AN 407
Raman Mapping of Strained Si/SiGe

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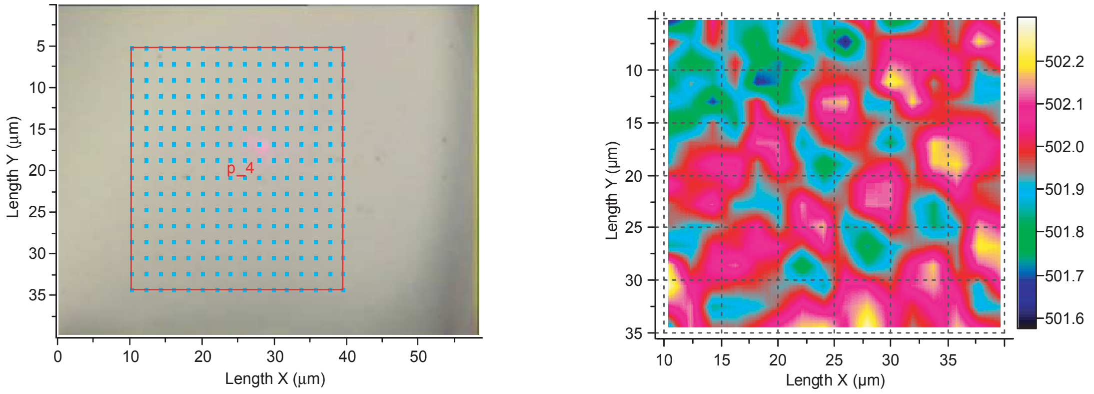
Discussion

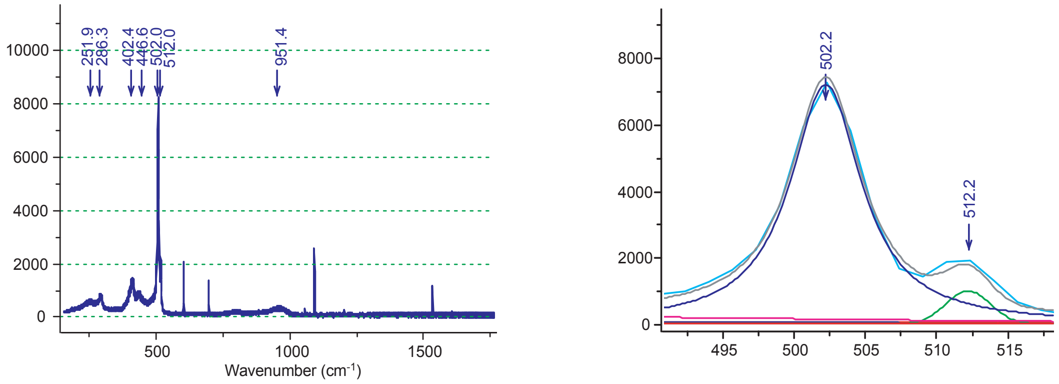
Lateral heterogeneity of strain in strained Si/SiGe materials can be a serious problem for the manufacturability of high mobility ICs that use these materials.

Visible Raman spectroscopy is used to probe the lateral strain in the underlayer SiGe of strained Si on Si$_{(1-x)}$Ge$_x$ substrate structures (cf. "In-plane strain fluctuation in strained-Si/SiGe heterostructures," Sawano et al, Appl Phys. Lett. V83, p. 4339, 2003). These structures typically have a thin (~10 nm) strained Si layer on top of a thicker (~ microns) SiGe layer on a Si substrate. A square area (~30X30 micron) was mapped using a visible Raman spectrometer excited with an Ar+ ion laser (514.5 nm wavelength, 1 mw in the sample, 1 micron spatial resolution) (Figure 1). The map represents the strained Si-Si spectral band in the SiGe underlayer. Unlike the UV Raman, the visible source results in a much deeper penetration, i. e. , analysis of the stress in the underlying SiGe layer.



