Optical studies and defect properties of GaP/GaNP core/shell nanowires

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Abstract

III-V core/shell nanowires (NWs) have recently attracted much attention due to their potential applications in optoelectronic and photonic devices, in particular solar cells and LEDs. Among all III-V compounds, GaP-based materials have the smallest lattice mismatch to Si and are, therefore, the best candidate for epitaxial growth of III-V materials on Si substrates. Adding a small amount of N to GaP allows one to tune the band gap energy and also to change the band gap character from an indirect one in GaP to a direct-like one in the GaNP alloys, leading to improvements in light emission efficiency. Unfortunately, the above described properties desired for optoelectronic applications have not been fully utilized, largely due to degradation of optical and electrical properties caused by defects present in GaNP. The growth of these materials in the form of NWs offers the possibility to overcome the limitations. In this work, we investigate optical properties and influence of defects on optical quality of the GaP/GaN_xP_{1-x} core/shell NWs grown on Si (111) substrates employing temperature-dependent photoluminescence (PL), time-resolved PL and optically detected magnetic resonance (ODMR) measurements.

The GaP/GaN_xP_{1-x} core/shell NW samples with x = 0.9% studied in this work were grown by gas-source molecular beam epitaxy (MBE). For a comparison, a 250 nm-thick $GaN_{0.009}P_{0.991}$ epilayer grown by gas-source MBE on a (001)-oriented GaP substrate was also investigated. Scanning electron microscopy (SEM) showed that the GaP/GaNP NWs are uniform in sizes and have an axial length of about 2.5 μm, a total diameter of about 220 nm, and a typical diameter of the GaP core of ~110 nm.

By using a variety of optical characterization techniques we demonstrate the NWs grown on Si substrates have an excellent optical quality that is comparable to that of the GaNP epilayer grown on GaP substrates. In all structures, the PL spectra have the same line shape and originate from radiative transitions within N-related localized states. However, the core/shell NW samples have weaker PL intensity and faster PL decay at room temperature, indicative for a higher defect density leading to efficient nonradiative recombination. From the performed ODMR measurements, the responsible defects most likely involve a P atom at their core and are located either at the GaP/GaNP interface or at the GaNP surface. The high defect density in the NWs is tentatively attributed to a high surface-to-volume and interface-to-volume ratios in these structures.