Abstract

Recent trends in research on optoelectronic applications have concentrated on metal-chalcogen based heterostructures due to their large light absorption coefficient, high responsivity, excellent separation efficiency of photogenerated charge carriers, and band gap tunability. Among various metal di-chalogenides such as MoS_2, $MoSe_2$, WS_2 and WSe_2, SnS_2 is one of the promising materials in this field due to its wide spectral response, and non-toxicity. One way to improve the performance of SnS_2 is to fabricate heterostructure with other functional materials having suitable band alignment such as silicon (Si). In the present study, four different types of photodetector devices were fabricated based on SnS_2 and Si nanowires (SiNW) heterostructures (SnS_2/SiNW) to understand their photoresponse behaviour. We have started with a high-quality SnS_2/SiNW heterostructure which was fabricated using a straightforward metal assisted chemical etching of a silicon wafer (to obtain SiNW) and wet chemically synthesized SnS_2 by spin coating. The fabricated photodetector was found to exhibit a photoresponsivity of 3.8 A/W, a specific detectivity of 10^{14} Jones, and an on/off ratio of 10^2 at zero bias at 340 nm wavelength. In addition, the heterostructure photodetector showed significantly encouraging values of the key parameters (responsivity ~ 5.3 A/W, detectivity ~ 7.5 X 10^{12} Jones, rise/decay time ~ 0.4 s/0.4 s,) at -2 V bias over a wide spectral range of 400 – 1100 nm. Then to improve the parameters, a detector with core-shell heterostructure consisting of SnS_2/SiNW was fabricated to get an advantage of larger interfacial area. The core-shell photodetector provided showed a responsivity of 383 A/W, and external quantum efficiency (EQE) of 1.3 x 10^5 %. However, maximum performance could not be achieved due to trapped charges in the defects in SnS_2. To passivate the defects, UV-treatment was performed on SnS_2/SiNW core-shell heterostructure. The UV-treated heterostructure device exhibited excellent photoresponsive behaviour compared to the untreated one with a responsivity of ~10^3 A/W, EQE ~ 10^6 %, and rise/decay time ~10 ms/40 ms. Finally, with an aim of improving the device performance further, we introduced Au nanoparticles of size 5 nm in SnS_2 to derive the benefit of localized surface plasmon effect for photocarrier enhancement. As a result of the plasmonic effect, it showed an excellent responsivity of 447 A/W which was found better than the SnS_2 /SiNW core-shell device mentioned earlier. Also the value of the EQE was found to be ~ 1.7 ×10^5 % at -2 V at 340 nm. Out of these four types of fabricated devices, investigated in the present work, the defect passivated SnS_2/SiNW core-shell device is found to have better performance than the others. The proposed device with great potential could be explored further to pave the way to integrate optoelectronic devices with silicon microelectronics for future technological advancement for the photodetection applications.

Keywords: *SnS_2/Si nanowire heterostructure, Core-Shell, EQE, Responsivity, Low-power photodetector, Defect passivation, UV treatment, Plasmonic.*