FABRICATION OF NICKEL DOPED ZNO/PEDOT: PSS SCHOTTKY DIODE BASED ULTRAVIOLET PHOTODETECTOR

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Abstract

This paper describes a strategy for developing a Nickel doped ZnO based UV Photodetector based on the formation of Schottky diode and PEDOT:PSS (poly(3,4-ethylenedioxythiophene) polystyrene sulfonate) as a hole transport layer. I-V characteristics of the fabricated device at room temperature (300K) is measured and the parameters such as dark current, photo current, sensitivity and responsivity were calculated from the measured data. The device response is experimented under 365 nm wavelength of UV lamp at various time intervals. The photo current and the dark current of the device is 160 A and 110 A respectively. The responsivity and sensitivity of the device is found to be 32x10-5 A/W-1 and 1.45.

Keywords: photodetector, schottky, PEDOT:PSS, sensitivity, responsivity.
1 INTRODUCTION

Ultraviolet (UV) Photodetector has been widely used in the application like flame detection, missile plume detection, environment monitoring, optical communications, UV imaging [1]. Nanotechnologies have sparked a vision for UV photodetector which has low power consumption and greater miniaturization. UV radiations are deadly harmful and ignite many chemical processes and health issues because these radiations are lethal. Sun is the primary source of UV radiations, too much exposure on the earth leads to ozone depletion. It produces more free radicals that involve in the development of various diseases such as cancer, Alzheimer’s disease, inflammatory disorders and other mild sicknesses. Some research shows that 1% volume of the ozone layer will decrease because of 2% increase in UV radiation, which prompts to result in raise of 3% skin cancer [2]. It is evident that study of UV photo detection has drawn extensive attention from the researchers [3]. Semiconductors are the first to perform UV detection and are preferably chosen for their unique optical properties. These optical properties of the semiconducting material can be controlled by modulating the size, composition, surface properties and crystalline structure of the nanostructure. Zinc oxide (ZnO) could be the most suitable sensing material for the UV photodetector due to its wide bandgap of 3.37 eV and ≈60 meV exciton binding energy at room temperature. It is a n-type material with ease of fabrication, non-toxic, high thermal stability and high transmittance in visible region, low cost [4,5]. These ZnO-based schottky barrier diodes are most promising for use as UV detectors [6]. Transition metal ions are an excellent candidate for ZnO semiconductor as a dopant. Introducing metal ions in the semiconductor is known as a diluted magnetic semiconductor (DMS). It modifies the electronic structure and band gap energy due to the interaction of electrons of a transition metal with the semiconductor[7,8]. Therefore it is better for the application of optical devices. PEDOT: PSS is an inexpensive hole conducting polymer which is used as an alternative to metal electrodes. It has very low density and conductivity, high optical transparency and thermal stability, environmental easy synthesis and processing into versatile forms which are beneficial for the
stability of the devices [9,10]. In this study, the Schottky based PEDOT: PSS/Nickel doped ZnO nanorods UV Photodetector were fabricated. The structural and optical characterization are analyzed using an optical microscope, Ultraviolet spectroscopy, photoluminescence characterization. The sensitivity and responsivity have been investigated. It was observed that the device exhibits high responsivity towards 365 nm UV illumination with quick response and recovery time.

2 EXPERIMENTAL METHODOLOGY

Fig. 1 (a) shows that the process flow of UV photodetector fabrication steps[11].

The schematic representation of the device is depicted in Fig 1 (b). The fluorine-doped tin oxide (FTO) substrate is rinsed with distilled water and ethanol using ultrasonicator. After that, the substrate is dried at room temperature. Seed solution is made by dissolving 5 mM of zinc acetate dehydrate and 5 mM of potassium hydroxide (KOH) in ethanol by continuous magnetic stirring about 10 minutes. ZnO seed is spin-coated on cleaned substrates for two times at the speed of 3000 RPM for 30 seconds with each time dried at 100°C for 10 minutes. Then the seeded samples are post-annealed at 150°C about 30 minutes. The aqueous solution was synthesised by mixing 4 mM of zinc nitrate with distilled water along with and 2 mM hexamethylenetetramine (HMTA) is added to a beaker with
the molar ratio was 1:1. The solution was stirred for 20 minutes in a stirrer. For ZnO nanorods growth, samples were kept in the slanting position, immersed at the bottom of the autoclave. Finally, keep the autoclave in hot air oven for annealing at 90°C for 5 hours. After that substrates was cleaned with DI water. PEDOT: PSS is a conducting polymer which is deposited by spin coating and it has low resistivity 10-3 Ω-cm and large work function of 0.5 eV. PEDOT:PSS is diluted with isopropanol to avoid etching of ZnO because of acidic property. The solution was spin-coated on the nanorods for thrice at the speed of 1000 RPM for 30s then the samples were annealed for 10 minutes.

3 RESULTS AND DISCUSSIONS

Deposition of thin film is characterized using optical microscope as shown in Fig. 2(a). From the image it is observed the uniform deposition of film. Fig. 2(b) shows the photograph of the fabricated device. Absorption spectrum of the sample is in the wavelength range of 300 to 600 nm at room temperature was carried out by UV-visible spectroscopy. Fig. 2(c) shows that a high absorption in of 300-400 nm (UV region) wavelengths, because of the quantum confinement effect [12]. The shift in the graph denotes the doping of nickel in ZnO. I-V characterization is performed using Keithley 6487 source meter. The IV characteristics graph shows the photo current increases as increase in bias voltage. The sensitivity (S) plays a major role in UV photodetector [13]. The UV photodetector

![Figure 2: (a) Photograph of the device (b) Optical microscopic picture of ZnO thin film (c) Absorbance Spectrum](image-url)
showed a sensitivity of 1.45 for 0.5 bias voltage which is derived from (1),

\[ Sensitivity(S) = \frac{I}{D} \]  

(1)

where I denotes the photocurrent and D represents the dark current. From the Fig. 3(a), it is found that photocurrent of the reported device is of 160µA and the measured dark current of the fabricated device is of 110µA under the illumination of optical source (Halogen lamp) of 50W. High rise in responsivity and quick response are important figure of merit for UV photodetector [14]. The responsivity is calculated from (2),

\[ Responsivity(R) = \frac{I}{AS} \]  

(2)

where I denotes the photocurrent, A refers the active area, and S is called irradiance of the light source. Fig. 3(b) shows the response of the device under UV illumination for various time intervals. It is observed that in the absence of UV light the resistivity of the device is around 14.6 KΩ. The device is exposed to 365 nm wavelength with 8W power UV lamp at different time interval. It is clearly observed that device resistivity decreases linearly with UV exposure. Thereby it increases the photo conductivity of the device.
4 CONCLUSION

Nickel doped ZnO schottky diodes were fabricated. The response graph of the diode reveals the resistance decrease under UV illumination. From the IV characteristics, it was observed that at the room temperature (300 K), the device exhibited high and stable sensitivity under low biasing. Under forward bias, improved sensing capability was due to the height of schottky barrier and the reverse bias due to the concentration of electrons. The high response of the ZnO nanorods was because of the large surface to volume ratio. From this, the device may be used as efficient UV photodetector under low biasing voltage.

References


