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 for Microbeam Radiation Therapy (MRT) by means of 2D focused beam scans	**Experiment number**: MI1202
Beamline: ID21	**Date of experiment**: from: 11/12/2014 to: 17/12/2014	**Date of report**: 24/02/2015
Shifts: 18	**Local contact(s)**: Murielle Salome	*Received at ESRF:*

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Report:

Aim of the experiment:

The aim of this experiment was to characterise innovative silicon mini- and micro-dosimeters of various types and configurations on device level, in photoelectric mode using a narrow X-Ray beam. The obtained characterisation will result in a comprehensive understanding of the individual sensitive elements. High resolution 2D efficiency maps that describe the charge collection dynamics in a sensitive element were obtained. The results are complimentary to the experimental data obtained at ID17 (compton scattering mode) where full sized sensors with up to 128 channels were tested. The time response of the devices was also obtained using a fast amplifier and a digital oscilloscope triggered by the RF signal of the synchrotron.

Sample description and experimental techniques:

The devices under test (DUTs) are different to the full-sized dosimeters, and were specifically designed to suit the experimental environment at ID21. They are miniature replicas of the full-sized dosimeters with the same sensing elements (some examples are shown in Fig.1a). Both the miniature replicas and the full-sized dosimeters have the unique thicknes of about 10μm. The ultra-thin feature is to reduce beam perturbation and to improve the tissue equivalency in recently emerging cancer radiotherapy. The key differences between the DUTs and the full-sized dosimeters are that the DUT are small in size (1 x 1 mm^2 sensitive area); and have a maximum of three channel readout for easy assembly and simple readout using off-the-shelf readout electronics.

A sample consisting of a sensor and custom designed PCB (Fig.1b), was mounted on a specific sample holder, as shown in Fig.1b (front) and Fig.1c (back). The experiment was then performed on the sample using the Scanning X-Ray Microscope (SXM) available at ID21. The micro-coax cables exit the sample holder from the back side (Fig.1c) and are connected to vacuum proofed SMA cables (Fig.1d shows the back of the SXM with the micro-coax exiting from the sample holder). The signals are then fed out of the vacuum chamber through a flange that provides SMA connectors on the outside where the readout instruments are attached.

The sensors have 3 readout channels. Two channels for two separate arrays of sensitive elements (strip #1 and #2) and one channel for the "steering-ring" used to limit the active volume of the sensitive element (channel #3). The operating voltage is applied on the backside (or ohmic side) of the sensor through an on-board RC filter using a Keithley 487 picoammeter.
The channels to be readout are connected to Keithley 485 electromenters and then to voltage to frequency (V2F) converters. The need for the two different instruments are related to the different requirements of the performed measurements.

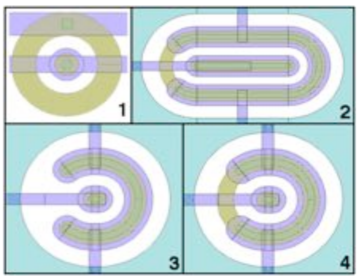

Fig.1a

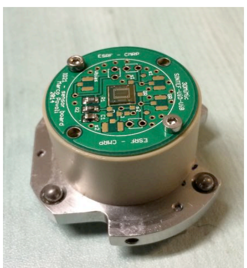
Fig.1b

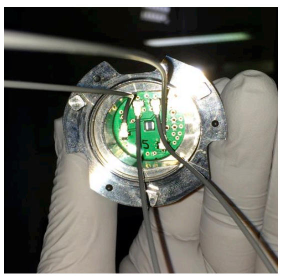
Fig.1c

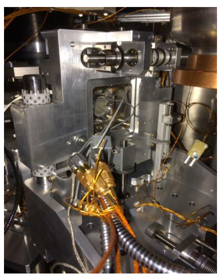
Fig.1d

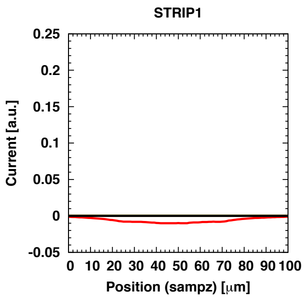

Fig. 2.a

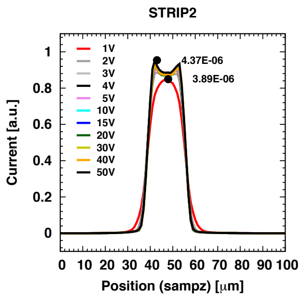

Fig. 2.b

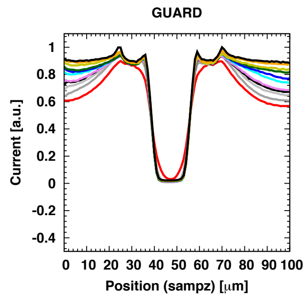

Fig. 2.c

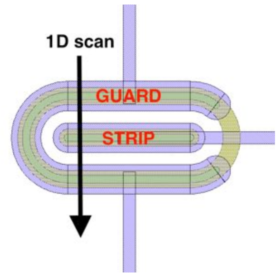

Fig. 2.d

Scanning along a single direction (1D) requires less time and the conversion time of the instrument is less significant. For the bi-dimensional scans (2D), a much faster acquisition routine is used ("zap scan"), making the conversion time of the instruments crucial. The 1D scans were performed using the slower Keithleys, while the 2D scans were performed reading out the V2Fs whose conversion time is much faster. The current of the sensors with respect to each hit positions of the X-ray beam was registered. The data coming from the beam monitoring detectors are used to normalize the signal coming from the DUTs to account for beam instability. In addition, the Transient Current Technique (TCT) was used to register the shape of the output signal as a function of time using broad band amplifiers and a digital oscilloscope connected to SPEC. Two different X-ray energies were used, 2.5 and 7.2 keV, in order to probe at different depths into the DUTs from the surface. The X-ray beam has a size of ~0.4x1.0 μm^2 and hits the sensors with a 30° tilt angle. Additional features of the SXM such as X-ray flourescence recorded by a Silicon Drift Detector (SDD) can allow the visualisation of different materials and elements in the sensor (e.g. the metal contacts).

