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.

ESRF	**Experiment title:** Stress micro-mapping in As- and Sb-implanted HgCdTe photodiodes	**Experiment number**: 32-02-756
Beamline: BM32	**Date of experiment**: from: 27/11/2013 to: 30/11/2013	**Date of report**: 10/02/2020
Shifts: 9	**Local contact(s)**: Jean-Sébastien MICHA	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Dr Habil Philippe Ballet* - CEA-Grenoble / LETI / DOPT / STM / LMS

Dr Ing Habil Xavier Biquard* - CEA-Grenoble / IRIG / DEPHY / MEM / NRS

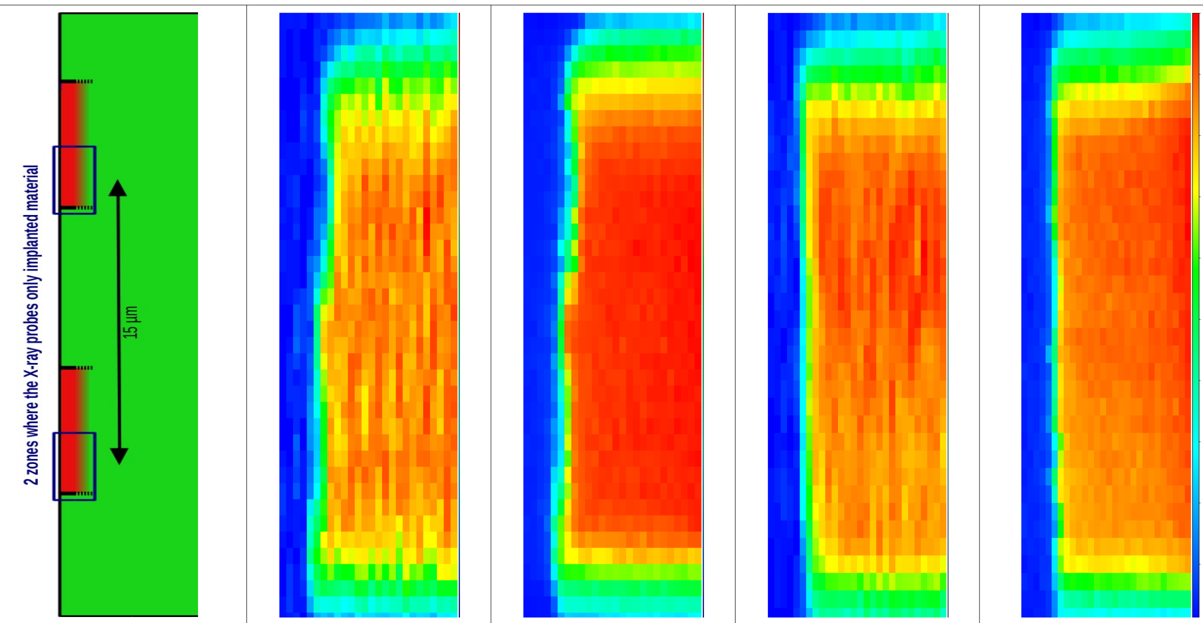
Dr Clément LOBRE* - CEA-Grenoble / LETI / DOPT / STM / LMS

Report:
The main goal of this proposal was to obtain the local crystal deformations and damages induced by the implantation of arsenic and to observe the effect of the activation thermal annealing.

The ternary alloy $Hg_{1-x}Cd_xTe$ is of the Zinc-Blende type and is constituted by 2 face-centred cubic sub-lattices (named A and B afterwards) offsetted by [¼,¼,¼] with the anion sub-lattice made of Tellurium while the cation sub-lattice hosts either Hg or Cd. Consequently, (hkl) reflections are only allowed if Miller indexes h, k and l have the same parity and their sum is either odd (odd indexes) or even (even indexes). Concerning their intensities, there is a major difference for even Miller indexes: (hkl) reflections with h+k+l=4n have an amplitude proportional to the square of the *sum* of atomic form factor $(f_A+f_B)^2$ while h+k+l=4n+2 have an amplitude proportional to the square of the *difference* of atomic form factor $(f_A-f_B)^2$. h+k+l=4n reflections are strong while 4n+2 reflections are weak.
As shown on table 1 for as-implanted sample, the diffraction signal almost goes down to background level in a 750 nm deep and #5 µm wide zone corresponding to As implantation zone. Moreover, that zone is roughly 500-750 nm thick, perfectly corresponding to expected penetration length of 360 keV As ions: diffraction intensity reduces because of implantation-induced damages. A detailed comparison on figure 1 shows that the weak diffraction intensity is 1.5 time more reduced than the strong one. The proposed explanation is that misfit dislocations occur in the damaged zone, thus inducing stacking fault in the crystal that locally transform the AB atomic structure into BA structure. Therefore, the two cfc sub-lattices are no more exclusively made of cations or anions, but of a mixture of both in various proportions: f_A and f_B difference lowers. And whatever the proportion of anion/cation mixing, this does not affect strong reflections but specifically decreases weak reflections until — in the limit case where anions and cations are fully mixed-up — weak reflection are zero since $f_A=f_B$. After annealing, we observe a complete restoration of the diffraction signal in the implanted zone: from both strong and weak diffraction intensities point of view, there is no more trace of implantation damages after annealing.

