Optical characterization of strain-compensated $Ge/Si_{0.16}Ge_{0.84}$ multiple quantum wells on silicon-based germanium virtual substrate

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Recent progresses in Si photonics suggest that Si-based materials could provide a strong support for the technological integration of optical functions in CMOS microelectronics. In this perspective, SiGe alloys are of particular interest because they can be epitaxially grown on Si substrates and are compatible with a large number of standard Si processes and CMOS technology. Bulk mobilities of SiGe alloys with high Ge content are higher than those of Si for both electron and holes. Moreover, SiGe technology allows the integration on Si substrates of high speed electronics devices.

In Ge, the direct gap at the Γ point is only 140 meV above the indirect fundamental gap at room temperature and the direct gap energy is within the range of wavelengths used in telecommunications. Ge/SiGe multiple quantum well (MQW) structures with Ge-rich barriers have attracted more attention because their optical properties are expected to exhibit close analogies to those of III-V direct-gap semiconductors. Recently, a strong quantum Stark effect associated with the direct-gap interband transition has been observed in strained Ge/SiGe MQW on relaxed Ge-rich SiGe buffers by photocurrent and transmission spectroscopy and electro-absorption modulators based on this effect have also been demonstrated [1,2].

In this study, a strain-compensated $Ge/Si_{0.16}Ge_{0.84}$ multiple quantum well (MQW) structure grown on a Ge-on-Si virtual substrate (Ge-VS) was characterized by using temperature dependent photoreflectance (PR) and piezoreflectance (PzR) techniques. Signals from every relevant portion of the sample, including Ge-VS, MQW and barriers were observed. The band gap blue-shifted and valence band splitting in the vicinity of the direct band-edge transitions of Ge revealed that the Ge-VS is compressively strained. This result provides useful information for crystal grower. The existence of compressive strain actually is contrary to the direction of recent technological development trend, where tensile strain has been used to shift the direct transitions in Ge/SiGe MQW stacks closer towards the telecommunication C-band. A comprehensive analysis of the PR and PzR spectra led to the identification of various quantum-confined interband transitions. In addition, the parameters that describe the temperature dependence of the excitonic transition energies were evaluated and found to be similar to that of the bulk Ge.

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