.

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