As a conclusion, we have observed that the activation thermal annealing has completely cured the epi-layer from its As implantation damages, an ideal situation for HgCdTe photodiodes.

[1] C. Lobre, 'Compréhension des mécanismes de dopage arsenic de CdHgTe par implantation ionique', phdthesis, Grenoble, Grenoble, 2014.



	As-implanted sample		Annealed sample	
	Weak reflection (8,-2,8) 14.8 keV	Strong reflection (6,-2,8) 14.5 keV	Weak reflection (6,0,8) 12.37 keV	Strong reflection (7,-1,7) 12.25 keV

Table 1: Comparison between diffraction intensity repartition for as-implanted and annealed samples. For each sample, we compare the most intense weak reflection with the corresponding strongest one that is closest in energy to avoid any penetration length distortion. Intensity is coloured coded from blue to red as shown at the extreme right and the localisation of implanted pixels is shown on the left. X-ray beam was raster scan every H=0.25 µm x V=1 µm.

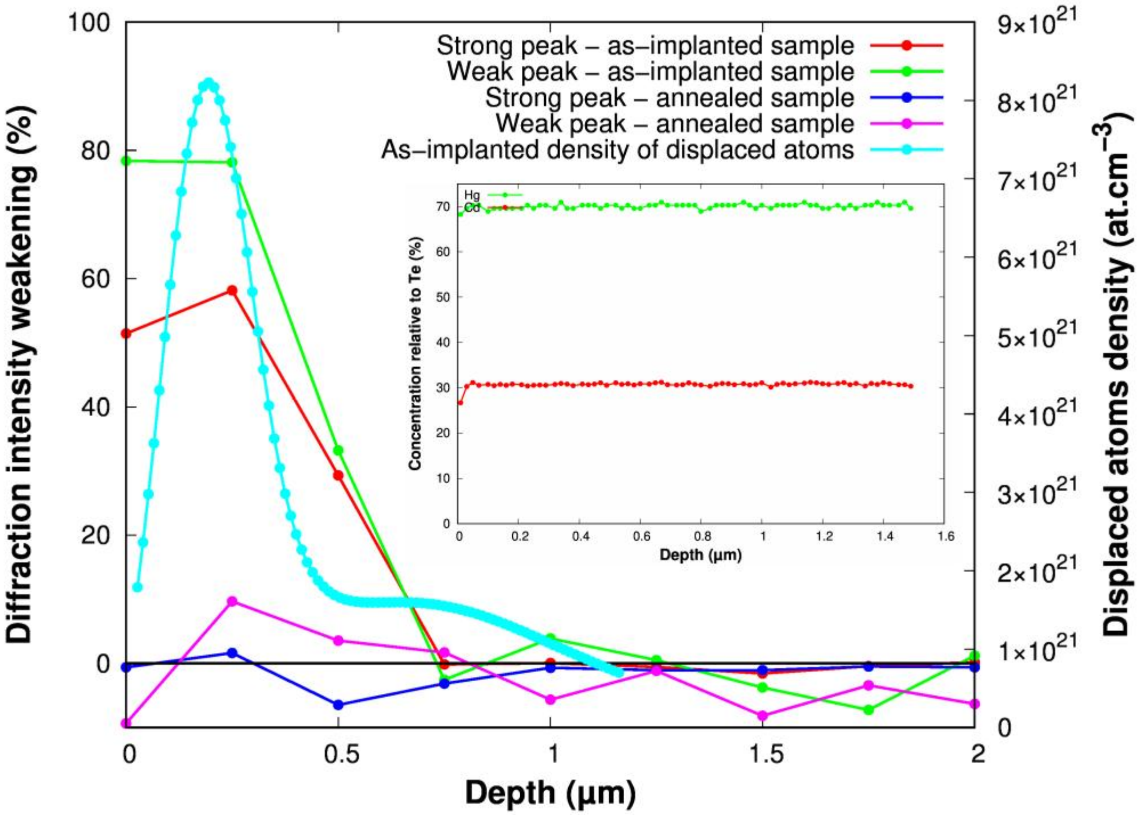


Figure 1: Comparison between strong and weak reflection for the pixel zone of both samples. Density of displaced atoms is also represented against the right scale. Insert: SIMS measurements of the concentration of cations Hg and Cd with depth