Abstract

Core-shell nanowire (NW) radial heterojunctions have gained recent interest in electronic and optoelectronic applications over its planar counterparts due to quantum confinement, high photon absorption, light trapping, and efficient carrier collection in an effective way. In this dissertation, we have studied the fabrication and characterization of p-Si/n-InP core-shell NW radial heterojunction on Si (100) substrates with an aim to monolithically integrate Si microelectronics with III-V semiconductor-based optoelectronics for the development of futuristic core-shell nanostructure-based devices for optoelectronic applications. The structure was fabricated by low-cost metal assisted chemical etching method for preparing SiNWs, followed by the growth of n-InP layer on SiNWs by metal organic chemical vapor deposition. The electrical properties of the core-shell structure showed the p-n junction diode-like behavior. It exhibits higher output current rating and rectification ratio along with lower reverse saturation current compared to a conventional planar Si/InP heterojunction diode. The optical reflectivity of core-shell NW arrays was found to be around 2.5% in the wavelength range 300 -1100 nm. Due to such superior light trapping and higher optical absorption, as a proof of concept, two different optoelectronic devices, viz. a photodetector and a solar cell were fabricated and studied using this structure. The core-shell NW heterojunction based photodetector was found to have good photodetection capability under illumination with different wavelengths of light. The transient response property of the device shows a fast, steady, and reproducible response in the infrared regime. The device showed a maximum responsivity and detectivity of 2.749 A/W and 5.52×10^{11} Jones, respectively, at 920 nm wavelength under a reverse bias voltage of 2 V. The photodetection properties indicate that the structure is suitable for an efficient near-infrared detector. In other work, a solar cell was designed with p-Si/n-InP core-shell NW structure and it was found to play a significant role in improved solar cell performance in comparison with conventional NW based solar cell. The external quantum efficiency was found to achieve its peak value of 59% as the substantial portion of the infrared part of the solar spectra matches well with the characteristic bandgap of the InP in the core-shell structure. The open-circuit voltage was found to be 0.56 V with a corresponding short circuit current density of 14.26 mA/cm^2 under AM 1.5 solar radiation. The solar cell was found to have a conversion efficiency of 4.39%. Surface defects in etched SiNWs act as effective recombination centers, leading to the degradation of the cell efficiency. Results of the study reported in this dissertation indicate that p-Si/n-InP core-shell NW structure could be a promising candidate for photonic and optoelectronic applications.

Keywords: Si Nanowires; Core-shell; Radial heterojunction; Photodetector; Solar cell.