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Responsivity and Response Time of Nano Silver Oxide on Silicon Heterojunction Detector

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ABSTRACT

In this manuscript, nano and micro silver peroxide and silver oxide thin films have been deposited and grown using a Reactive Pulse Laser Diode (RPLD) technique. The peroxide of silver has been deposited on p-silicon substrates. Annealing of the films has been taken under vacuum above (200 °C -600 °C) to produce oxide films. The I-V characteristics were investigated and discussed. The better reverse current has been changed from 20µA to 16mA in the graph of the curve of the I-V characteristics, the current had changed proportionally with voltage. The responsivity sensing had been sensed more optically for green (560nm) and near IR (840nm).

Keywords: Ag2O3, RPLD, Herostructure, Detector Parameters.

1. INTRODUCTION

Silver is a chemical element with symbol Ag. Silver-oxygen system (Ag-O) was extensively attracted by researchers due to its novel applications in high density optical storage devices, gas sensors, photovoltaic cells, photo diodes and antibacterial coatings. Thin films of metal oxides are known to have spectrally selective characteristics suitable for applications in photo thermal and architectural applications [1-3]. Ag_2O thin film form is a p-type semiconductor with band gap ranging from 1.2 to 3.4 eV due to the deviation in the stoichiometry [4, 5], One of the most important p-type semiconductors with a direct band gap around 1.4 eV is the Silver oxide (Ag_2O) [6-8]. Thin films of this material have some unique physical properties that have attracted much interest [9, 10]. They have been used widely in the batteries electric pole and in the photography [11], as well as in the SERS (surface-enhanced Raman spectroscopy) and in a surface-plasmon (SP) source. Many methods can be used to prepare and deposit the AgOx, such as the (CBD) chemical.-bath deposition. [12], thermal evaporation and (RMS) reactive magnetron sputtering, exposing the films of silver to atomic oxygen environment, and Pulsed Laser Deposition techniques [13].

The reactive Pulsed Laser Deposition uses pure silver targets while feeding it with oxygen gas as a catalyst to increase the interaction between pure silver atoms and gas to obtain and control oxygen composition ratio and to allow the use a low energy of lasers for deposition [14]. The optical properties of AgO_x have been studied previously [15], the correlation between the microstructural features and the process parameters during deposition has not yet been well established. In this work, we studied the optical properties of deposited AgO_x thin films on the glass substrate. The additional analysis by X-ray diffraction results as shown by other research work [16-18].

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As previously mentioned, AgxOx is used in many applications ; oxide nanocrystals and thin films have been intensively pursued for promising applications as a catalyst for ethylene and methanol oxidation , as a sensor for the detection of carbon monoxide and ammonia , as photovoltaic materials , as important components in optical memories and Plasmon photonic devices , or as active cathode materials in silver oxide/zinc alkaline batteries The use of silver oxide thin films in super-resolution near-field structure has been demonstrated to resolve small signals beyond the optical diffraction limit using a combination of optical super-resolution for optical data storage and a scanning near-field optical microscope (SNOM). Recently, a silver oxide thin film has also been used as surface enhanced Raman scattering (SERS) [19-21].

In this paper, we present the PLD as a technique to deposit Ag_2O over substrate of Si. The research continued to study and analyze the effect of annealing temperatures on the growth mechanism of the material and, thereafter, I-V results, Rλ, and Rt are presented and discussed deeply.

2. MATERIAL AND METHODS

Undoped Ag_2O thin films were prepared and deposited on a cleaned slide of glass as a substrate using tattoo removal Nd: YAG laser. The pulse duration of the Q-switched Nd: YAG laser is 7 ns (FWHM) with wavelength= 1.064 nm, the laser beam was focused through a lens with a focal length=10 cm spotted on a silver target (99.999% provided from Fluka com.). The targets spin at a rate of one cycle per minute. The energy density of a pulse laser at the target surface was maintained within the range 57 mJ/cm^2. All prepared thin films were created by 50 laser shots at the temperature of the substrate is 150 ^{o}C. A (P-type) Cuprous oxide (Ag_2O_3) nanostructure thin film was deposited using the RPLD technique, with the aid of halogen lamp at oxidation temperature of (623 K) and (90 sec) as an oxidation time. The calcinations process was done at 250 °C for 30 min in static air within oxygen atmosphere to remove any organics. (Lenton VTF/12/60/700) tube furnace was employed to anneal the prepared samples at 400, 500 and 600 °C, respectively.

