ESRF	**Experiment title:** Investigation of Ge diffusion in perfectly laterally ordered Ge and Cge quantum dots on Si by in-situ grazing incidence x-ray diffraction at high temperatures	**Experiment number**: SI-511
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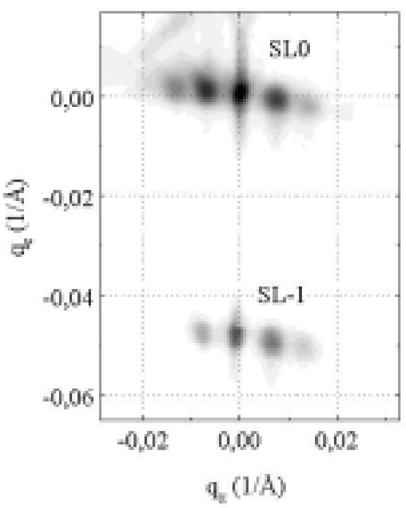
Report:

The original purpose of the measuring time was to investigate the changes in self-assembled small SiGe islands at interfaces in SiGe/Si superlattices during annealing at 900°C in high vacuum. However, it was not possible to operate the high vacuum furnace at such high temperatures and we decided to perform another measuring program.

We have investigated self-organized one-dimensional structures of the interfaces in a SiGe/Si a superlattice. The superlattice has been grown by MBE method on a Si (001) substrate misoriented by 3.5 deg and it consisted of 20 periods, each period contained a $Si_{0.55}Ge_{0.45}$ layer nominally 25Å thick and a Si spacer 100Å thick. Due to the large crystallo-graphic miscut of the substrate, a self-organized stepped structure at the interfaces has been created during the growth, leading to the formation of laterally ordered Ge rich wires. This self-organization process can be described by means of the concept of the lateral movement of monolayer steps during epitaxial growth [1]. Due to the strain in the growing layer the monolayer steps agglomerate and a sequence of mesoscopic steps and terraces results. In our previous work [2] we have used small-angle x-ray scattering for the investigation of the form of the terraces and for the correlations of their positions in the superlattice. We have demonstrated that these correlations substantially depend on the surface distribution of the strain originating in the buried stepped interface.

In this report we show the first results of the investigation of the strain distribution by means of coplanar high-resolution x-ray diffraction. We have measured the reciprocal space distributions of the intensity diffracted by the superlattice close to the reciprocal lattice points 004 (symmetrical Bragg-case diffraction), 404 and 044 (asymmetrical diffractions). An example of the reciprocal space map is shown in figure 1. In the map, both the 0^{th} and -1^{st} vertical su-



perlattice satellites can be seen (denoted by SL0 and SL-1, respectively). Close to the main (coherent) superlattice satellites lateral ones appear, due to the lateral ordering of the steps and wires at the interfaces. The distance of these satellites is inversely proportional to the mean distance L between the steps, from the map we have determined $L = (850 \pm 50)\text{Å}$.

Figure 1
The reciprocal space map of the SiGe/Si multilayer close to 404 reciprocal lattice point. q_x and q_z axis are parallel to the crystallographic axes, their origin is in SL0.

In the left panel of figure 2 we have plotted the cuts of the measured map parallel to q_x-axis crossing the SL0 and SDL-1 satellites. It is obvious that the heights of the lateral satellites are not symmetrical with respect to the q_z-axis, and in addition, this asymmetry is different in SL0 and SL-1 vertical satellites.

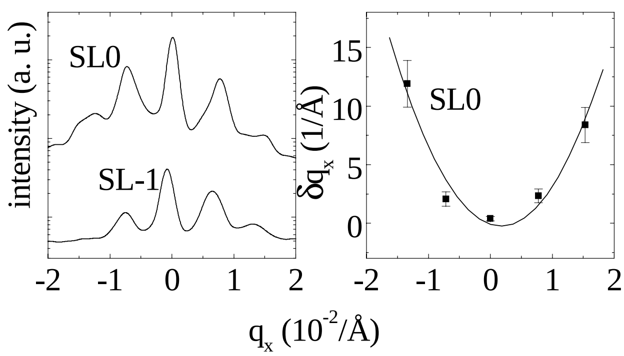


Figure 2.
Cuts of the measured reciprocal space map across SL0 and SL-1 satellites (left). The widths of the lateral satellites and their parabolic fit (right).

As we have shown previously in the case of self-assembled quantum dots [3], this asymmetry is caused by the strain distribution below and above the stepped interface. In the region of reciprocal space close to SL0, the intensity is mainly determined by the strain status in an area distant from the step, while the close neighborhood of the step is responsible for the intensity distribution in the region around SL-1.

The widths of the lateral satellites obey a parabolic law indicating that the steps are laterally arranged according to a short-range order model. From these widths we have determined the root mean square deviation of the step distances to $\sigma = (80 \pm 20)\text{Å}$.

In conclusion, high-resolution coplanar x-ray scattering is a very suitable tool for the investigation of morphology and strains in superlattices with self-organized stepped interfaces and wires. From the measurement we have determined the mean distance of the steps and wires as well as their mean deviation. The distribution of the deformation field around the steps will be determined by a detailed comparison of the measured data with simulations based on elasticity theory and kinematical x-ray diffraction.

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[3] V. Holy, A. A. Darhuber, J. Stangl, S. Zerlauth, F. Schaeffler, G. Bauer, N. Darowski, D. Luebbert, U. Pietsch and I. Vavra, Phys. Rev. B **58**, 7934 (1998).