EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

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.

	Experiment title: In situ GIXRD study of the electrically induced phenomena on Schottky and MOS rectifier diodes	**Experiment number**: MA-5391
Beamline:	**Date of experiment**: from: 28/03/2023 to: 01/04/2023	**Date of report**: 19/07/2023
Shifts:	**Local contact(s)**: RUBIO ZUAZO, Juan	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Sara Román-Sánchez &, *, Instituto de Cerámica y Vidrio (ICV), CSIC, Madrid, Spain
Alberto Moure *, Instituto de Cerámica y Vidrio (ICV), CSIC, Madrid, Spain
Aida Serrano #, Instituto de Cerámica y Vidrio (ICV), CSIC, Madrid, Spain
Jesús López-Sánchez #, Instituto de Cerámica y Vidrio (ICV), CSIC, Madrid, Spain
Marina París *, Universidad Autónoma de Madrid (UAM), Madrid, Spain
Juan Rubio Zuazo *, SpLine beamline at The ESRF, Grenoble France

& Main proposer # Remote users * Experimental users

Report:

Press-fit rectifier diodes are commonly employed in the automotive field for the transformation of the alternating current (AC) provided by the alternator into direct current (DC), in order to be suitable for powering the vehicle. A critical issue for the reliability of the diodes is the appearance of undesirable effects during their performance, such as overheating by the Joule effect or thermomechanical stresses, as a consequence of the high electrical current they endure.

These devices are basically constituted by a semiconductor element, a metallic heat sink and a mechanically protective epoxy. The former defines the performance of the diode, depending on the technology it presents (metal-oxide-semiconductor (MOS), Schottky, PN-junction, etc.).

Thus, the goal of this proposal was to assess *in situ* the crystallographic modifications occurring in the semiconductor component of commercial press-fit rectifier diodes with different technology (MOS and Schottky) while they are under operating conditions. Samples were evaluated by single-crystal X-ray diffraction technique at the BM25-SpLine beamline at an energy of 18.26 keV. As it is a superficial technique, measurements were performed on the cross-section of diodes. For that, they were cut and mirror-polished following a specific procedure with various steps involving sanding using papers with different grain sizes and polishing with diamond and silica.

Once the diodes were prepared, two different experiments, consisted of the acquisition of θ-2θ spectra and reciprocal space maps (RSM) of the semiconductor component (Si) while the diode was subjected to operating conditions, were performed. In one of them, a forward current was applied at different intensities, and data were taken each time the current was increased after letting the sample stabilize for about 5 min. In the other one, diodes were subjected solely to heating, and measurements were acquired at selected temperatures after the sample was thermally homogenized for about 5 min. The setup of both current and temperature experiments are shown in Figure 1(a) and (b), respectively.

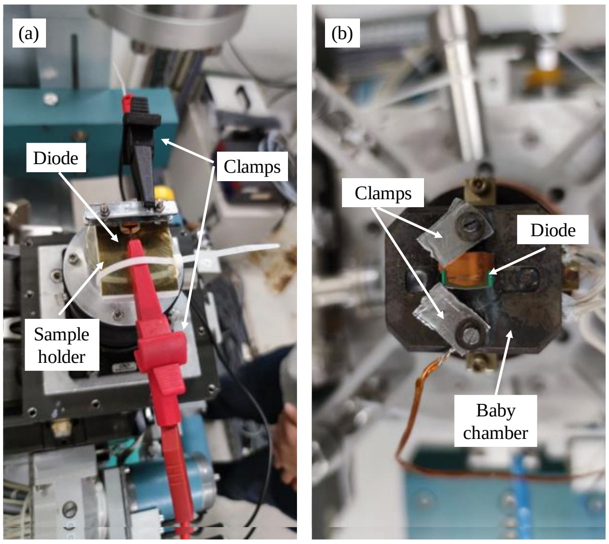

Figure 1, Setup of the

Figure 2 displays the diffraction peak of MOS and Schottky diodes taken at each current and temperature. As shown, in both cases and for both technologies, the peak tends to shift towards lower 2θ values which, according to Bragg's law, could be attributed to a thermal expansion of the crystal lattice. It should be pointed out that the shift of the diffraction peak is more noticeable when the diode is subjected only to temperature. This could be due to either the current intensity applied does overheat the diode at such high temperatures (diodes usually work at 40 A), or the current inducing mechanical stress or other phenomena that shift the diffraction peak in the opposite direction to that caused by temperature. Note that the Si plane is different for each experiment. This is due to the impossibility of cross-section the diode in a not-random direction.

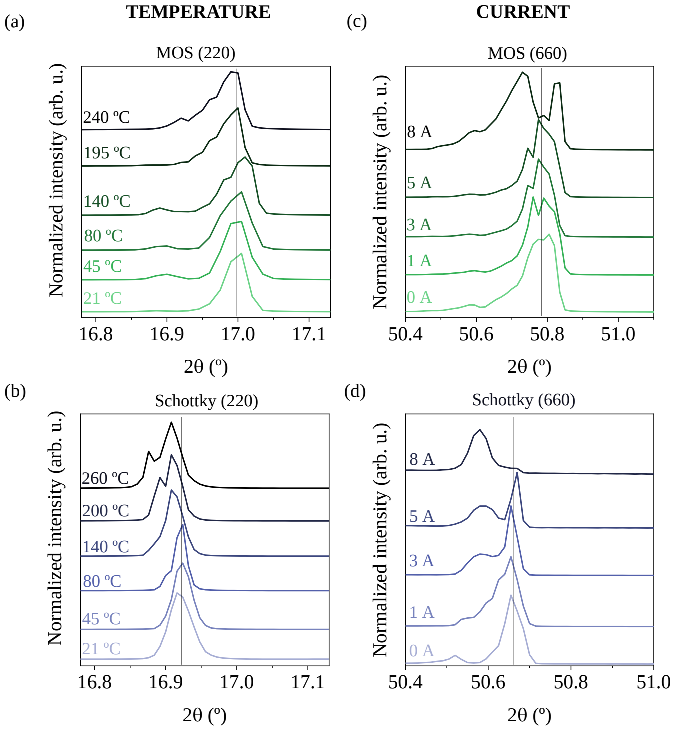

Figure 2. (a-b) Evolution with the temperature of the diffraction peak at the 220 plane of the Si embedded in a MOS and a Schottky diode, respectively. (c-d) Evolution with the current intensity of the diffraction peak at the 660 plane of the Si embedded in a MOS and a Schottky diode, respectively. Vertical black line is a visual guide.

Results also reveal that the diffraction peak of the Schottky diode appears at lower 2θ values than the one corresponding to the MOS diode. This occurs even at room temperature and may be indicating that the initial conditions of the crystal lattice of Si are different for each one. We can associate these variations with either the stress caused by the dopants in the Si structure, which differs from one technology to the other for having different doping schemes; or with the stress generated during the manufacturing process. However, as the provider of both diodes is the same, it is assumed that the differences in the latter are negligible.