Abstract

The study on quantum confined Si nanostructures and mechanically flexible Si is a promising field of research due to their potential applications in CMOS compatible novel optoelectronic and photonic devices. One dimensional Si nanocone templates or black Si with their capability of forming radial heterojunctions and quantum confined Si nanocrystals with size tuneable emission characteristics are very promising for high performance optical sources and detectors. Whereas, ultra-thin Si membranes can be utilized to fabricate heterojunction based mechanically flexible and efficient optoelectronic devices. In this dissertation, we have studied optoelectronic properties of black Si template based radial heterojunctions, Si nanocrystals embedded in SiO_2 matrix and mechanically flexible direct band gap semiconductor heterojunctions on Si membranes.

Conical CdS/ black Si heterojunction arrays have been fabricated by metal assisted chemical etching technique followed by deposition of CdS film by pulsed laser deposition system to study the light emission characteristics of CMOS compatible light emitting devices. A broad band electroluminescence (EL) ranging from 450 to 860 nm is achieved at room temperature on applying a low forward bias. The EL emission appears yellowish white in colour with CIE chromaticity coordinates of (0.35, 0.41) and improved light extraction characteristics controlled by nanocone textured geometry of black Si. Using the same black Si templates, MoS_2/Si nano-conical heterojunction based broad band photodetector has been fabricated by spin coating MoS_2 quantum dots on black Si. The unique light trapping mechanism in black Si has increased the overall absorbance of the fabricated heterojunction, resulting in an enhanced broad band photoresponse with peak responsivity of 1.39 A/W at ~665 nm for 5 V bias.

Beside black Si templates, Si nanocrystals embedded in SiO_2 matrix have been fabricated and developed into wavelength tuneable optical sources. The plasma enhanced chemical vapour deposition (PECVD) grown SRO films were annealed at different temperatures to form Si nanocrystals of different diameters. Typical red-shift in EL peaks is observed with increasing annealing temperature confirming the formation of quantum confined Si nanocrystals of different diameters. Both Fowler-Nordheim tunnelling and direct tunnelling contributes in the current conduction mechanism through the active light emitting layer.

To explore the mechanical flexibility, ultra-thin Si membranes (~3 to 5 µm thick) were fabricated by anisotropic chemical etching. Using these Si membranes, mechanically flexible heterojunction optoelectronic devices were fabricated by depositing ZnO thin films using RF sputtering technique. The fabricated heterojunction exhibited UV-visible photoresponse having a responsivity of 0.20 AW^{-1} and detectivity of 4.8×10^{11} jones for zero bias. Strain induced piezo-phototronic effect in piezoelectric ZnO thin films, enhanced the photoresponse performance of the device. With a gradual increase in the external tensile stress, the photocurrent increases by 22%. In addition, a broad band and mechanically flexible LED was fabricated based on ZnO/Si membrane heterojunction, having similar device structure. The device exhibits EL in a wavelength range of 400-850 nm at room temperature under forward bias condition. Results of the study reported in the dissertation indicate that there exists innovative opportunities to integrate Si-based, CMOS compatible optoelectronic devices for future photonic integrated circuits.

Keywords: *Black Si, Si nanocrystals, quantum confinement, photodetectors, LEDs, radial heterojunctions, electroluminescence, flexible Si membranes, piezo-phototronics.*