EUROPEAN SYNCHROTRON RADIATION FACILITY

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ESRF

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 via the User Portal: *https://wwws.esrf.fr/misapps/SMISWebClient/protected/welcome.do*

Deadlines for submission of Experimental Reports

Experimental reports must be submitted within the period of 3 months after the end of the experiment.

Experiment Report supporting a new proposal ("relevant report")

If you are submitting a proposal for a new project, or to continue a project for which you have previously been allocated beam time, you must submit a report on each of your previous measurement(s):

- even on those carried out close to the proposal submission deadline (it can be a *"preliminary report")*,
- even for experiments whose scientific area is different form the scientific area of the new proposal,
- carried out on CRG beamlines.

You must then register the report(s) as "relevant report(s)" in the new application form for beam time.

Deadlines for submitting a report supporting a new proposal

- 1st March Proposal Round - **5th March**
- 10th September Proposal Round - **13th September**

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.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report in English.
- include the experiment number 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:** Assessment of the influence of manufacturing- and doping-induced stress on the performance of press-fit rectifier diodes by in situ GIXRD experiments	**Experiment number**: A25-2-1074
Beamline:	**Date of experiment**: from: 01/04/2023 to: 05/04/2023	**Date of report**: 19/07/2023
Shifts:	**Local contact(s)**: RUBIO ZUAZO Juan	*Received at ESRF:*

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& Main proposer # Remote users * Experimental users

Report:

Press-fit rectifier diodes commonly employed in the automotive field endure different effects during their performance (heating, mechanical stress…). These factors affect the behavior of the device (mainly the semiconductor component) to a greater or lesser extent, depending on the characteristics of the diode (technology, design…). As they usually occur simultaneously, the separate assessment of each one is complex.

Thus, the aim of the proposal was to study the influence of stress on the crystal structure of Si wafers whose characteristics, in terms of dimensions and doping level, are similar to those embedded in the diodes. This allowed us to evaluate the stress phenomenon separately from other effects to which the semiconductor component of diodes is subjected.

For that, several single-crystal (110) Si wafers implanted with different concentration levels of B were studied *in situ* by single-crystal X-ray diffraction (SCXRD) under the application of mechanical stress. Experiments were performed at the BM25-SpLine beamline at The ESRF (Grenoble, France) at an energy of 18 keV. Table 1 summarizes the samples evaluated in the experiment. After the implantation, wafers were subjected to a thermal treatment that helps doping atoms to place in active sites of the lattice.

Table 1. Samples evaluated in the SCXRD experiments at the BM-25 SpLine beamline

	doping level [at·cm^{-3}]
undoped	0
M3	$1\cdot10^{19}$
M2	$2\cdot10^{19}$
M1	$4\cdot10^{19}$

Figure 1(a) and (b) show the setup employed for the experiments, identifying the different elements. The wafer, with a surface of 5 x 5 mm^2 and a thickness of 520 µm, was placed in the sample hole of the microtensile test device (*Deben*), which was coupled to the stage of the SCXRD system. Then, an increasing uniaxial compressive force is remotely applied from 0 to 110 N in steps of 10 N. Spectra were taken each time the force was increased and after stabilizing the system for ca. 5 min. In addition, reciprocal space maps (RSM) were performed in order to elucidate the presence of strain or other effects at the interfaces.

