Evaluation of radiation-hard Magnetic Czochralski (MCz) Silicon Diodes in Electron Processing Dosimetry

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Abstract

A dosimetry system using radiation hard Magnetic Czochralski (MCz) silicon diodes has been designed for measurement of high absorbed doses (10 kGy to 2 MGy) and dose rates up to 8 kGy/s in electron processing field. These p^+-n-n^+ junction devices were processed on high resistivity n-type bulk material of 300 µm thickness with junction of 0.36 cm^2 active area by the Microelectronics Center of Helsinki University of Technology in the framework of the CERN RD50 Collaboration. With the diodes unbiased, the dosimetric characterization was performed in the direct current mode by connecting its frontal layer (p^+) to the input of a Keithley® 6517B electrometer, while grounding its back side (n^+). The irradiations were carried out in the Radiation Technology Center at IPEN-CNEN/SP with 1.5 MeV electron beam from a DC 1500/25/4 – JOB 188 Accelerator with a dose rate of 4 kGy/s. The current response of the diodes was measured as a function of the irradiation time in steps of 7.12 kGy to achieve an absorbed dose of 2.25 MGy. The results showed a fast and significant current decrease for doses up to 250 kGy, followed by a very small decay even for high doses about 2 MGy. To mitigate this sensitivity loss, the diodes were pre-irradiated with 250 kGy and after this procedure, despite of being less sensitive, the current signals were more stable with coefficient of variation (CV) of 3.1%. This CV value added the accelerator instabilities which are covered up in static dosimeters such as cellulose triacetate (CV≈3.0%) and PMMA (CV≈5%) dosimeters, routinely applied in radiation processing. The dose-response curve of the diodes, given by the charge (integration of the current signal versus time) as a function of the dose, were fitted by a second order polynomial function with correlation coefficient higher than 0.99. To monitor possible electron radiation damage effects produced on the diodes, their dynamic leakage currents were also measured as a function of the absorbed dose. For comparison, the dosimetric response of a standard Float Zone (FZ) diode was investigated at the same experimental conditions. So far, the results evidenced that the MCz diode is substantially more tolerant to radiation hardness than the FZ device, despite of both diodes exhibited high sensitivity and good repeatability. This indicates the potential use of MCz diodes in high dose online radiation processing dosimetry. The reproducibility and radiation damage studies are under way.