Radiation Damage of the SimbolX and BepiColombo Silicon Detectors: Measurement of the Current Related Damage Rate at −50° C

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1. Introduction

SimbolX [1] and BepiColombo [2] will be the first space missions equipped with X-ray spectrometers based on DEPFET [3] macropixel matrices. These detectors will receive proton doses of 3.8×10^8 and 2.8×10^{10} 10-MeV equivalent protons/cm^2 respectively. Such high proton doses, combined with the large pixel areas of 625×625 μm^2 and 300×300 μm^2 respectively, will generate an increase of the leakage current due to bulk damage, which will be responsible for the degradation in energy resolution. In addition, since the sensors will be kept during the travel and the experiment at temperatures below −40° C, no remarkable beneficial annealing of the leakage current would occur.

The experiment described in this report was performed at the MLL accelerator facility in order to measure, for the first time, the current related damage rate in absence of annealing and, according to the results, check the feasibility of the experiments or plan a possible annealing procedure to reduce the leakage current.

2. Experimental Setup

The diodes used for these measurements were available in 10×10 mm^2 dies, each one including three 3.2×3.2 mm^2 squared diodes with guard ring and a capacitor. These diodes were obtained from 450 μm thick wafers produced in the MPI Semiconductor Laboratory with the same technology used in the DEPFET production. Every die was mounted on a module including a mechanical support to facilitate handling and biasing, a Peltier module and a PT100 sensor to allow thermal control and temperature monitoring. A 60 cm long vacuum cylinder was equipped in order to place the diodes along the proton beamline. On one side the cylinder was interfaced with the MLL vacuum pipe, while with the other side a flange was placed with a cold finger supporting the diode module.

The dosimetry was performed by counting the proton interactions with the diodes: the diodes were depleted during the irradiation and connected to a charge-sensitive preamplifiers so that the frequency of protons signals exceeding a fixed threshold could be measured with digital counters. The dose was monitored online from the control room.

The diodes were irradiated with 10-MeV protons at a temperature of −50° C. The beam parameters were adjusted in order to achieve a beamspot as wide as possible (of the order of 8×14 mm) to irradiate the dies uniformly and and keeping the proton rate below 1-1.5 MHz to allow proton counting. After every irradiation, the leakage current was measured before warming up the samples, venting the cylinder, and replacing them.

3. Results and Conclusions

The current related damage rate is defined as the increase of leakage current (normalized at 20° C) per unit of volume, divided by the fluence, expressed in 1 MeV equivalent neutrons/cm^2. The flux was corrected to include the effect of dead time and the effect of non uniform energy loss at different depths in the silicon (the latter was simulated with GEANT4 [4]).

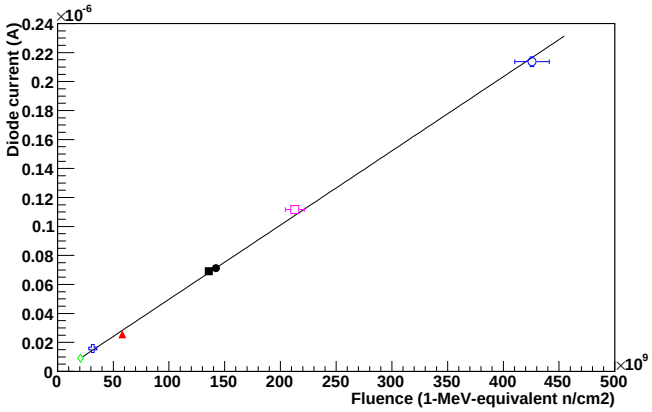

Fig. 1: The diode current measured at −50° C (and normalized at 20° C) as a function of the corrected fluence expressed in 1-MeV-equivalent neutrons. The fit is superimposed to the experimental measurement.

The measured diode leakage current is shown in Fig. 1 as a function of the corrected fluence and from this fit, a value of $(11.1\pm0.2)\times10^{-17}$ A/cm was extracted. In order to compare this measurement with the average provided by the RD 48 [5] collaboration, and therefore validate the whole experiment, the leakage current was measured after several annealing steps of fixed duration at 60° C and the measured value after 80 minutes was $(3.66\pm0.05)\times10^{-17}$, which is close to the one obtained from the RD 48 Collaboration of $(3.99\pm0.03)\times10^{-17}$.

The most important conclusion is that, with this damage rate, for the SimbolX experiment, it will be still possible to achieve the required resolution at the project temperature and integration time. In the BepiColombo mission, an annealing procedure will be required, in order to achieve the needed resolution. Further irradiations of DEPFET pixels and matrices will be the object of the next experiments.

References

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