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Effect of Growth Temperature of GaAs/$Al_{0.4}Ga_{0.6}As$ Lower Cladding Layer on the Photoluminescence Intensity of InAs/Sb:GaAs Quantum Dots Monolithically Grown on Ge/Si Substrate by MOCVD for Laser Application

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1. Introduction

Since the proposal by Arakawa and Sakaki [1], research on quantum dots (QDs) and its application to the next-generation photonics devices have been gaining increasing interest, due to their 3-D quantum confinement properties. Recently, Ge-based Si substrate has drawn considerable attention for the direct growth of III-V-on-Si [2] for silicon photonics application. QD laser grown by molecular beam epitaxy (MBE) on Ge/Si substrate has been recently demonstrated [3]. However, metal organic chemical vapor deposition (MOCVD) is preferred over MBE for industrial application and fabrication of QD laser by MOCVD is of great interest. Here, we report on the effect of growth temperature of GaAs/$Al_{0.4}Ga_{0.6}As$ lower cladding layer (LCL) on the photoluminescence (PL) intensity of InAs/Sb:GaAs QDs monolithically grown on Ge/Si substrate by MOCVD.

2. Experimental details, results and discussions

The samples were grown by low pressure MOCVD on Ge/Si substrate. A 800 nm thick high structural quality i-GaAs buffer layer with a low surface roughness was first grown on Ge/Si substrate by a three-step growth method [2]. Further, a 1.2 μm n-GaAs (1 $x10^{18}$ cm^{-3}) layer was grown at 650^{o}C, followed by a 1.4 μm n-$Al_{0.4}Ga_{0.6}As$ (6 $x10^{17}$ cm^{-3}) LCL, and a 100 nm i-GaAs capping layer (Fig. 1 inset (i)). Al(Ga)As/Ge/Si wafer was then cooled down for the growth of QDs. High density (above 4 x 10^{10} cm^{-2}) coalescence free InAs/Sb:GaAs QDs (Fig. 1 inset (ii)) emitting at 1.3 μm were grown according to Sb-SMG technique [4,5]. The study involves samples with the LCL grown at 650, 675, and 700^{o}C respectively. Fig.1 compares the room temperature (RT) PL spectra of the samples with the LCL grown at different temperatures. Of considerable significance is that, the PL intensity of the ground state transition of QDs was found to critically depend on the growth temperature of the LCL. The strongest PL intensity for QDs is obtained from the sample with the LCL grown at 700^{o}C. The increase in the PL intensity of QDs may be attributed to the reduction in the density of defects propagating to the QD active layer and improvement in the structural quality of the LCL grown at higher temperatures. Fig. 1 inset (iii) shows the dependence of RMS surface roughness of GaAs/$Al_{0.4}Ga_{0.6}As$ layer on the growth temperature as determined by 10 x 10 $μm^2$ AFM scans. The surface roughness increases with increase in the growth temperature. At higher growth temperatures (above 650^{o}C) surface pits with a diameter of ~ 0.3 μm appears, and the pit density increases with temperature. However, substantial reduction in both, the surface roughness and pit density was observed, when the LCL grown at 700^{o}C was capped by i-GaAs layer grown at lower temperature (~ 650^{o}C) (not shown here).

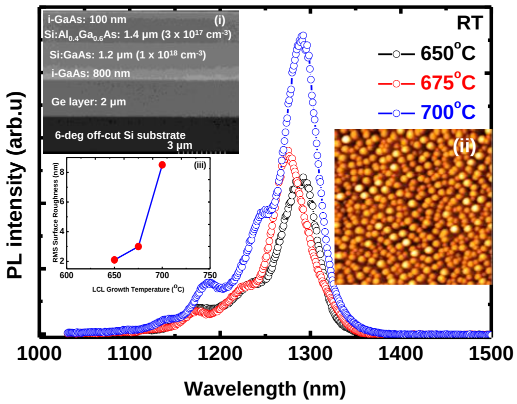

Figure 1 compares the RT PL spectra of QDs grown on Ge/Si substrate at different growth temperatures of LCL. Inset (i) shows cross-sectional SEM image of the sample, (ii) 1 x 1 $μm^2$ AFM image of the uncapped InAs/Sb:GaAs QDs (iii) dependence of RMS surface roughness on the LCL growth temperature.

3. Conclusions

We have demonstrated that the RT PL intensity of InAs/Sb:GaAs QDs grown on Ge/Si substrate is strongly dependent on the GaAs/$Al_{0.4}Ga_{0.6}As$ LCL growth temperature, with the highest PL intensity observed for LCL grown at 700^{o}C. These results are promising for the realization of a QD laser monolithically grown on Si substrate by MOCVD for silicon photonics application.

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