Results:

A vast amount of data was collected during the experiment. A total of 9 different sensor geometries were tested. In this report, only the data taken using a beam energy of 7.2 keV will be discussed. The functionality of the entire assembly was checked by a quick current measurement which was then compared to the the measurement prior to the assembly on sensor level.. The results were similar pre- and post- assembly which demonstrated that the assembly, including wire-bonding and transportation was successful, despite the sensors being only ~10μm thick. A transmission measurement was performed to confirm the expected thickness of the sensor. The result shows roughly 76% transmission through silicon. This corresponds to approximately14μm, which is in good agreement with the expected values.

Prior to a more sophisticated 2D scan, the 1D scan was performed across one single sensitive element biased at different operating voltages. Fig.2d shows one of the elements that was scanned indicating the the scan direction.The corresponding results are shown in Fig.2.a, Fig.2.b and Fig.2.c for STRIP1, STRIP2 and GUARD respectively. The beam was focused on STRIP2.

The resulting charge collection profile (Fig.2.b) is very close to a uniform distribution. The FWHM value is in agreement with previous numerical simulations and is found to be ~17 μm. The decrease in collected charge situated in the middle of the profile is caused by the presence of the n+ implantation in the strip. This area consists of high concentration of n+ dopants that resulted in high local charge recombination. The signal on the GUARD is complementary to the one on STRIP2 and the n+ implantations are also visible. No signal is observed on STRIP1 thanks to the stering ring avoiding cross-talk.

The fluorescence detector allows to precisely probe where the metal contact is present and a result is reported in Fig.3.a (compare with blue layer in Fig.2.d). The signals for the strip and guard are reported in Fig.3.b and 3.c respectively. Sharp profiles and nice uniformity are observed. The n+ implantations are again visible (orange regions). High signal regions are observed under the metal links, suggesting that some MOS effects are present. This situation is not optimal and will be corrected in the next batch of detectors. In addition, it is very important to observe how well defined the signal in STRIP2 is, confirming that the "steering ring" is performing well and as intended, limiting charge generated outside to drift toward the inside. Signal dependence on the operating voltage was also studied and the optimal operating voltage was found to be between 5 and 10V depending on the sensor geometry.

To fully understand the charge collection dynamics, additional measurements were performed using 2Ghz preamplifiers and a digital oscilloscope to study the signal shape coming from the device as a function of time. A result is reported in Fig.3.d. The beam was focused on the strip and the bias voltage was ramped up sequentially. At V_{bias}=0V a very long tail is present in the signal, showing how the majority of the device was not depleted. This means that the charge collection must rely on the diffusion mechanism which is slow. Nevertheless, the charge collection is completed in less than 10ns. As the bias voltage increases, signals increase in amplitude and become narrower. At the maximum tested voltage (40V) the width of the signal is <1ns and the rise time is in the order of few hundred picoseconds. In addition to the results here reported, the measurements at lower energies clearly showed the toporgaphy of the sensor upper surface layers, due to their much lower absorption length (2.7 μm).

The beam test was a success and a very large amount of data was collected. The data analysis is now completed and and has provided detailed information on the performances of the sensors. Additional numerical simulations will now be launched to complete this in-depth understanding of devices. The collected data together with the numerical simulations will be compiled into a set of publications that describe the comprehensive physical and theoretical understanding of the sensors, planned to be submitted in the coming months. Moreover, the extracted information from the experiment is vital for design optimisation in the new sensor run that is currently being fabricated at SINTEF MiNaLab in Oslo, Norway.

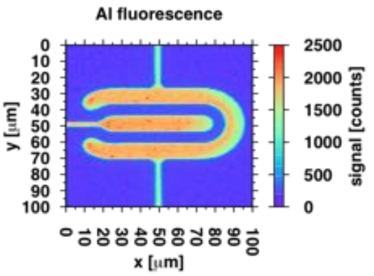

Fig.3.a.

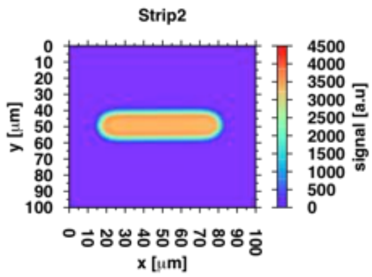

Fig.3.b.

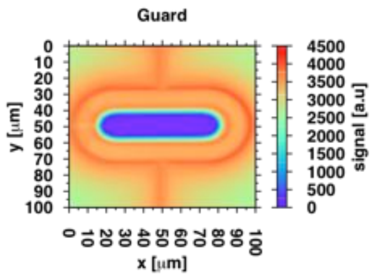

Fig.3.c.

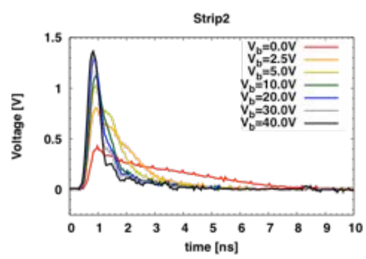

Fig.3.d.