ESRF	**Experiment title:** 5D space mapping of compositionally graded SiGe pillar array using resonant FFDXM	**Experiment number**: HC-3804
Beamline: ID01	**Date of experiment**: from: 7.12.2018 to: 10.12.2018	**Date of report**: 18.2.2020
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Report:

The realization of high quality X-ray photon counting devices, based on monolithic integration, is essential for the next generation of detectors employed in manufaturing, high-energy physics and medical imaging applications. The latenium™ is an X-ray detector recently developed by the company G-ray, consisting of a CMOS processed pixel readout electronics monolithically integrated with a sensor wafer by wafer bonding. The sensor can for example be a Si, GaAs wafer or an epitaxial wafer, such as epitaxially grown SiGe microcrystals [1] on a patterned Si wafer. Understanding the stuctural quality of these microcrystals is crucial for the performance of the device. Investigations of defects inside constant composition [2] or graded SiGe microcrystals [3] have been previously studied by X-ray scanning microdiffracion at ID01 beamline [2,4]. Here, the local distribution of defects, lattice bending and strain has been reconstructed inside the individual microcrystals as a 3D map. Unfortunately only one microcrystal could be probed at once.

In this experiment we have investigated compositionaly graded SiGe microcrystals, using Full Field Diffraction X-ray Microscopy (FFDXM) technique, where the whole 0.4 x 1.1 mm^2 image area with thousands of microcrystals is measured for various points of reciprocal scpace. Thus a 2D information in reciprocal and 2D information in real space is obtained. Moreover, we have performed measurements also for various energies, which allow us to resolve the Ge concentration varying along the height of the graded SiGe crystals, which provides information along the 3rd dimension in real space.

In Fig. 1 we display an optical microscope image, together with the X-ray microscope image, and a scanning electron microscope (SEM) image in the red inset. During the X-ray measurement we focused on the red inset area, where only a row of 10 crystals was present. However, the region fully occupied by SiGe crystals was also measured simultaneously. Since each microcrystal has a different tilt due to

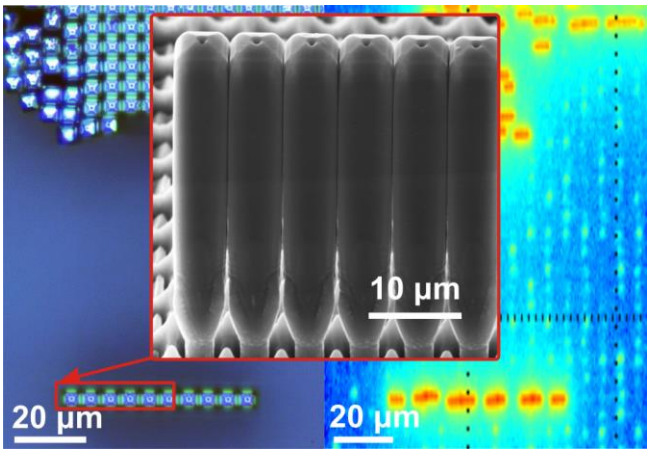

Fig. 1*: Micrographs of the row of 10 isolated graded SiGe microcrystals, 35 µm tall, recorded by an optical microscope (left – view from top) and by FFDXM (right – view from side) at certain reciprocal space point – fixed Ge composition. The FFDXM image is extremely sensitive to crystal lattice parameter, tilt etc. making visible only parts of crystals. Microcrystal details by SEM are in the middle.*

lattice bending [4], the intensity points seemingly do not form a rectangular lattice, and sometime randomly overlap. Additionaly, the maximum intensity points from individual crystals change their relative position on the detector screen when changing the incidence angle. This happens because each Q_z position in reciprocal space map (RSM) corresponds to a different lattice parameter, thus to a different Ge content c_{Ge}, and different position along the microcrystal height. Only the intensity map integrated over the large Q_z range gives the whole image of SiGe microcrystals projected from the side, see inset of Fig. 2.

