Fabrication of heterostructure with MoS_2 layers and GaN for photoresponsive device application

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Introduction: Gallium nitride (GaN) is one of the most suitable substrate for heteroepitaxy of molybdenum disulfide (MoS_2) layers for novel optoelectronic device applications.[1,2] GaN has been widely used for light emitting diodes (LEDs), photodiodes and high power electronics devices. In this prospect, the lattice matched MoS_2/GaN heterostructures is a promising and practically applicable technology for photodiode and other applications. In this work, we report on the deposition of MoS_2 few-layers on free-standing GaN wafer and observation of the photovoltaic photoresponsivity in the fabricated heterojunction device.

Experimental: Molybdenum oxide (MoO_3) (approximately 0.1g) was deposited on the surface of GaN using thermal evaporator. Subsequently, sulfurization was carried out at a temperature of 750 ºC in argon and hydrogen gas mixture. Indium (In) electrode were deposited on GaN and two electrodes, namely gold (Au), aluminum (Al) were deposited on MoS_2 layers. Current density-voltage (J-V) measurements were carried out using two probe system and Keithley 2401 Source Meter. In addition to the above, further material analysis was done to understand the device characteristics.

Results and discussion: A rectifying diode and photovoltaic photoresponsivity were obtained under monochromatic light illumination for the fabricated MoS_2/GaN heterojunction. Irrespective of the metal contacts on the MoS_2 layers a photovoltaic action was obtained in the MoS_2/GaN heterojunction fabricated device. The open circuit voltage (V_{oc}) was 0.09 V and 0.2 V, where the short circuit current density (J_{sc}) was 0.002 mA/cm^2 and 0.054 mA/cm^2 for the devices with Al and Au electrodes, respectively. The photoelectron spectroscopy analyses showed a significant valance band offset in the fabricated heterojunction and a suitable conduction band offset, which signifies the presence of a junction potential. A photovoltaic photoresponsivity was obtained for both the fabricated devices with different electrodes due to presence of a suitable band alignment at the heterointerface of MoS_2 and GaN.

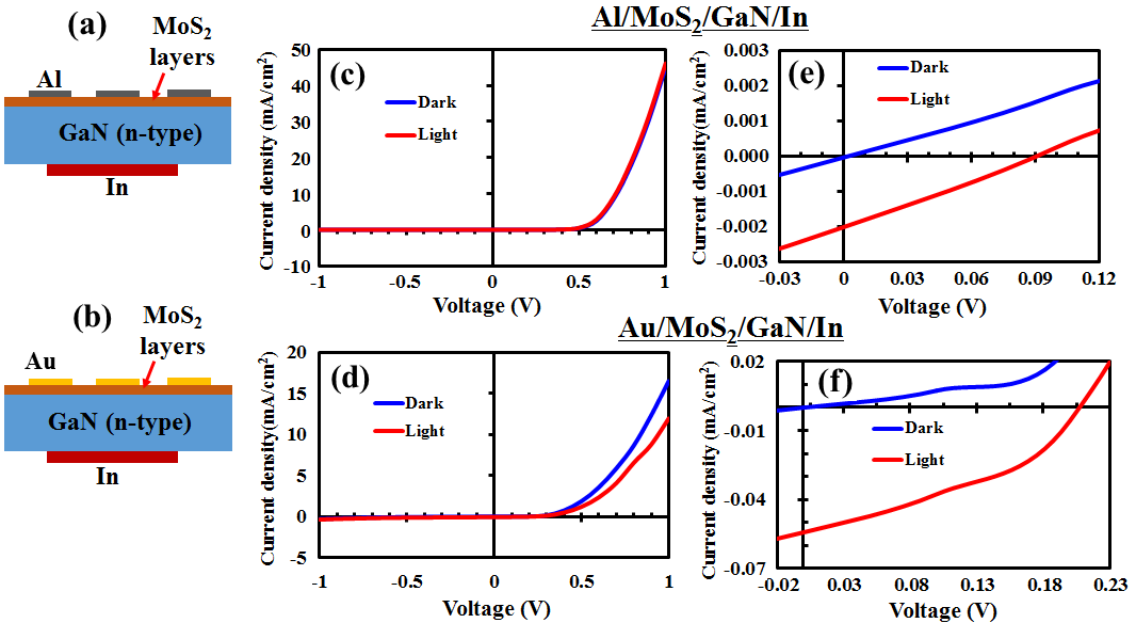

Figure (a),(b) Schematic diagram of the MoS_2/GaN heterojunction device with Al and Au electrodes on the MoS_2 layers. (c,d) J-V characteristics with and without light illumination in voltage range +1 to -1 V with Al and Au electrodes (e),(f) J-V characteristics under dark and light presenting the photovoltaic action for the device with Al and Au electrodes.

Reference 1. Ruzmetov, D. *et al.* ACS Nano 10, 3580-3588 (2016). 2. Zhang, K. et al. Nanoscale 10, 336-341 (2018).