Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office using the **Electronic Report Submission Application:**

http://193.49.43.2:8080/smis/servlet/UserUtils?start

Reports supporting requests for additional beam time

Reports can now be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

ESRF	**Experiment title:** Coherent x-ray scattering from a single extended defect in implanted Si	**Experiment number**: SI-1736
Beamline: ID01	**Date of experiment**: from: 11.2.2009 to: 17.2.2009	**Date of report**: 18.2.2009
Shifts: 18	**Local contact(s)**: Thomas W. Cornelius, Till Hartmut Metzger	*Received at ESRF:*

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Report:

Diffuse x-ray scattering is a well-known tool for the investigation of the structure of defects in crystal lattices. In this method, the signal scattered into a given point ***Q*** of reciprocal space is averaged over a large irradiated sample volume, i.e., about a large statistical ensemble of defects, so that mean parameters of the defect structure can be obtained. This ensemble averaging is important for obtaining statistically relevant mean data, but it smears out tiny details of the diffraction picture characteristic for one particular defect.

The aim of the beamtime was to measure x-ray scattering around a chosen reciprocal lattice point from a small volume of a Si single-crystalline sample containing one or few defects and to reconstruct the displacement field around the defect by a numerical retrieval of the phase of the scattered wave. We have investigated two types of samples:

a) Si-implanted Si wafers after rapid thermal annealing. The parameters of the implantation and annealing were chosen so that the mean distance of individual extended defects was several 100 nm, the samples have been prepared at Forschungszentrum Rossendorf. A cross-section transmission electron micrograph of the sample is shown in Fig. 1.

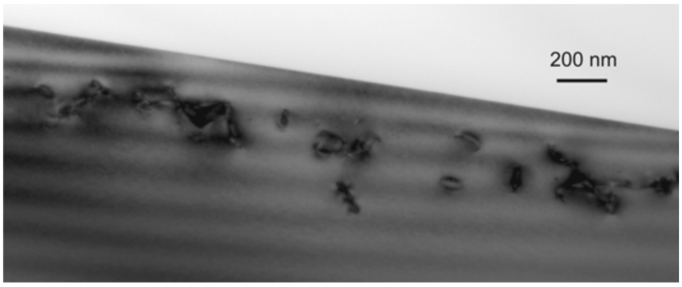
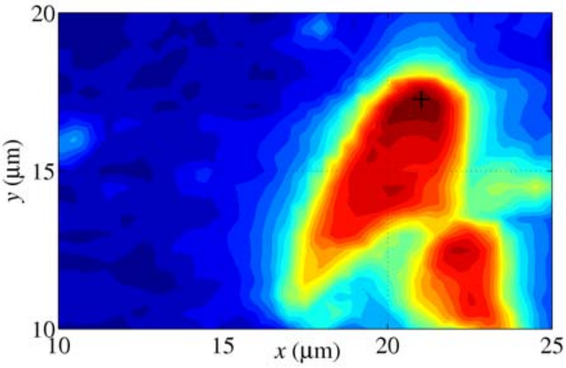


Fig. 1. Transmission electron micographs of a Si-implanted sample

b) SiGe relaxed epitaxial layers with a low Ge concentration (approx. 5%) and thickness of 100 nm. The mean distance of the misfit dislocations and the dislocation bunches is several μm, the samples have been grown at the Institute of Semiconductor Physics, Kepler University Linz, Austria (prof. F. Schäffler).

For the x-ray diffraction measurement we have used a very narrow x-ray beam with the energy of 8 keV. The beam was focused by a Fresnel zone plate; a narrow slit in front of the plate (60x20 μm^2) assured a perfect transversal coherence of the beam. A beam-stop was placed just behind the zone plate that screens out the directly transmitted beam, and we have used only a part of the convergent wavefront using an additional narrow aperture behind the zone plate placed out of the optical axis. We used symmetric coplanar 004

diffraction and the diffracted beam was detected by a two-dimensional CCD detector (256x256 pixels) in a far-field position. The angular resolutions were 0.003 deg and 0.009 deg in the directions along and across the scattering plane, respectively. For the diffraction used, the size of the footprint on the sample surface was approx. 500x200 nm^2.



