Journal of Electron Devices, Vol. 21, 2015, pp. 1830-1833

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Journal of Electron Devices
www.jeldev.org

WO_3 NANOWIRE BASED DIODE FOR ULTRA VIOLET LIGHT SENSING APPLICATIONS

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Received 17-02-2015, 04-03-2015

ABSTRACT
In this paper, we report a simple approach to fabricate UV photo-detector based on WO_3 nanowires. The WO_3 nanowires were synthesized by a simple hydrothermal method using tungsten powder as a precursor, Palladium nanoparticles as catalytic to remove excess of H_2O_2 and Na_2SO_4 as a structure-directing agent. The structural properties of the WO_3 nanowires are analyzed by the UV-spectroscopy, XRD and SEM. XRD and SEM results indicated that the WO_3 nanowires are hexagonal. Device has been made by using spray coating method keeping substrate on hot-plate and Palladium contacts has been deposited on film by using thermal evaporation method. After fabrication of the device, device has been characterized for electrical properties in dark condition and in the presence of UV light with UV illumination and Agilent B1500A Semiconductor device Analyzer.
Keywords: Tungsten Oxide nanowires, UV Photo-detector and sensor.

I. INTRODUCTION

Among the transition metal oxides, tungsten oxide has drawn great attention due to its distinctive physical and chemical properties and therefore has been extensively investigated for applications like electrochromism, photochromism, gas sensing, photo catalysis, photoluminescence, and many more [1-7]. Tungsten oxide has been used to construct photochromic smart-windows, flat panel displays, optical modulation devices, gas sensors, humidity and temperature sensors. Tungsten oxide is an indirect, wide-gap semiconductor. Upon bandgap photoirradiation, electron–hole pairs are produced. Depending on the behavior of the newly photogenerated electrons and holes, the optical absorption of tungsten oxide can be altered, leading to a color change from transparent to blue. It is well known that nanostructes have unique physical and chemical properties and can be used as elementary units of optoelectronic devices. Tungsten oxide (WO_3) nanostructures have outstanding properties which make it valuable as functional building blocks for the fabrication of biological sensors, optoelectronic devices, optical memories and other areas [1].

Photo-detectors convert incoming optical energy into electrical energy. Si-based UV photo-detectors can be very sensitive in UV region with low noise and quick response, however it has some limitations, such as lower efficiency or the need of an ultra high vacuum environment and a very high voltage supply. To avoid these disadvantages UV photo-detectors based on wide band gap semi-conductors have received more attention. ZnO based photodetectors are very popular.

The UV detector based on polycrystalline ZnO thin film shows law photoresponsivity and long response time of the order of few minutes. ZnO/Porous-silicon photovoltaic UV detectors have been demonstrated to be ultra fast and have high responsively [8]. Near ideal characteristic ZnO thin films have been characterised for UV detectector applications [9]. WO_3 is also a potential material for detecting UV radiation because it has large energy band- gap [2,3]. One directional (1D) nanostructure wide band-gap semi-conductors (e.g. WO_3), have high responsivity, high thermal stability and high speed. So WO_3 nanowires can be used as a sensing element for UV photo- detectors as it has a very high photoconductivity gain. UV photo-detectors are highly suitable for a wide range of industrial, military, environmental and biological applications [4]**.**

II. EXPERIMENTAL

In experiment two steps has been followed for making the tungsten oxide nanowires. In first step WO_3 sol was prepared whereas in second step WO_3 nanowires was obtained from WO_3 sol. For preparation of WO_3 sol, Tungsten powder was dissolved into hydrogen peroxide. The aqueous solution was kept in an ice water bath under slight stirring [5]. After centrifugation, a transparent solution was formed. A small amount of Palladium nanoparticles were added to remove the excess of H_2O_2. A homogeneous and stable WO_3 sol was obtained by adding distilled water and oxalic acid to the mixture and adjusting the pH value of the solution to 1.1 by using the NaOH solution(1 mol per liter).

In second step WO_3 sol was transferred into an autoclave, and then Na_2SO_4 was added in the sol and autoclave was maintained at 180^0C for 24 hours. Product was washed with ethanol and water to remove the ions and dried at 60^0C and hexagonal WO_3 (h-WO_3) nanowires were obtained [6]. These nanowires were coated on p- type silicon substrate by using spray coating method keeping substrate on hot-plate. After that, annealing was done at 500^0C in presence of Nitrogen. At last Palladium contacts were deposited on film by using thermal evaporation method with 12A 4 Hind hivac vaccum coating unit.