The white light response of the photodiode was tested by placing it under illumination of a (100W) tungsten filament lamp, placed 15 cm away. The I-V characteristics were measured using a DC power supply and Keithley electrometer. The spectral responsivity of the photodiode was measured for the spectral range (450-900nm) using a calibrated monochromator. All measurements were carried out at room temperature. The Photoconductive property of semiconductors can be used to determine the excess minority carriers lifetime.

3. RESULTS AND DISCUSSION

3.1 Electrical Measurements of Constructed Device

3.1.1. Current-Voltage Characteristics

Using n-type silicon substrate Ag_2O_3/Si heterojunction device was deposited, the results of the current-voltage (I-V) measurements in the dark for the prepared heterojunctions is shown in figures (1). These characteristics are very important to describe the heterojunction performance and all heterojunction parameters depending on these characteristics. This characterization was used to determine the ideality factor (n) whose value is calculated by the following equation

$$n = \frac{KT}{q} \cdot \frac{\Delta V}{\ln \frac{I_p}{I_s}} \tag{1}$$

These characteristics are very important to describe the heterojunction performance and all heterojunction parameters depending on these characteristics. In this curves, for the I-V characteristics under reverse bias, it is clear that the curve contains two regions; the first is the generation region where the reverse current is slightly increased with the applied voltage and this leads to generation of electron-hole pairs at low bias. In the second region, a significant increase can be recognized the reverse bias is increased. In this case, the current resulted from the diffusion of minority carriers through the junction. We can also note from this figure the rapid incremental in the reverse current at high reverse voltage, which is probably due to the leakage current arising from the surface layer. While the results in the forward bias, two regions are recognized; the first one represents recombination current while the second represents tunneling current. The ideality factor of (Ag_2O_3/Si) junction at optimum conditions of O_2 pressure and substrate temperature was estimated to be 1.3. These values refer to good rectification properties for the prepared junctions. C-V measurement is one of the most important measurements since it determines different parameters such as built-in potential, junction capacitance and junction type.

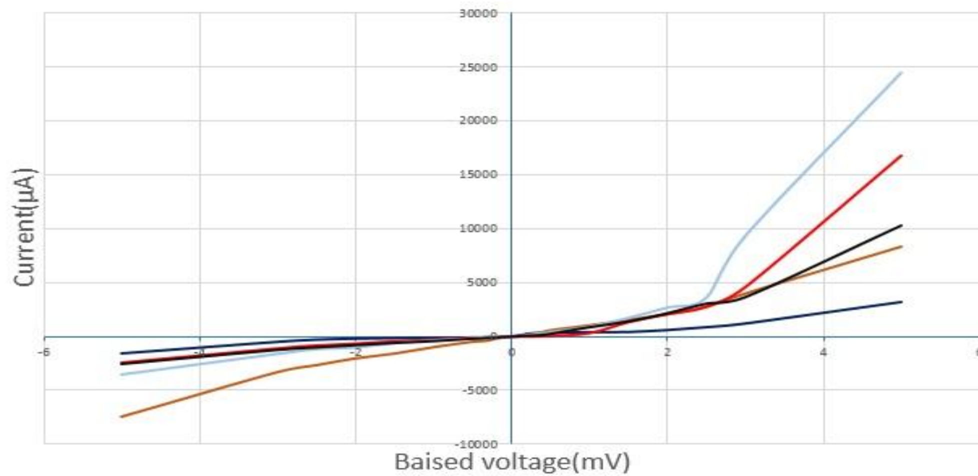

Figure 1. I-V characteristic under forwored and reverse baise.

3.2. Measurements of Device Parameters

3.2.1. Spectral Responsivity (Rλ)

The measurements of the spectral responsivity were performed using a double-beam UIR-210A spectrophotometer operating within the range (0.15-1.1)µm of wavelengths while the current measurements were performed using a 8010 DMM Fluke digital multimeter. The spectral responsivity was determined using the following equation:

