ESRF	**Experiment title:** Investigation of laterally ordered interface and surface structures by grazing incidence diffraction and reflection measurements	Experiment number: **SI-562**
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Shifts: 18	**Local contact(s):** Dr. Salvador FERRER (e-mail: ferrer@esrf.fr)	*Received at ESRF:*

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Report:

Self-assembled epitaxial growth is a promising method in semiconductor technology yielding superlattices with nearly regularly laterally patterned interfaces. The periodicity and homogeneity of the lateral patterning is substantial in order to obtain optically active structures. X-ray scattering is very suitable for the investigation of these parameters 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 and the strain distribution of the quantum wires has been investigated by grazing incidence diffraction (GID) at ID03 using the wavelength λ=1.213 Å. The experimental arrangement is sketched in Fig. 1. Similarly to GISAXS, changing the input and the exit angles $\alpha_{i,f}$ we can tune the information depth. We have measured two-dimensional distributions in scattered intensity in reciprocal space (reciprocal space maps – RSMs). In all the measured RSMs the measured reciprocal plane was parallel to the one-dimensional reciprocal lattice corresponding to the wire array. In the longitudinal arrangement, the diffraction vector is parallel to the scan direction, in the transversal arrangement, the diffraction vector is perpendicular to it. .

The elastic displacement field $\mathbf{u}(\mathbf{r})$ enters the formula for the scattered intensity in the scalar product $\mathbf{h}.\mathbf{u}(\mathbf{r})$. Since the wires are very long, the displacement vector $\mathbf{u}$ is always perpendicular to them. Therefore, the longitudinal scans are extremely sensitive to the deformation field, whereas the transversal scans do not depend on the deformation at all. In these scans, the intensity distribution depends only on the chemical composition.

The measured RSMs are plotted in Fig. 2. In the transversal RSM, the central part of the map has been omitted and it has been measured in a separate RSM (middle panel). In the RSMs, several characteristic features can be seen. In both the transversal and longitudinal arrangements, the wire periodicity is manifested by a periodic sequence of intensity maxima along the horizontal $Q_{\|}$ axis. The intensity distribution along a particular maximum depends on the correlation of the wire positions at different interfaces. If these positions are correlated, the intensity is concentrated in sheets, their distance is $2\pi/D$, (D is the superlattice period) and their angle with the horizontal axis equals the replication angle χ defined in figure 3. This behavior is quite obvious in the transversal RSMs, where the intensity distribution is not affected by the strain field. In the longitudinal RSM, the strain field affects mainly the envelope curve of these maxima giving rise to a lateral asymmetry of the intensity pattern. Up to now we have succeeded in the numerical simulation of the transversal RSMs only. An example of the results is shown in Fig. 3. The simulations of the longitudinal scans along with the calculations of the elastic strain field of a buried wire array are in progress.

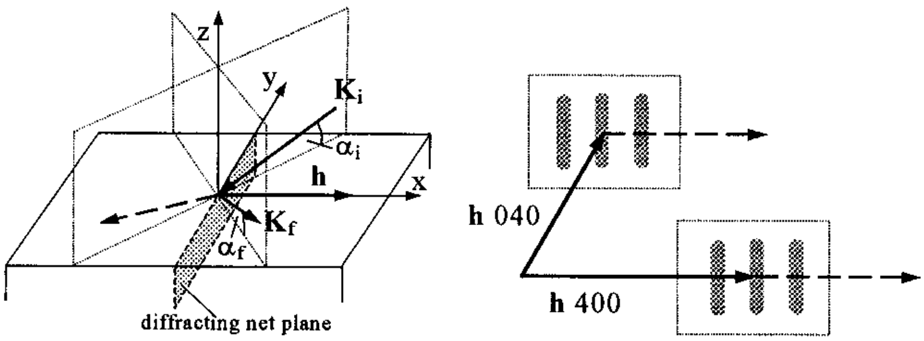

Figure 1. Sketch of the GID geometry in real space (left), longitudinal (400) and transversal (040) scans in reciprocal space (right). The gray stripes denote the satellite maxima cause by the wire array, the dashed arrows represent the scan