III. RESULTS AND DISCUSSION

III.1. Structural Analysis

Figure 1 a-b shows the scanning electron microscope (SEM) images of as prepared WO_3 nanowires synthesized using the hydrothermal method at different magnifications. The few nano meter wire-like structure is clearly seen uniformly across the specimen. Figure 2 shows the XRD pattern of the as-synthesized product. It can be indexed to the hexagonal phase of the WO_3 nanowires with the lattice constants a=7.324 A^0, C= 7.662 A^0 (JCPDS 85-2459).

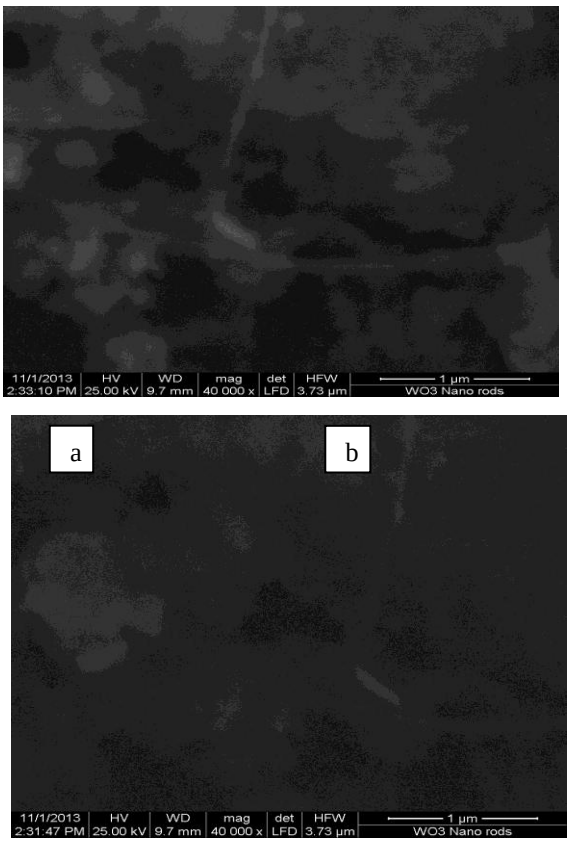

Figure 1: SEM images of synthesized WO_3 nanowires

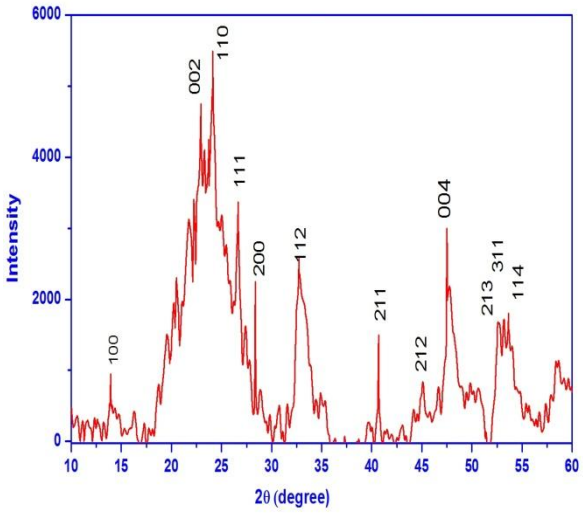

Figure 2: XRD pattern of WO_3 nanowires.

III.2. Optical and Electrical Analysis

Figure 3 shows the UV absorption spectrum of as-prepared WO_3 nanowires. Energy band gap can be found by using formula

$$\alpha h\nu = a(h\nu - Eg)^{r} \ldots\ldots(1)$$

(where α is the absorption coefficient, a is a constant which does not depend on the photon energy and r is the numerical constant which has the value of ½), the band gap varies as the absorptance (α^2) [7]. Figure 4 shows the plot of $(\alpha h\upsilon)^2$ versus hυ. The intercept with the hυ axis of the tangent to the curve of $(\alpha h\upsilon)^2$ plotted against hυ gives a good approximation of the energy band gap (i.e. E_g is~ 4.17 eV), seen from the figure 4

