	Experiment title: Grazing incidence diffraction on quantum dots: discrimination of composition and strain	**Experiment number:** SI-549
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Report:

Using surface sensitive x-ray diffraction, based on three dimensional intensity mapping of selected regions in the reciprocal space, self-assembled dots were analyzed with a method which yields both the shape, the lattice parameter distribution and the vertical interdiffusion profile on a sub-nanometer scale [1]. In addition we report on results which were not yet published so far: Quantum wires can be realized either by lithography and etching techniques or via self-assembled epitaxial growth, using regular steps induced by step-bunching as a template for the formation of wires. X-ray scattering is very suitable for the investigation of such structures, especially for buried interfaces. We have investigated MBE-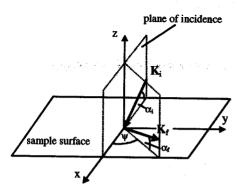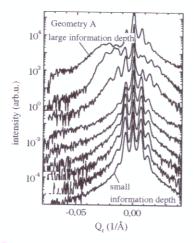grown SiGe/Si superlattices with 20 periods of $Si_{0.55}Ge_{0.45}$ (25Å)/Si (100Å) grown on a Si substrate misoriented from (001) by 3.5°. Due to this large misorientation (miscut), a nearly periodic pattern of (001) terraces and steep steps has been created at the interfaces during the growth, this structure acts as a sequence of one-dimensional quantum wires.

The structure of the quantum wires has been investigated by grazing incidence small angle x-ray scattering (GISAXS) at ID10B using the wavelength $\lambda = 1.5545$Å. The experimental arrangement and the coordinate axis system is shown in Fig. 1. We have measured a series of scans keeping the incidence and the exit angles $\alpha_{i,f}$ constant and changing the scattering angle ψ in two azimuthal positions of the sample: A – perpendicular to the wires (the wires are parallel to the x-axis) and B – parallel to the

Figure 1: Sketch of the method

wires (wires are parallel to y-axis). The laterally periodic arrangement of the wires gives rise to a periodic sequence of intensity maxima in reciprocal space positioned at the points of a one-dimensional reciprocal lattice with the lattice constant $2\pi/L$, where L is the wire period. In the arrangement A, the variable scattering vector $\mathbf{Q} = \mathbf{K_f} - \mathbf{K_i}$ nearly intersects these lattice points giving rise to a sequence of intensity maxima in the scans (see Fig.2). In the B geometry, the vector $\mathbf{Q}$ is perpendicular to the one-dimensional reciprocal lattice and no intensity maxima can be observed.
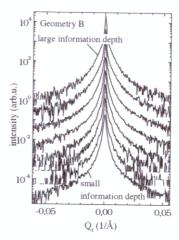

Figure 2. GISAXS scans measured in both azimuthal directions A and B. Changing the angles $\alpha_{i,f}$ we tune the depth in the sample, where the scattered intensity comes from (the information depth).

From the distance of the intensity maxima in the arrangement A (the left panel in Fig. 2) we have determined the mean width of the terraces (i.e. the period of the quantum wire array) to be $L = (900\pm50)$ Å. The envelope curve of the intensity maxima sensitively depends on the mean shape of an individual wire.

From the width of the maxima the degree of periodicity of the wire array can be determined. In Fig. 3 we show the result of a numerical simulation of a GISAXS scan. In the simulation, we assumed a short-range-order model of the wire array and a partial replication of the positions of the wires at subsequent interfaces in the multilayer [2,3]. From the simulation we have determined the angle β of the terrace with the mean interface: $\beta=(0.7\pm0.2)°$. Since this angle is much smaller than the miscut angle (3.5°), the terraces are not atomically flat and they contain monoatomic steps as well. The angle χ determining the direction of the replication of the terrace positions was estimated to be $\chi = (25\pm5)°$.
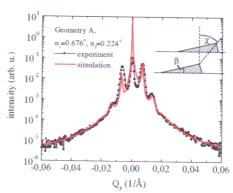

Figure 3. Measured and simulated GISAXS scan

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