Multitechnique Characterization of Sandwiched Si/SiGe/Si Heterostructures

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In recent years, much interest has arisen in the growth of strained layer $Si_{1-x}Ge_x$/Si and related structures, and the application of SiGe/Si quantum structures for heterojunction bipolar transistors, infrared detectors using intersubband transitions and other devices. These materials and structures can be easily incorporated into the well-developed Si integrated technology, promoting new developments of electronic and optoelectronic devices.

Molecular beam epitaxy (MBE) is a suitable technique for the growth of $Si_{1-x}Ge_x$, which was attempted in early years at a high growth temperature (T_g), for example, of 750°C. In order to decrease the misfit dislocation density and grow pseudomorphical films, efforts have been explored to employ the buffer interlayer structure or grow these heterostructures at sufficiently low T_g.

In this study, we have prepared Si/SiGe/Si sandwiched structures by MBE at a very low temperature of 450°C. They were characterized by various techniques, including x-ray diffraction (XRD), Raman scattering (RS), photoluminescence (PL), Fourier transform infrared (FTIR) spectroscopy, secondary ion mass spectroscopy (SIMS), Rutherford backscattering spectrometry (RBS) and ion channeling.

The XRD measurements confirmed the single crystallinity and the (100) orientation of $Si_{1-x}Ge_x$ layer. The Ge compositions and layer thicknesses were precisely determined by RBS. Ion channeling indicated good crystalline perfection. Raman spectra exhibited the characteristic Ge-Ge and Ge-Si vibration modes and the Ge-Si alloying features. Low temperature PL measurements for the as-grown sample without any annealing or special treatment showed a broad luminescence band centered around 0.8 eV [10]. After D-passivation, the SiGe no-phonon free exciton line at ~0.97 eV and its phonon replicas at ~0.95 and 0.91 eV appear sharply. FTIR revealed the vibration modes of Si-O-Si from the oxidation on surface and Si-H due to the hydrogenization during growth. The SIMS depth profiles showed that the Si cap/SiGe interfaces are sharp with slight Ge interdiffusion only.

A more detailed investigation is underway. This interdisciplinary analysis deepens our understanding on the properties and physics of MBE-grown SiGe alloy layers in these microstructures, which is useful for fabrication of SiGe-Si superlattices and quantum well devices as well as nano-scale structures.