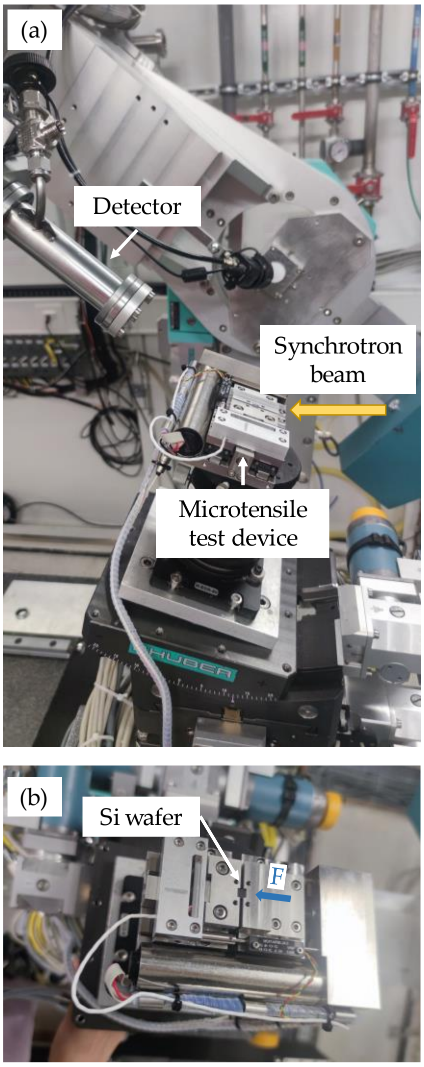

Figure 1. (a) Setup employed for the in situ compressive experiments, indicating the location of the detector, the microtensile test device and the direction of the synchrotron beam. (b) Microtensile test device shown in detail, indicating where the sample is placed and how the force is applied.

Figure 2(a) displays several spectra at selected applied forces of the sample M1, as representative. Inset reveals how the diffraction peak shifts towards higher 2θ values as the compressive force increases, which may be a consequence of the reduction of the lattice parameter of Si, according to Bragg's law.

Figure 2(b) displays the diffraction peak of the different studied samples with no applied force, disclosing the influence of the content of B in the crystal lattice of Si. As the doping level increases, the diffraction peak shifts towards higher 2θ values. Since the B atomic radius is lower than that of Si, the structure of the sample may be compressing. These results will enable us to perform a calibration curve.

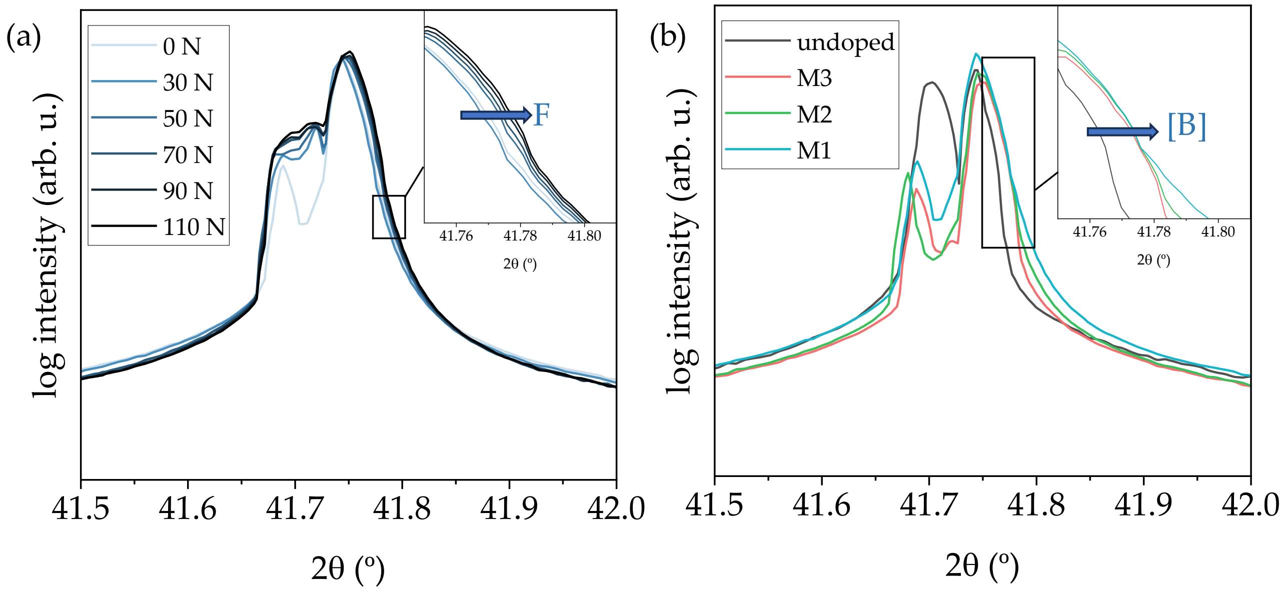

Figure 2. θ-2θ spectra of the (a) M1 sample (as representative) at selected applied forces. (b) All studied samples at 0 N. Insets: zoom of the spectra in the region 41.75-41.81 º, indicating with the arrow the increasing force and boron concentration, respectively in (a) and (b).

This experiment enabled to isolate the stress and doping contribution from other effects that diodes endure, and which were evaluated in previous experiments. The deconvolution of the different effects provides a better insight into the behavior of press-fit rectifier diodes, which is useful for increasing their lifetime and diminishing costs.