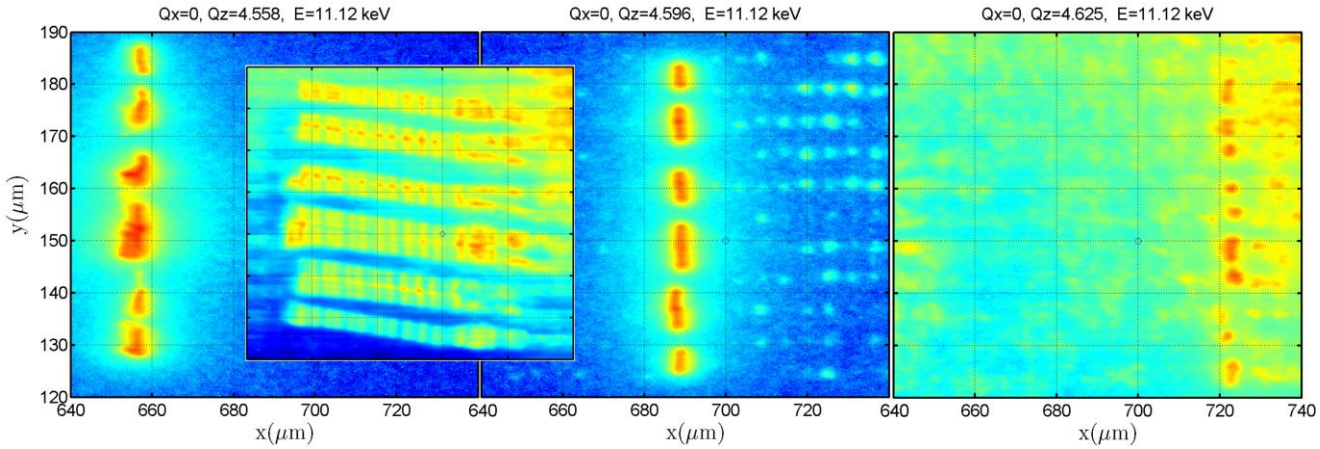

Fig. 2: A *series of FFDXM images for different poins in reciprocal space (various theta/2theta) corresponding to different concentrations c_{Ge} of Ge in SiGe alloy at different positions above the substrate surface. SiGe crystal top with highest c_{Ge} (left), crystal center (middle) and crystal bottom with lowest c_{Ge} (right). The inset image shows the itensity integrated over many incident angles, all c_{Ge} involved (Q_z from 4.551/Å to 4.62 1/Å), giving the microcrystal shape projected as side view.*

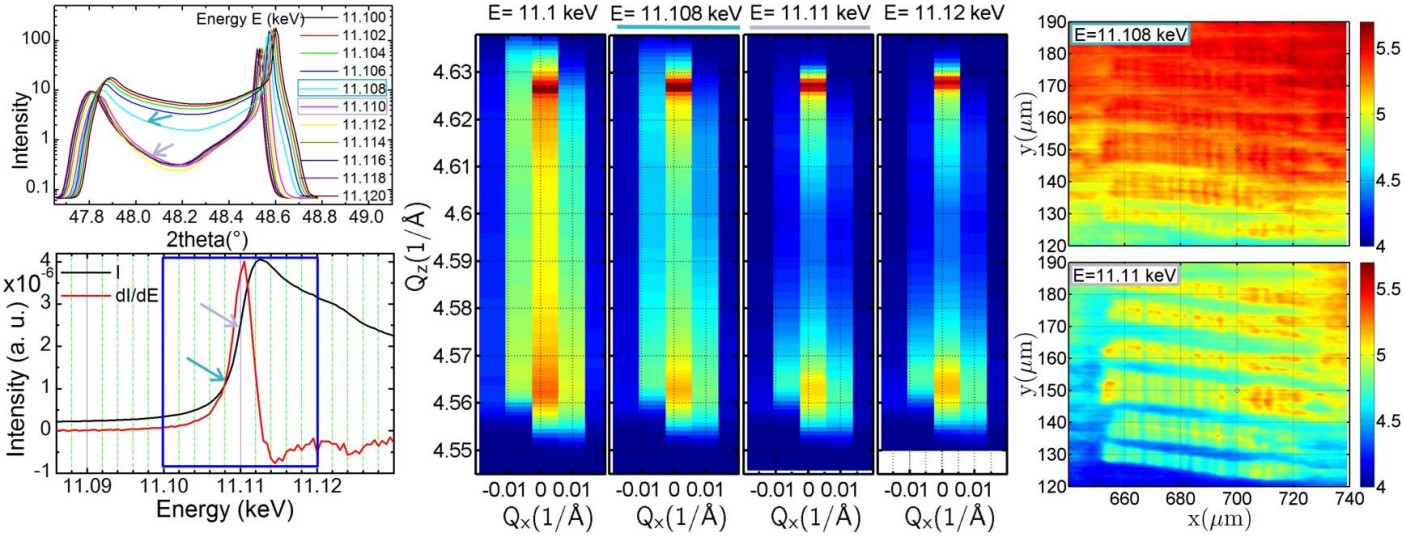

Fig. 3: *A rocking curve scan recorded for various energies close to Ge absorption edge (left top) and Ge absorption edge spectra (left bottom). Recoreded RSMs for various selected energies (middle). The intensity map in real space integrated over incident angles shows the low anf high contrast of SiGe microcrystal depending on energy position at the absorption edge (right).*

We have collected FFDXM images for various theta/2theta angles building RSMs also at various energies around the Ge absorption edge, see Fig. 3. Different intensity contrast between Si and SiGe signal is evident for various energies. For lower energies, below the Ge edge, the contrast between different SiGe concentrations is surpressed but above the Ge edge the signal from SiGe material increases with respect to pure Si substrate. This will allow us to determine Ge content c_{Ge} independently .

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