Fabrication and Analysis of ZnO Based Ultra Violet Photo Detectors on (100) Si Substrates

Saeed Esmaili Sardari, Andrew Berkovich, and Agis A. Iliadis

Department of Electrical and Computer Engineering, University of Maryland, College Park MD 20742 USA, saeedesmaili@yahoo.com

Device fabrication and analysis of thin film zinc oxide (ZnO) based ultraviolet (UV) photo detectors on (100) silicon substrates are presented and electrical characteristics along with optical responses of the devices are investigated. Two types of devices are investigated; one exploits the linear transport characteristics of an Ohmic-ZnO junction (photoresistor), and the other uses the nonlinear characteristics of a metal-ZnO junction. ZnO has a direct wide bandgap of 3.37 eV which makes it a promising material for UV optoelectronic applications [1]. We have employed pulsed laser deposition (PLD) at optimized growth temperature and oxygen pressure to grow high quality ZnO thin films on oxide removed (100) n and p-type Si substrates. The electrical properties of the devices as well as their photo responses under dark and UV illumination conditions are examined. For these conductometric devices, the principle of operation relies on the modulation of ZnO conductivity due to UV illumination [2] [3]. More specifically, excess carriers generated by UV illumination affect the film conductivity which in turn affects the output characteristics of our devices including the resistance or the slope of the IV characteristics for photoresistors and rectification properties for Schottky diodes. Photoresistors are fabricated by deposition of two Ohmic contacts on ZnO to exploit linear IV properties while Schottky diodes use the rectification properties of the metal-semiconductor (MS) junction; thus, for one of the two contacts of the device, a Schottky material is used. Standard lithography process has been employed to etch ZnO thin film and deposit metal contacts. Following the band alignment theory and the reported values of ZnO's electron affinity (χ_e= 4.5 eV), bandgap, and the work functions of several materials [4], Al (Φ_M= 4.06 — 4.26 eV) was selected as the Ohmic contact for ZnO/n-Si and Schottky for ZnO/p-Si devices. Au (Φ_M= 5.31 — 5.47 eV), on the other hand, was selected as the Ohmic contact for ZnO/p-Si and Schottky for ZnO/n-Si devices [5].

Our results confirm the successful fabrication of Ohmic and Schottky devices with an average contact resistance of 9.4 Ωcm^2 for Al/ZnO/n-Si structure and significantly lower resistance of 2.0 Ωcm^2 for Au/ZnO/p-Si devices. Based on our experimental calculations, Schottky barriers of 3.5 eV for Al/ZnO/p-Si and 0.88 eV for Au/ZnO/n-Si are formed which are in good agreement with theoretical values [6]. Finally, optical modulation~~s~~ of the output characteristics are observed for photoresistors and Schottky diodes. Maximum sensitivities of 1.51 Ω.μW for the photoresistor and 78 V^{-1} at -81 mV for the diode were both achieved at 365 nm UV illumination. Figures 1 and 2 show the output characteristics of a photoresistor and a Schottky diode under dark and UV illuminated conditions respectively.

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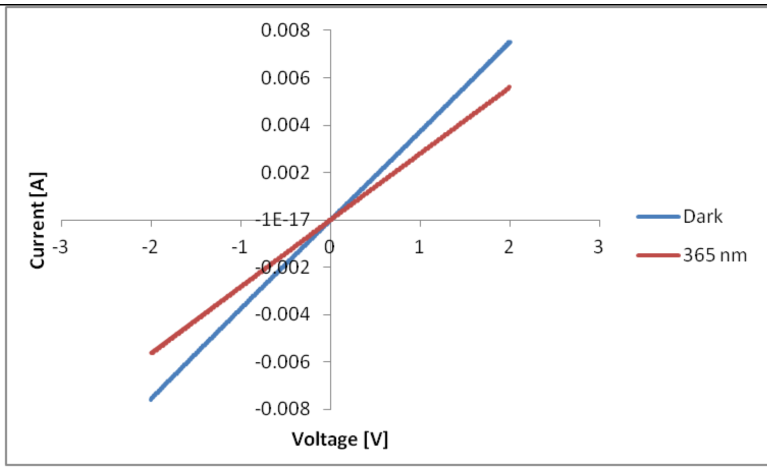

Figure 1. The IV characteristics of a ZnO/n-Si photoresistor grown at low oxygen overpressure and 300 ^{o}C. The response of the device is derived at 365 nm.

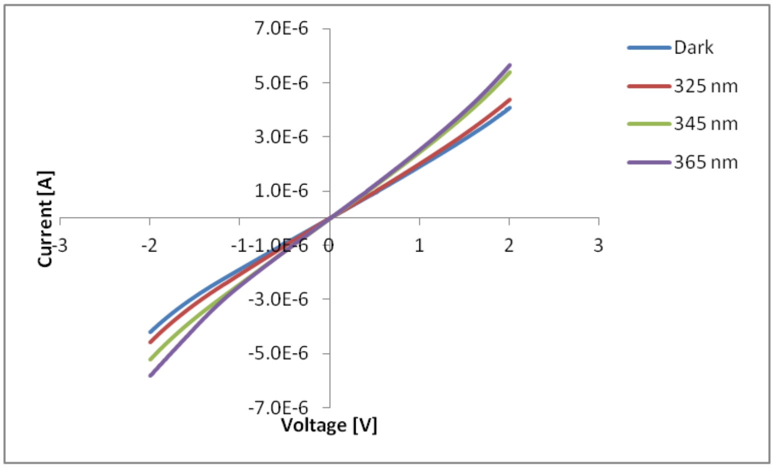

Figure 2. The IV characteristics of a ZnO/p-Si Schottky diode grown at high oxygen overpressure and 300 ^{o}C. The differences between dark and light (λ=320, 345, and 365 nm) responses of this device are evident.

References

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