Optical view of a Si-SiGe sample surface where probed area is marked

Raman map of strain



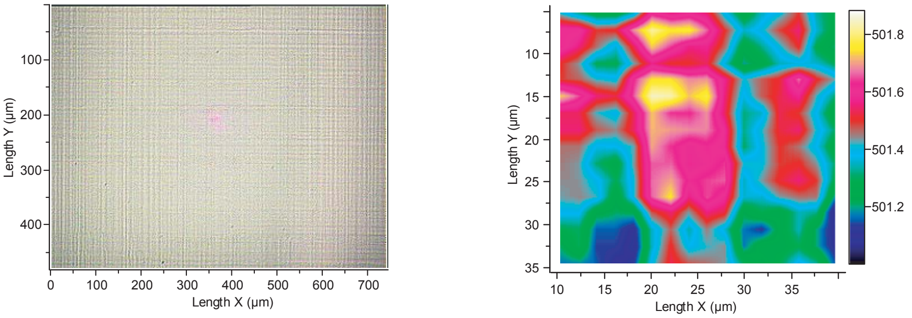
Raman spectra of the area

Individual Si-Si bands of SiGe (502 cm^{-1}) and of strained epi Si (512 cm^{-1})

Figure 1. Mapping of Si-Si Mode of SiGe

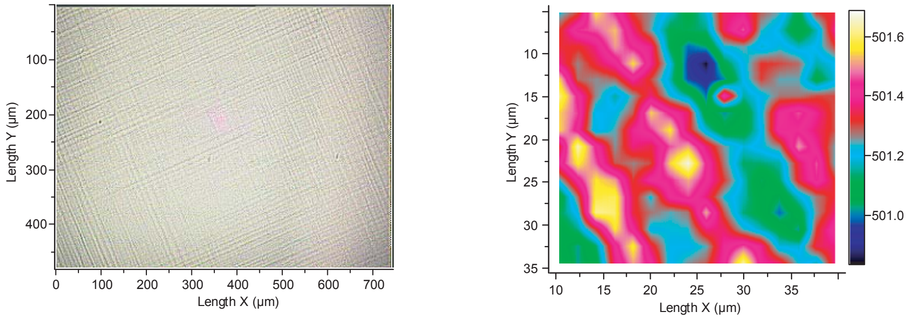
A clear pattern of wavenumber emerges along the <110> directions and is conserved when the physical sample was rotated with ~45° around the Z-axis (Figure 2). The Si-Si wavenumbers (in the SiGe) depend both on the Ge concentration and on the residual, unrelaxed strain developed in the SiGe due to lattice mismatched systems heteroepitaxial grown of SiGe beyond its critical thickness. The lattice mismatch results in the formation of misfit and associated threading dislocations which lead to the characteristic cross-hatch pattern typically seen on the Si strained epilayer surface. The Si-Si wavenumber pattern in the SiGe layer should be a stress related pattern caused by the strain developed in the SiGe layer and not to any latteral Ge distribution on the micron scale, as the Raman mapping (imaging) mimics the cross-hatch usually observed optically (Figure 2) or through AFM. The lateral scale of stress variations depends on the individual samples and is found to be from 4 to 12 micron (ridge to ridge) with a stress range up to 0.2 GPa. The lateral scale of 12 microns is close to the cross-hatch pattern of the optical image of the sample (Figure 2) and is comparable to the threading dislocation densities of 10^6/cm^2.

As the penetration depth of 514.5 nm light is ~0.5 micron in SiGe samples with ~30 % Ge, the strain cross-hatch pattern is related to the same stress distribution developed through the entire layers of Si-SiGe, which are ~ few microns thick.



Optical view of Si-SiGe sample surface with cross-hatch pattern

Raman map of strain, which corresponds to left optical view



Optical view of Si-SiGe sample rotated 45°

Raman map of strain for rotated sample

Figure 2. Cross Hatch Pattern

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