A comparative analysis of the interface roughness and abruptness of SiGe/Si strained superlattices by means of XRD, RBS, TEM and SIMS techniques

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We study compressively strained SiGe/Si(001) superlattices (SLs) grown by Ultrahigh Vacuum Chemical Vapor Deposition from SiH_4 and GeH_4 gas sources. The influence of the growth temperature on the interface roughness and abruptness is underlined. For that purpose, two samples were grown at different temperatures keeping identical nominal Si and SiGe thickness (20 nm and 7 nm) and Ge content (0.30). The structural characteristics of these seven-period SLs are assessed by means of High Resolution X-Ray Diffraction (HR-XRD), Rutherford Backscattering Spectroscopy (RBS), Cross-sectional Transmission Electron Microscopy (XTEM), and Secondary Ion Mass Spectroscopy (SIMS).

As revealed by TEM micrographs, the first SL fabricated at 625°C exhibits vertically self-aligned SiGe thickness undulations smoothed out after Si overgrowth. Their amplitude and periodicity increase up to ~11 nm and ~120 nm along the growth direction. Stranski-Krastanov growth mode enhancement by a localized strain field is usually evoked to explain this phenomenon. By lowering the temperature down to 600°C, the SiGe-to-Si interfaces become flat and the transition regions appear abrupt. A computer processing of the XTEM images is performed to evaluate the interfaces abruptness linked to Ge segregation.

The strain state, Si and SiGe layers thickness and the Ge content of these SLs are determined by simulating the (004) HR-XRD spectra on the basis of the dynamical theory. Thickness and composition values are compared with those obtained by fitting RBS spectra. The superperiod is corroborated by SIMS and XTEM micrograph analysis, while the correlation length is assessed by means of XTEM and x-ray reciprocal space mapping.

Discrepancies between the results from the different methods are discussed together with the technique limitations. Finally, we show how such a comparison can be helpful in assessing the morphology, the strain-state and the interface roughness and abruptness.