| ESRF | **Experiment title:** Exploring near-perfect environments for quantum devices: Strain mapping in dislocation-free SiGe grown by lateral selective epitaxy | **Experiment number**: MA-5576 |
|---|---|---|
| **Beamline**: ID01 | **Date of experiment**: from: 27.06.2023 to: 30.06.2023 | **Date of report**: |
| **Shifts:** 9 | **Local contact(s)**: Edoardo Zatterin, Tobias Schülli | *Received at ESRF:* |


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**Report:**
The aim of the proposal was to characterize the lattice strain $\varepsilon$, lattice rotation $w$ and alloy composition $x$ in $Si_{1-x}Ge_x$ layers grown by lateral epitaxy, shown schematically in Fig.1a. [1] They leverage a horizontal aspect ratio trapping mechanism to block dislocations, [2] as seen in the corners of Fig.1b.

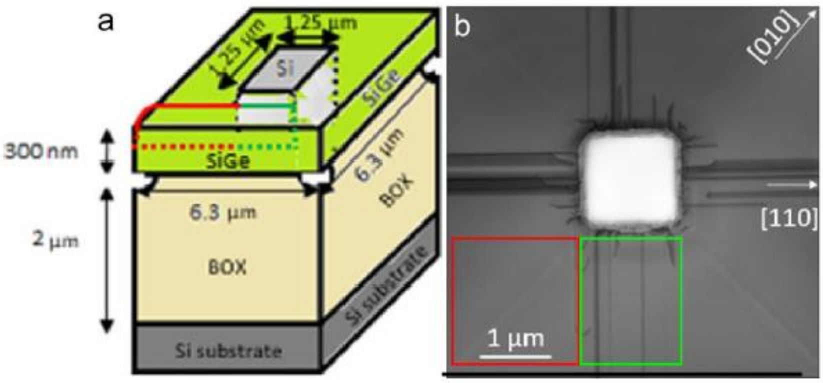


Fig. 1: (a) Schematic of the sample structure; (b) Plane-view TEM image of the lateral-selectively grown SiGe with the misfit-free regions at the corners.

We expect that both local gradients of the Ge content $x$ and anisotropic plastic relaxation may induce local deformations of the $Si_{1-x}Ge_x$ lattice. A suitable characterization requires a technique combining small spatial resolution with high sensitivity to the crystal lattice, which is enabled by Scanning Diffraction Microscopy (SXDM) at ID01. [3]
Due to the high demand of beamtime at ID01, we received only 9 shifts of beamtime instead of 15 that were requested. Nonetheless, full 5D SXDM datasets (3D reciprocal space + 2D real space) were collected for two samples. One of these two samples was grown with a nominally constant Ge content, while the other has a step in the radial profile of the Ge content. Each dataset consists of spatial mappings of three reflections from the {426} family of lattice planes.
During the experiment, we observed a strong spatial dependence of the orientation of the $Si_{1-x}Ge_x$ lattice planes around the pillar (see Fig. 2), which required us to cover a wide range of rocking angles $\eta$ in the measurement. This was partially alleviated by moving the detector close to the sample and did not signifantly

hinder the measurements.

In addition to the diffraction signal, the fluorescence from the Ge was measured with an additional energy-resolved X-ray detector (last panel of Fig.2), which allowed for tracking and compensation of spatial sample drift during the measurement. No loss of beam time and no signifcant technical problems occurred during the experiment.

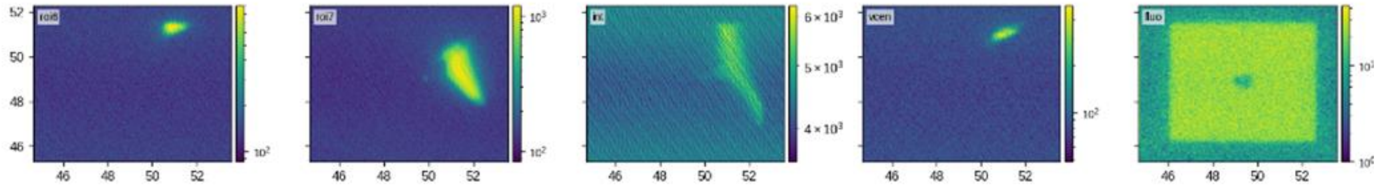

Figure 2: Maps of the intensities of the scattered X-rays from the laterally grown $Si_{1-x}Ge_x$ on various ROIs of the detector.

From the SXDM datasets, we expect to determine the full lattice strain tensor and rotation tensors for both samples, leveraging an analysis procedure relying on the linear combination of spatial mappings for three asymmetric Bragg reflections. [4] For this purpose, automated scripts will be employed which have already been utilized in the publication of several similar strain mapping experiments at ID01. [5,6] A forthcoming publication will describe the lattice characterization of these laterally grown structures, providing insight into their nanoscale strain landscape and furthering the understanding of the lateral growth mechanism

**References**

[1] K. Anand, M. A. Schubert, A. A. Corley-Wiciak *ECS J. Solid State Sci. Technol*. (2023) 12, 024003 [2] [2] Y. Yamamoto et. al., *ECS J. Solid State Sci. Technol*. (2014), 3, 353 [3] Chahine *et al.*, *J. Appl. Cryst.* **47**, 762 (2014) [4] C. Richter, V. M. Kaganer, A. Even *et al. Phy. Rev. Appl.* 2022, 18, 6 064015 [5] C. Corley-Wiciak, C. Richter, M. H. Zoellner, *et. al. ACS Appl Mater Interfaces.* (2023) 15(2), 3119-3130 [6] C. Corley-Wiciak, M. H. Zoellner, I. Zaitsev *et. al. Phys. Rev. Applied.* (2023) 20, 024056