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

Reports supporting requests for additional beam time

Reports can 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:** X-Ray beam characterisation of high-precision silicon dosimeters fabricated with 3D technology by means of 2D focused beam scans	**Experiment number**: MI-1229
Beamline:	**Date of experiment**: from: 08/12/2015 to: 16/12/2015	**Date of report**: 26/02/2016
Shifts: 18	**Local contact(s)**: Murielle Salomé	*Received at ESRF:*

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Report:

Aim of the experiment:

The aim of this experiment was to characterise innovative silicon micro-dosimeters of various types and configurations, on device level, in photoelectric mode using a focused X-Ray beam. The characterisation obtained will complete the understanding of the sensor operation. High resolution 2D efficiency maps that describe the charge collection dynamics in a sensitive element were obtained. The time response of the devices was also studied using a fast preamplifier and a digital storage oscilloscope (DSO) triggered by the RF signal of the synchrotron. These results will be used as a benchmark for the next generation of micro-dosimeters produced using 3D technology.

Sample description and experimental techniques:

The Devices Under Test (DUT) are silicon micro-dosimeters fabricated on high resistivity p-type material (~10kΩcm) and thinned down to roughly 50µm. Each sensor is composed by 1296 cylindrical sensitive volumes (Fig.1(a)) spaced by 50µm and readout in groups of 216. Two different cell radiuses are available, 7.5 and 15 µm. Each single cell is composed by an n+ "inner core" responsible for the collection of the charge generated in the region of interest, and by an n+ "steering-ring" that has the task of collecting the charge generated outside of the sensitive volume. The bias voltage is supplied using a uniform p+ implantation on the back side of the device. The steering ring should assure a precise definitition of the sensitive voulme, crucial for the correct measurement of radiation dose when operated in dosimetry mode. The cells are comparable in size to human cells. Each die is glued and wire bonded to a custom designed PCB that fits on the standard ID21 sample support (Fig.1(b)) that can easily be exchanged in the Scanning X-ray Microscope (SXM). Micro-coax connectors are available on the back side of the PCB (Fig.1(c)) to allow flexible cable connections to the outside of the SXM vacuum chamber through a flange that provides hermetic SMA connectors to connect to the external instruments (Fig.1(d) shows the vacuum chamber).

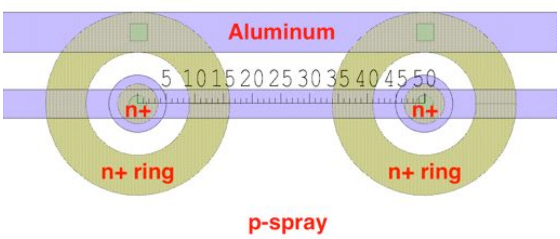

Fig. 1(a). Sensor layout.

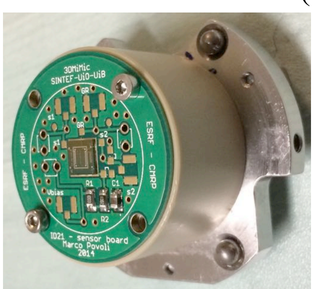

Fig. 1(b). Sample (front).

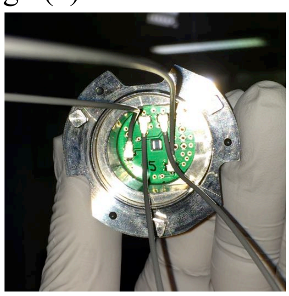

Fig. 1(c). Sample(back)

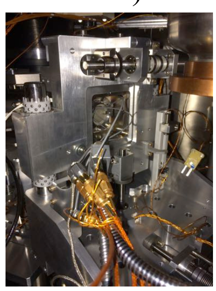

Fig. 1(d). SXM

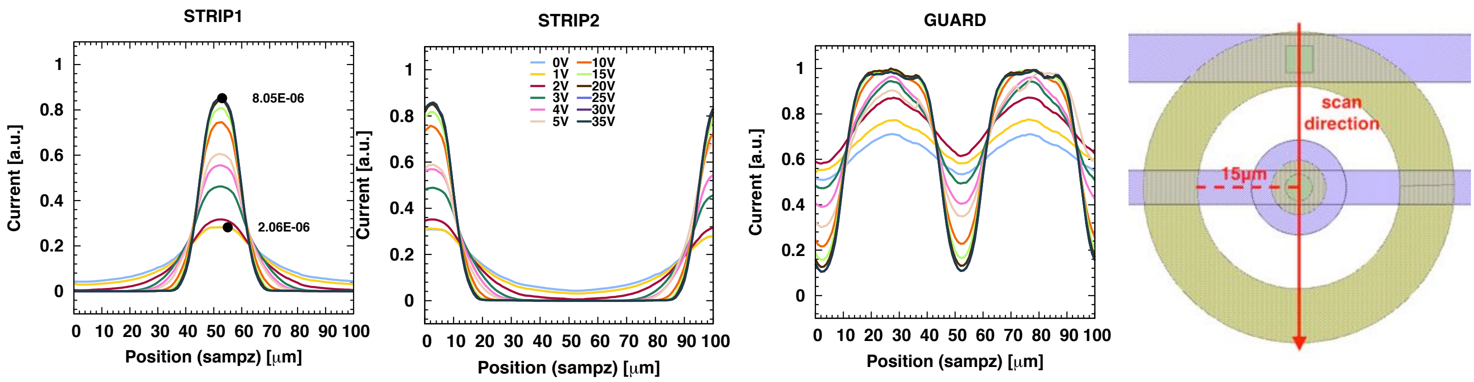

Fig. 2(a). Core 1 signal *Fig. 2(b). Core 2 signal* *Fig. 2(c). Ring signal* *Fig. 2(d). Layout*