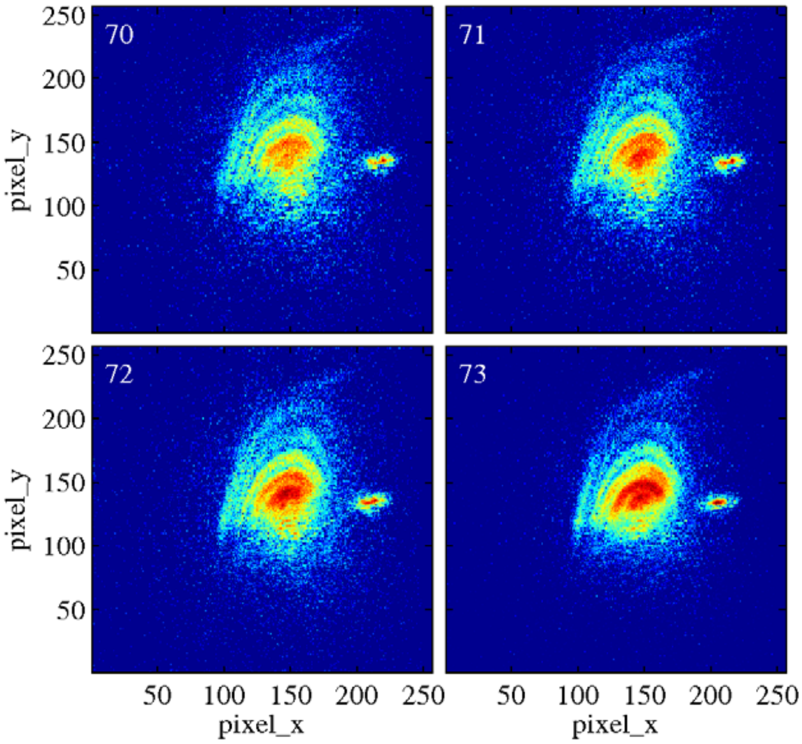


Fig.2. Map of the surface of the sample of type a), diffraction 004. The cross denotes the position of the primary beam used in Fig. 3

Fig. 3 (right) Four consecutive CCD frames taken in the sample position indicated in Fig. 2

Figure 2 presents a xy-map of the intensity scattered into a suitably chosen range-of-interest (roi) on the CCD detector, keeping constant the incidence angle ω and the angle 2θ between the primary beam and the detector arm. The maxima on the map correspond to individual defects. We have chosen the maximum denoted by cross in Fig. 2 and we have taken a series of CCD picture for various ω and constant 2θ. As an example we show here four consecutive CCD frames as an example, taken with the stepsize Δω = 0.05 deg (Fig. 3). The narrow maximum in Fig. 3 corresponds to the intersection of the crystal truncation rod with the detector plane, this maximum moves with changing the angle ω. The intensity fringes stem from the irradiated defect.
From the series of the CCD frames we obtain a three-dimensional distribution of the scattered intensity in reciprocal space. The measurement of the sequence of the CCD frames has been repeated in various sample positions around the central position (the cross in Fig. 2); this is necessary for the application of the ptychography method of the retrieval of the phase of the scattered wave [1,2].

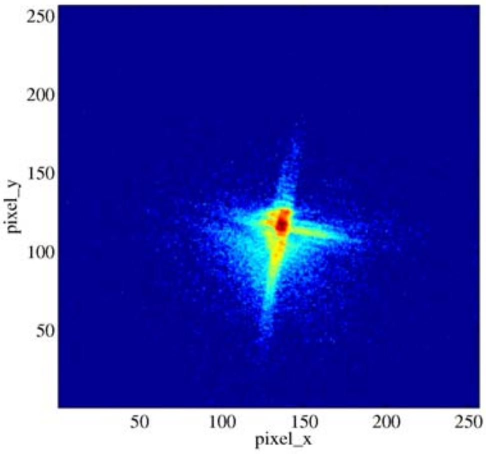


Fig. 4 A CCD frame taken from the sample of type b), symmetric 004 diffraction

The same geometrical arrangement was used also for the sample of type b), an example of a single CCD frame taken in the position of a dislocation bunch is presented in Fig. 4. Interference fringes are visible.
The measured data will be processed using the phase retrieval [3] and ptychography algorithms [1,2], from which we intend to reconstruct the displacement field around a single defect.

[1] J. M. Rodenburg and R.H.T.Bates, Phil. Trans. R. Soc. Lond. A 339, 521 (1992).
[2] L. J. Allen and M. P. Oxley, Optics Commun. 199, 65 (2001).
[3] J. R. Fienup, Appl. Optics 21, 2758 (1982).