A comparative study of strain field in strained-Si on SiGe-on-Insulator and SiGe virtual substrates

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We performed a comparative study of strain field in strained-Si grown on SiGe-on-insulator (SGOI) and SiGe virtual substrates, and clarified the origin of the strain fluctuation in the strained-Si film. A periodic strain fluctuation, which reflects the strain field of underlying cross-hatch pattern, was observed in the sample on the virtual substrate. On the other hand, a feature-less strain fluctuation with suppressed amplitude was observed in the sample on SGOI substrate. By analyzing the correlation of the Raman peak positions of the Si-Si mode in strained-Si and SiGe, the compositional fluctuation in SiGe was found to be the origin of the strain fluctuation.

The fabrication process of SGOI substrate contained growth of 8nm amorphous Ge layer on a commercially available 30nm Si-on-Insulator (SOI) substrate using a solid-source molecular-beam-epitaxy (MBE) system, deposition of 300nm protective SiO2 cap layer, and thermal treatment at 1100°C for 1 hour. By this simple process, SiGe (001) single crystal layer with relaxation ratio of more than 70% can be fabricated as confirmed by electron back-scattering pattern analysis (EBSP) and X-ray measurements.[1][2] The SiGe virtual substrate was grown by a gas-source MBE system (AirWater VCE-S2020) with SiH4, GeH4 and H2 as source gases on a Si (001) substrate at 700°C, which consisted of compositionally step-graded Si1-xGex (x=0-0.22) and 1µm uniform Si0.78Ge0.22 layers. Both on SGOI and SiGe virtual substrates, 15nm-thick strained-Si layers were grown. Spatially-resolved micro-Raman spectroscopy (Tokyo Instruments Nanofinder) was carried out to investigate the strain fluctuation as well as its origin in strained-Si layer.

Figure 1 shows a typical Raman spectrum of strained-Si on SGOI. The three peaks located approximately at 508cm⁻¹, 515cm⁻¹ and 520cm⁻¹ are assigned as coming from the Si-Si vibration mode of the SGOI, the strained-Si layer, and the Si substrate under the buried oxide layer, respectively. The amount of the strain in strained-Si on SGOI was estimated to be 8.1x10⁻³ by the liner equation ε=-∆ω/832, where ∆ω is the shift of the strained-Si peak from the Si substrate peak in cm⁻¹. It is noted that this value is large enough to enhance the mobility of the electron, but is lower than 8.9x10⁻³, which is estimated from coherently strained-Si on fully relaxed Si0.78Ge0.22. The residual strain in SGOI would be relaxation ratio of more than 70% can be fabricated as confirmed by electron back-scattering pattern analysis (EBSP) and X-ray measurements.[1][2] The SiGe virtual substrate was grown by a gas-source MBE system (AirWater VCE-S2020) with SiH4, GeH4 and H2 as source gases on a Si (001) substrate at 700°C, which consisted of compositionally step-graded Si1-xGex (x=0-0.22) and 1µm uniform Si0.78Ge0.22 layers. Both on SGOI and SiGe virtual substrates, 15nm-thick strained-Si layers were grown. Spatially-resolved micro-Raman spectroscopy (Tokyo Instruments Nanofinder) was carried out to investigate the strain fluctuation as well as its origin in strained-Si layer.

In summary, strained-Si on SGOI was shown to have less strain fluctuation compared with that on the SiGe virtual substrate, which shows that SGOI is promising as a substrate for strained-Si. Reduction of the compositional fluctuation in SGOI will be effective for further reduction of the strain fluctuation to improve the carrier mobility in strained-Si.

This work was in part supported by Industrial Technology Research Grant Program of NEDO.