Wang, Xue, “MBE Growth and Characteristics of Antimonide-Based Quantum Dots”

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Semiconductor quantum dots (QDs) are an important class of low dimensional materials for optoelectronic applications since they offer the possibility of three-dimensional carrier confinement. Among III-V semiconductor material systems, antimony-based QDs hold the promise for the realization of low threshold room-temperature mid-IR lasers because of the low band gap energy (0.17 eV at 300K) of InSb and the large lattice mismatch between InSb and GaSb. The fabrication of InSb/GaSb self-assembled QDs for optoelectronic applications by Molecular Beam Epitaxy (MBE) is ventured in this dissertation.

Here both uncapped and capped self-assembled InSb QDs are fabricated by MBE on nominal GaSb (100) ±0.1o and GaSb (100) having an offcut ±6o toward [110]. The growth conditions are optimized to obtain QDs with both high density and good uniformity. The influence of growth parameters (i.e. substrate temperature, nominally deposited thickness, annealing time and substrate orientation) on QD size, uniformity and distribution are systematically studied. The structural and optical properties of these QDs are characterized using in-situ Reflection High-energy Electron Diffraction (RHEED), and ex-situ Atomic Force Microscopy (AFM) and Photo-Luminescence (PL) measurements. Confined energy levels in the strained InSb/GaSb QD system are estimated theoretically and compared with the experimental results.

Three-dimensional uncapped InSb QDs were successfully grown on GaSb (100) substrates at a density of 2.8×109 /cm2 by MBE via the Stranski-Krastanov mode of self-organization. This mode works off the strain arising from the mismatch between the substrate and the epilayer. The average base side length of the resulting QDs is 100±24 nm and the height is 4.9±1.6 nm. The best size uniformity, with standard deviations of 23% for base length and 48% for height was obtained under the optimized growth conditions of 3.9ML material deposition, a growth temperature of 405ºC, and 60 seconds of post growth annealing.

The 3D uncapped InSb QDs were grown on GaSb (100) ±6º substrates. QD density increased from 1.3×109/cm2 on normal substrates to 2.1×109/cm2 on off-axle substrates under the same growth conditions. PL energies of 0.75eV from the QDs and 0.79eV from the WL were observed from InSb QDs embedded on the GaSb (100) ±0.1º substrates, which agree with the theoretical calculation.

The study provides a large set of experimental data on the fabrication of InSb QDs and discusses their importance in the development of quantum dot optoelectronic devices, such as serving as the active layers in lasers.