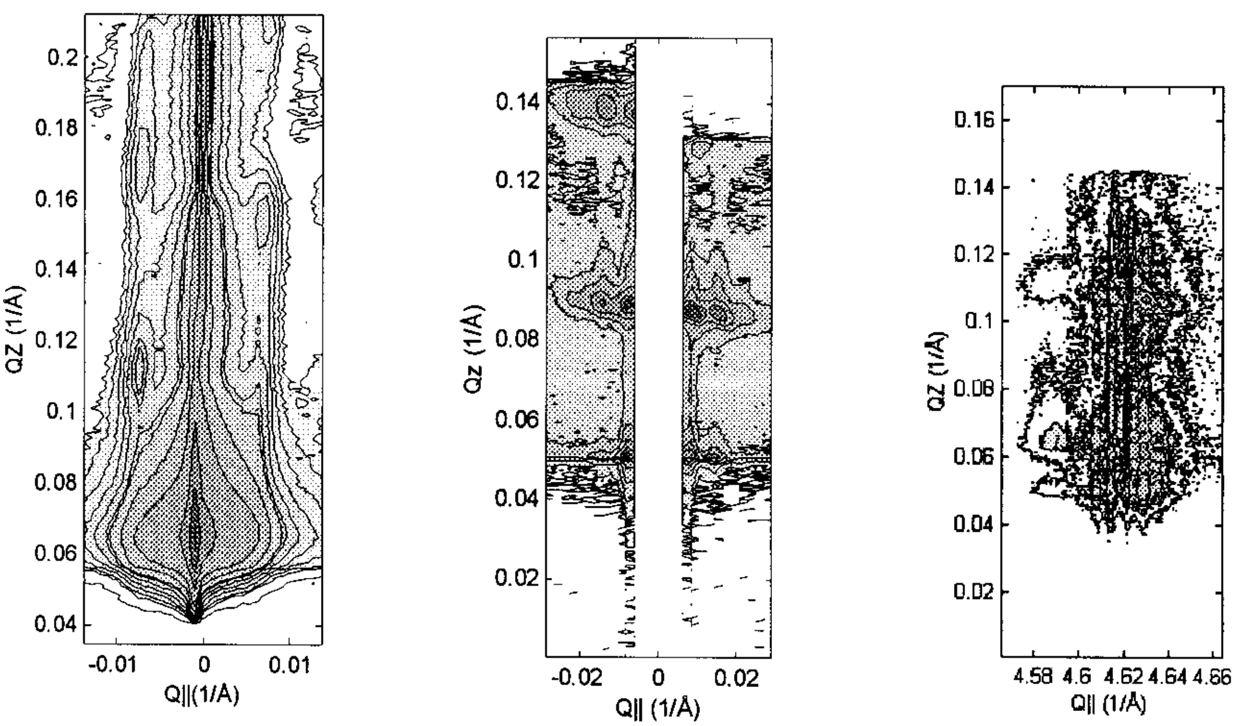

Figure 2. The GID reciprocal space maps in transversal (left and middle panels, in the middle panel the central part of the intensity is shown) and longitudinal (right panel) geometries. The asymmetry of the longitudinal RSM is clearly visible.

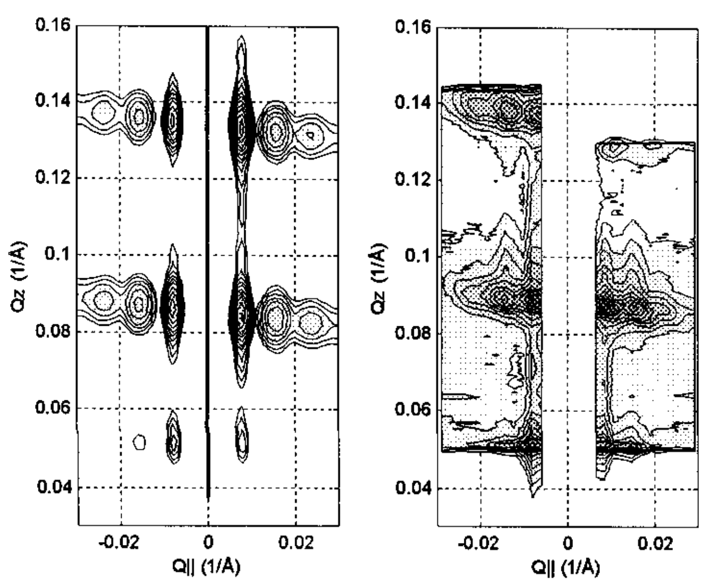

Figure 3. Simulated (left) and measured (right) lateral RSM.