$$R_\lambda = \frac{I_{ph}}{P_l} \tag{2}$$

where Iph is the measured photocurrent and Pl is the incident optical power

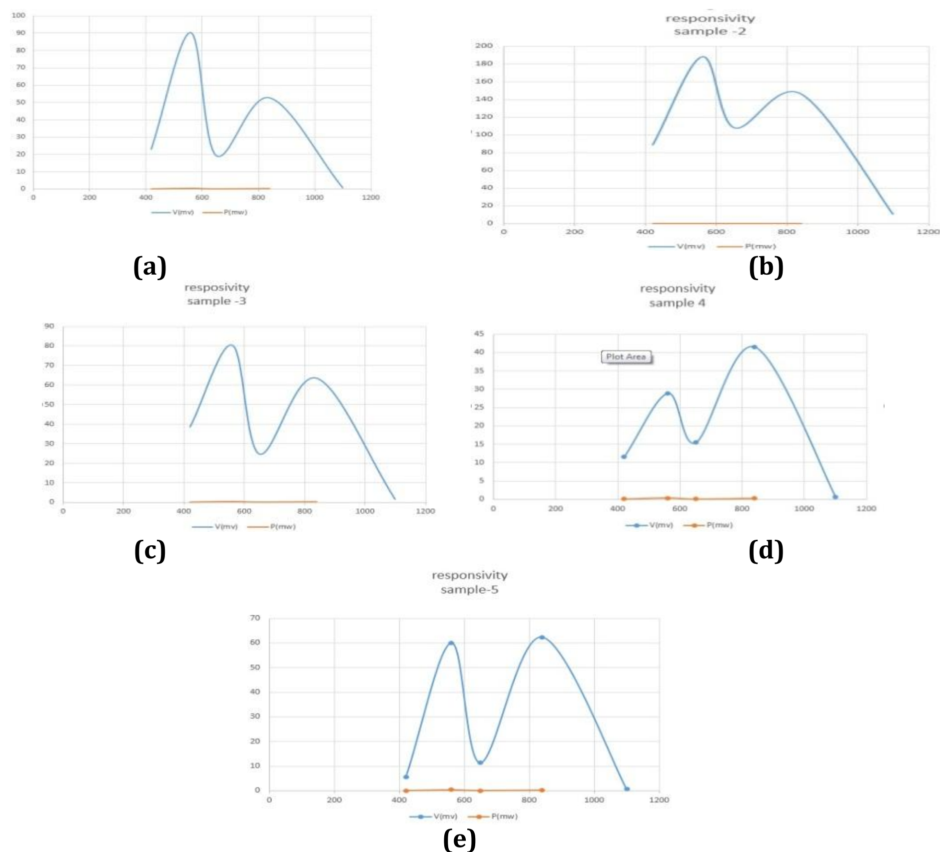

Figure 2. The responsivity characteristics at different annealing's.

We have two packs in this result as it's responsive to the wavelength that used in the experiment these two curves:

One for the silver that responsive for green wavelength
One for the silicon and that is responsive for IR wavelength

Figure (3) give the open voltage decay pulse of the Ag_2O/ Si and we could recognize the long carries life time of about (211 μsec) which give rise in the enhancement of other device photocurrent and quantum efficiency.

Figure 3. Open voltage decay pulse.

Figure (4) presents the obtain the response time pulse from fabricated detector device, which find to be (58.3 μs),

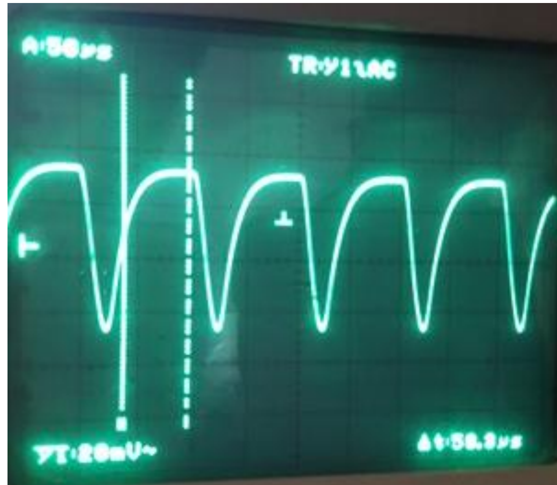

Figure 4. Device rise time.

4. CONCLUSION

The encouraged optoelectronic properties of this heterojunction suggest that it candidate to be visible- enhanced photo detectors. The method of fabricating Ag_2O layer by RPLD method are, cheep, and it is hoped it can be improved either by doping or annealing.

According to the obtained electrical properties a good enhancement in the device performance could be achieve and it could recognize clearly that device has three main peak of the Responsivity, at (650nm). The encouraged optoelectronic properties of this heterojunction suggest that it candidate to be visible- enhanced photo detectors. The photodiode exhibited good rectifying characteristics and the turn-on voltage was around I-V. The C-V measurements showed an abrupt type junction and a diffusion potential of I-V.

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