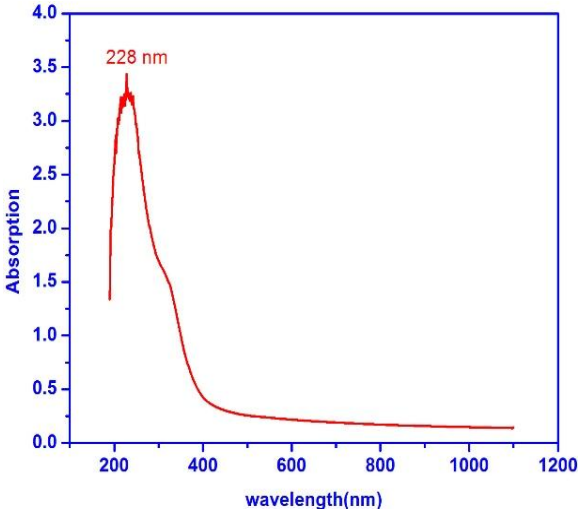

Figure 3: WO_3 nanowire UV absoption spectrum

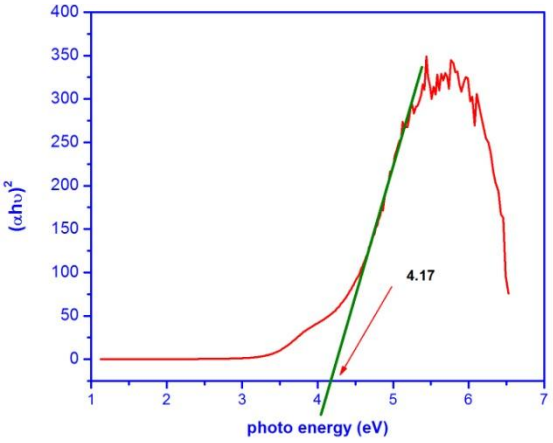

Figure 4: Plot of $(\alpha h\upsilon)^2$ versus photon energy (hυ) .

The I-V characterization was performed with UV illumination and an Agilent B1500A Semiconductor Device Analyzer. Figure 5 shows the rectifying nature of the device in both the condition i.e. dark condition and illuminated condition. From the I-V characteristic shown in figure 5 it is obtained that the forward current increases after the exposure of the light. Under UV light illumination, electron-hole (e-h) pairs are generated in WO_3 film and holes are migrated to the WO_3 surface which then became neutralized by reacting with the oxygen ions. In this manner, the unpaired electron density in WO_3 film increases, which is responsible for an increase in forward and reverse current under UV light illumination. I-V curves are obtained when the nanodevices was exposed to the UV light with wavelength 365 nm at a constant light intensity of 650 µW. At 2 V photo current was 47.5 µA and dark current was 16 µA.

Figure 6 is the plot of current density versus voltage. Current density can be found using formula,

$$currentdensity = \frac{current}{area}$$

Diameter of the contact was 2 mm.

Responsivity(R) of the photo-detector relates the electric current flowing in the device to the

incident optical power. R has units of A/W and It is expressed as,

$$R = \frac{I_P}{P} \text{ .....(2)}$$

where I_P is the photocurrent, and P is the intensity of the optical power.

Responsivity of the device is .0730 A/W at wavelength of 365 nm and with light intensity 650 µW.

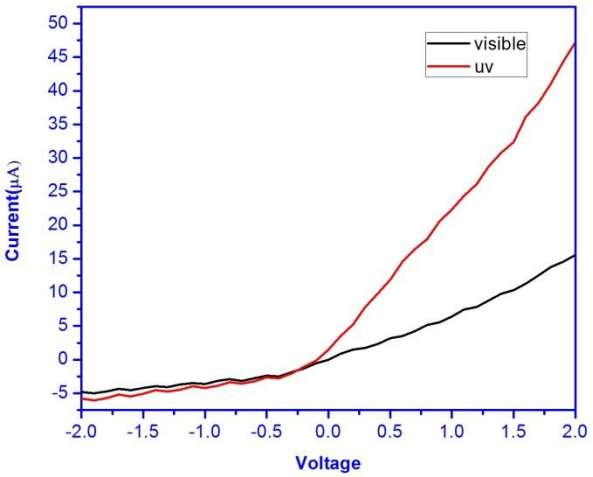

Figure 5: I-V Characteristics of UV Photo-detector.

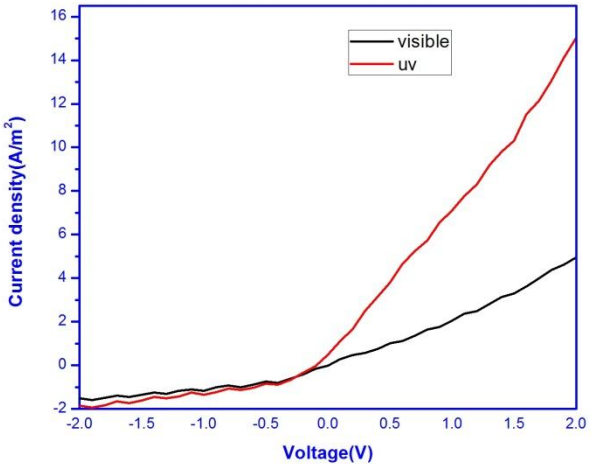

Figure 6: Current density versus Voltage plot of UV Photo-detector.

IV. CONCLUSION

WO_3 nanowires have been synthesized using hydrothermal method. This WO_3 nanowires based UV photo-sensor is very sensitive to UV illumination; an increase in current is obtained under UV illumination at 365 nm with optical power of 650µW. Adsorption of oxygen molecules on the surface of the WO3 nanowires has a significant influence.

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