Effects of radiation damage on the dosimetric properties of standard float zone (FZ) and magnetic czochralski (MCz) diodes in high-dose electron processing applications

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Introduction: Silicon detectors have been largely used in High Energy Physics (HEP) experiments due to fast response, good spatial resolution and high signal-noise ratio that they present [1]. However, in these experiments, the devices are exposed to high radiation doses demanding efforts to enhance their tolerance to radiation damage. In this research context, technological advances have led to the production of rad-hard Magnetic Czochralski (MCz) silicon diodes which are promising devices for high-dose dosimetry [2]. This work describes the dosimetric properties of such MCz diodes as on-line electron processing dosimeters in the range from 5 kGy to 2MGy. For comparison, all measurements were carried out with standard float zone (FZ) silicon diodes under the same experimental conditions. The effects of 1.5 MeV electrons damage on the response of MCz and FZ diodes were mainly investigated with respect to both current/charge sensitivities and leakage current/capacitance changes as a function of accumulated dose.

Experimental: MCz and FZ devices were processed in a similar structure on n type Si wafers of 300 μm thickness and 25 mm^2 active area. Each diode was housed in a black PMMA probe with an entrance window of 3.6 mg/cm^2 thick aluminized mylar. The planar frontal pad (p+) of the diodes, were directly connected to the input of a Keithley 6517B electrometer while the back planes (n^+) kept grounded. The irradiation was performed with 1.5 MeV electron beam with 4kGy/s dose rate and radiation field size of 2.5 x 100 cm^2. The dosimetric probe was placed on a conveyor belt with 3.36 m/min which corresponds to an absorbed dose of 1,78 kGy each forward and backward pass of the diode in the electron radiation field. The current signals induced on the diodes during the conveyor movement in each pass were registered as a function of the time for doses up to 700 kGy. To foresee how radiation induced defects will affect the current/charge sensitivity and response stability of these devices, dynamic current and capacitance of the diodes were measured after each step of irradiation.

Results and Discussion: Current waveforms induced on the diodes during the conveyor movement in the electron radiation field are presented in Fig.1 (MCz and FZ). This figure shows that the peak current values are achieved when the devices just passed underneath the electron accelerator window. As expected, significant current sensitivity decay is observed with the accumulated dose. As a consequence, the relation between charge and absorbed dose are not linear for doses up to 700 kGy for both diodes. Despite of this, dose-curves have been well fitted by a second order polynomial function (correlation coefficient ≈ 0.999). Studies about radiation induced defects have been performed by dynamic measurements of current and capacity as a function of dose, after each step of irradiation. Up to 700 kGy, the dark current of the diodes has increased with the accumulated dose and, so far, no capacity changes are observed. Analyses of these results are in progress.

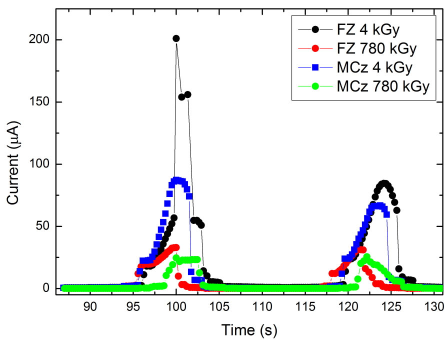

Fig. 1 - Current waveforms induced on the FZ and MCz diodes as a function of the time.

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References:

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