Two measurement modes where used: (i) with the use of Keithley 458 electrometers, the sensor response was recorded as a function of beam position and (ii) with the use of 2.3GHz wide band preamplifiers and the DSO the temporal response of the sensors was acquired. Both 1D and 2D spatial scans were performed. Two different X-ray energies were used, 2.5 and 7.2 keV, in order to probe at different depths into the DUTs, i.e. according to the X-ray beam absorption depths. The X-ray beam had a size of less than 1.0x1.0 μm^2 and hit the sensors with a 30° tilt angle. Additional features of the SXM such as X-ray flourescence recorded by a Silicon Drift Detector (SDD) allowed precision visualisation of different materials and elements in the sensor (e.g. the metal contact edges), and the up- and down-stream beam intensity monitors were used to normalize the later analyzed scan data.

Different measurement strategies were used: 1D and 2D scans using electrometers (with data recorded via voltage to frequency (VTF) converters), and 1D and 2D scans using the wide band preamplifier-triggered DSO arrangement. The two measurements provide similar information but the latter has the additional advantage of also returning the 'shape' of the signal, i.e. its time evolution. Using this information it is possible to study the charge collection dynamics more in depth. In addition, an X-ray transmission measurement was performed returning an estimated sensor thickness of ~55μm, as expected (~33% transmission). The results from one of the first 1D scans are reported in Fig.2 together with the layout of the scanned area. The beam was scanned across one core and the signal was recorded on all available channels using the electrometers. The signal profile obtained is in good agreement with expectations: the amplitude is increasing with bias and the FWHM becomes lower as the votlage is increased. The final FWHM of roughly 16 μm is in agreement with numerical simulations performed before testing. The operation of the ring is as expected, collecting all the charge generated outside of the core, thus properly limiting the extension of the core active volume. In order to check the sensor response uniformity, the same measurements were repeated in 2D scans over an area including roughly 6 cores. Data were acquired from the electrometers and VTF converters in 'zapscan' mode in order to make the measurement faster. Results are reported in Fig.3. The sensor shows a good response uniformity, with the shape of the core active volumes very similar to each other. A slight "parallax distorsion" can be noted in Fig.3(a) and Fig.3(b), caused by the fact that the beam is hitting the sensor with a 60° angle to its surface. The 2D scans were repeated using the wide band preamplifiers: for this, the synchrotron RF was divided-down according to the 16 bunch machine mode timing and used to trigger the DSO acquisitions. By this means, signal/noise was improved by DSO signal-averaging at each scan position.. Signals for the core and for the ring are plotted as function of bias voltage in Fig.3(c) and Fig.3(d) for the hit position highlighted in Fig.3(a). The core signal has a very fast rise time (a few hundred picoseconds) and the total signal evolution lasts only a few nanoseconds. Even when the beam is focused on the core, the ring sees a rather large signal because of the angle between the sensor and the beam. The signal on the ring has also a fast rise time but a much longer "tail" due to the fact the it collects charge from a much larger area than the core electrode and thus more time is required for the process to be completed. These results are crucial for understanding the operation of this sensor technology and will be used as the benchmark for the new micro-dosimeters fabricated using 3D technology that are now ready to be tested.

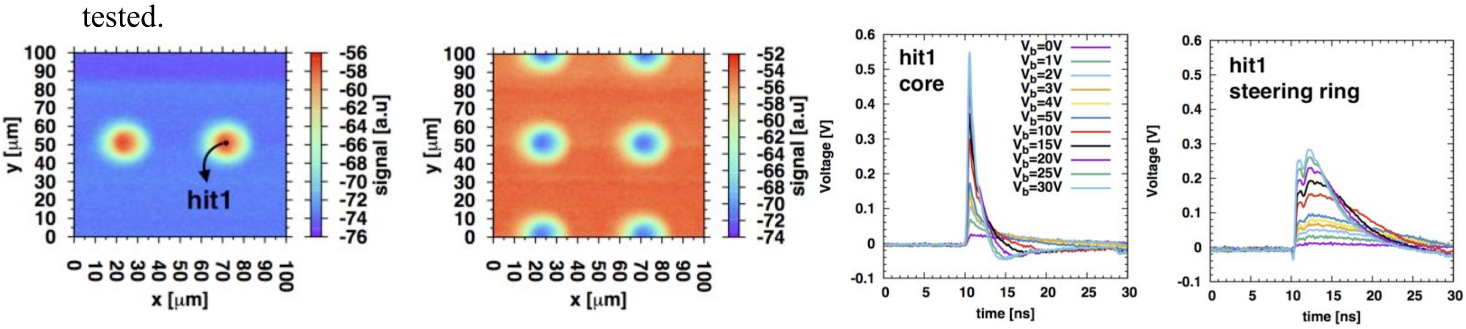

Fig. 3(a). 2D scan, core signal. *Fig. 3(b). 2D scan, ring signal.* *Fig. 3(c). Time evolution of the core signal.* *Fig. 3(d). Time evolution of the steering ring signal.*