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Fabrication and characterization of Al:ZnO based MSM ultraviolet photodetectors

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ABSTRACT

This work reports fabrication and characterization of aluminum doped zinc oxide (AZO) thin films based metal–semiconductor–metal (MSM) ultraviolet photodetectors. AZO thin films were grown on Si substrates at room temperature by radio-frequency magnetron sputtering method. Four interdigited metal–semiconductor–metal (MSM) devices with equal inter-electrode spacing and width of 5 μm, 10 μm, 20 μm and 50 μm were fabricated by lithography. Palladium was used as metal electrodes and ultraviolet (UV) light of wavelength 372 nm and power 2.8 μW is used as a UV source. The variation in the value of dark current and photo current according to inter electrode spacing were examined for all the four MSM photodetectors. It was seen that in both conditions (under dark as well as under UV illumination), the current decreases as the spacing between electrodes increases. The results show that the effect of inter-electrode spacing on the dark current is more significant than that of photo current. These investigations will be useful for designing high-performance optoelectronic devices based on AZO thin films.

1. Introduction

Ultraviolet (UV) or solar-blind photodetectors are having a large range of application in space research, ozone layer monitoring, missile warning systems, high temperature flame detection and environmental monitoring, etc. [1,2]. In recent times, wide-band-gap materials like gallium nitride (GaN), aluminum gallium nitride ($Al_xGa_{1-x}N$), boron gallium nitride (BGaN), silicon carbide (SiC), diamond, zinc oxide (ZnO) and magnesium zinc oxide ($Mg_xZn_{1-x}O$) are being explored extensively for selective UV photodiodes applications [3–7]. Among these particularly, ZnO thin film based UV detectors have made much progress because of ZnO's significant properties including ease of availability, high exciton binding energy (60 meV), large photo response and excellent radiation hardness [8–11].

In order to further improve the electrical and optical properties of ZnO thin films, some impurities such as Ga, Al and In are being used by different research-groups nowadays [3,12]. Among these, Al doped ZnO (AZO) thin films have attracted much attention because of its some merits like non-toxicity, thermal and chemical stability and low-cost synthesis etc [12–14].

ZnO and AZO thin films can be grown by various methods, including hydrothermal, sol–gel, RF sputtering and thermal evaporation, etc. [12–17]. Among these above mentioned methods, RF sputtering method is commonly used method for deposition of thin films because of its low-cost, simplicity and high efficiency. Although, AZO thin film based devices were

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studied by many groups yet very few groups have reported on Al:ZnO MSM photodetectors for ultraviolet (UV) applications till now. Xu et al. reported sol–gel deposited AZO based UV photoconductive detectors with Au interdigited electrodes. The photo-generated current for their device was 58.05 mA at a bias of 6 V [14]. Mamat et al. reported AZO nanorods array based UV photoconductive sensors. They have investigated the performance of their sensors with annealing in the air or in oxygen ambience [15]. Inamdar et al. investigated effect of buffer layer deposition on the performance of UV photodetectors. They fabricated photodetectors based on ZnO and AZO thin films grown on the ZnO buffer layer coated on glass substrate by a spray pyrolysis method [18]. The AZO-based UV photodetectors with ZnO buffer layer shows a maximum photoresponsivity of about 340 A/W. Till now, no any groups have reported about study of current–voltage (*I–V*) characteristics of AZO based MSM UV PDs with different inter-electrode-spacing. In this work we investigated the dependence of dark current and photo current of MSM PDs, with increasing inter-electrode spacing experimentally.

2. Experiments

2.1. Deposition of AZO thin films

Initially Si substrates were cleaned by Radio Corporation of America (RCA) solutions, RCA-1 and RCA-2 and then dipped and cleaned with DI water. The DI water was obtained from the Milli-Q water plant (Millipore, USA) and it's resistivity was 18 M Ω cm. AZO thin films were deposited on Si substrates by RF magnetron sputtering system, the base pressure and sputtering pressure were, 10^{-5} mbar and 2.6×10^{-3} mbar respectively. The target used in the RF magnetron sputtering system was a ceramic target with mixture of ZnO and Al_2O_3 (with 99.99% purity). The Al_2O_3 was added 2% in weight to the ZnO sputter target. The sputtering power, distance between sputter target and substrate and the argon (Ar) gas flow rate were 100 W, 7 cm and 30 sccm respectively.

2.2. Fabrication of interdigited electrodes

MSM photodetectors were fabricated onto the as-grown AZO thin film samples with the help of photolithography technique. An array of four interdigited electrode patterns was designed on the AZO/Si sample. The inter-electrode spacing (*s*) and width (*w*) of these MSM devices were kept same and it was 5 μm, 10 μm, 20 μm and 50 μm for MSM-1, MSM-2, MSM-3 and MSM-4 respectively. Each device consists of total 10 (i.e. five pairs) fingers with a length of 500 μm. Prior to photolithography on AZO samples, the samples were cleaned by isopropanol (IPA) and acetone and dehydrated at 120 °C for 5 min. The photoresist S1813 was applied on the samples using a spin coater. The samples were prebaked for 2 min at 90 °C on a hot plate and afterward subjected to UV illumination with help of double sided mask aligner (DSA). After UV exposure through DSA, the pattern was developed in a MF319 developer for 25 s and the substrate was then cleaned with DI water. At the last the samples were post-baked for 3 min at 90 °C.

After lithography, blanket deposition of Pd metal (with 100 nm thickness) was done, above patterned AZO thin film samples. Pd was deposited using metal sputter system, the sputtering power; base pressure; deposition rate and Ar flow rate

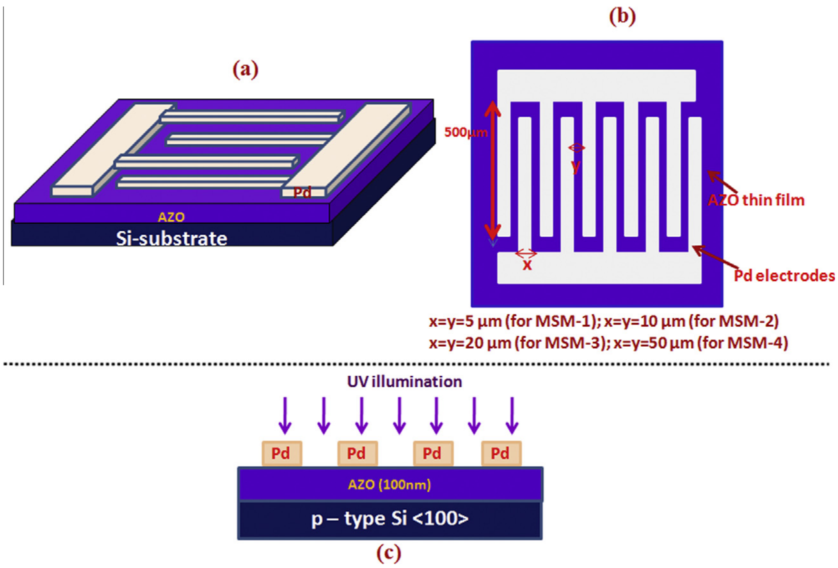

Fig. 1. (a) Schematic cross-sectional view of MSM photodetectors. (b) Schematic top view of MSM photodetectors. (c) Schematic diagram of MSM Photodetectors working under UV illumination.