SiGe Planar Microcavities With Strain-Balanced SiGe/Si Distributed Bragg Reflectors

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SiGe planar microcavities with strain-balanced distributed Bragg reflectors (DBRs) were successfully grown on relaxed SiGe virtual substrates, and their optical properties were investigated.

The samples were grown on Si(001) substrates by gas-source molecular beam epitaxy. As virtual substrates, 2 μm relaxed $Si_{0.89}Ge_{0.11}$ layers were grown on graded buffers at 680 °C followed by annealing at 800 °C to enhance the relaxation of the buffers. A bottom DBR with 39 pairs was fabricated by growing quarter-wavelength-thick Si and $Si_{0.73}Ge_{0.27}$ layers alternatively on the virtual substrates. On the DBR mirror, a one-wavelength-thick $Si_{0.73}Ge_{0.27}$ cavity layer with five Si/Ge quantum wells (QWs) was successively grown. A two-pair Si/CaF_2 DBR was fabricated as a top mirror by electron-beam deposition.

The strain balancing of the $Si_{0.73}Ge_{0.27}$/Si DBRs was confirmed by Raman spectroscopy. That is, Si-Si vibration modes of the Si and $Si_{0.73}Ge_{0.27}$ layers showed shifts of -4 cm^{-1} and 6 cm^{-1} due to the tensile and compressive strain, respectively, indicating that the DBR layers were grown psudomorphicaly on the virtual substrate. X-ray diffraction spectrum of the DBR also showed the clear satellite peaks reflecting the periodicity of the DBR layers.

A reflectivity spectrum of the 38.5-pair DBR mirror is shown in Fig. 1. A large improvement of the reflectivity was realized compared with conventional SiGe/Si DBRs on Si substrates, and a record reflectivity of approximate 90% was achieved at 1.32 μm. It is noted that the loss of reflectivity due to the deterioration of the crystalline quality coming from strain accumulation is hardly seen, and it is confirmed that the strain balance method is very effective to fabricate thick Si/Ge heterostructures.

Figure 2 shows PL spectra of the SiGe microcavity structure. A sharp luminescence line with the width of 17.5 nm can be seen at 1312 nm, which corresponds to the resonant wavelength of the microcavity. It is also seen that compared with the conventional Si/SiGe quantum wells, the spectral width is drastically narrowed. The directionality of the luminescence is seen to be generated by the formation of the microcavity as shown in Fig. 3. These results clearly show that the microcavity effects are achieved in the present SiGe planar structures and the luminescence is well modulated as expected.

In conclusion, we fabricated strain-balanced SiGe/Si DBRs with high reflectivity on the relaxed SiGe virtual substrates and observed modulated luminescence from SiGe microcavites composed of the DBRs and Si/Ge QWs, which may realize optical inter-connection on Si substrates. These results promise to develop microcavity optical devices.

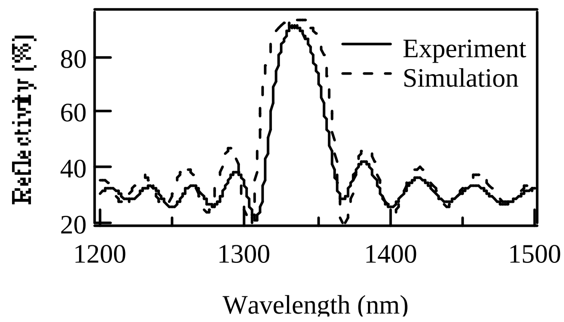

Fig. 1 Room-temperature reflectivity spectrum of the 38.5-pair DBR.

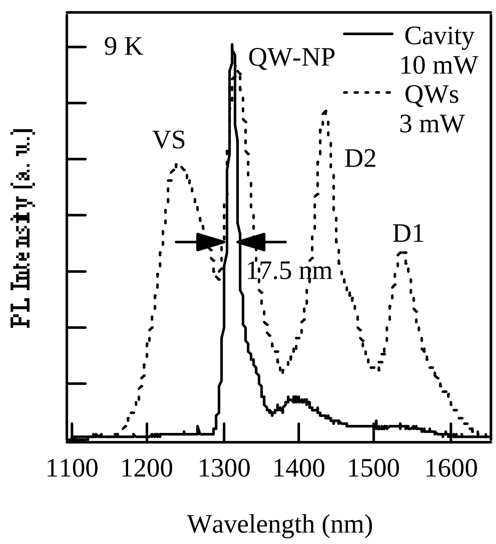

Fig. 2 PL spectra at 9 K.

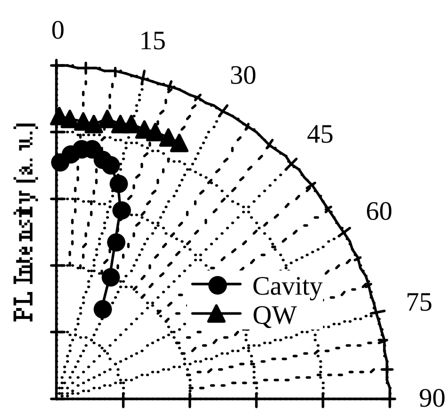

Fig. 3 Angular dependence of PL intensity.