Multi-MGy Radiation Hard CMOS Image Sensor: Design, Characterization and X/Gamma Rays Total Ionizing Dose Tests

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ABSTRACT:
A Radiation Hard CMOS Active Pixel Image Sensor has been designed, manufactured and exposed to X and ^{60}Co γ-ray sources up to several MGy of Total Ionizing Dose (TID). It is demonstrated that a Radiation-Hardened-By-Design (RHBD) CMOS Image Sensor (CIS) can still provide useful images after 10 MGy(SiO_2) (i.e. 1 Grad). This paper also presents the first detailed characterizations of CIS opto-electrical performances (i.e. dark current, quantum efficiency, gain, noise, transfer functions, etc.) in the MGy range. These results show that it is possible to design a CIS with good performances even after having absorbed several MGy.
Four different RHBD photodiode designs are compared: a standard photodiode design, two well-known RHBD layouts and a proposed improvement of the gated photodiode design. The proposed layout exhibits the best performances over the entire studied TID range and further optimization are discussed.
Several original MGy radiation effects are presented and discussed at the device and circuit levels and mitigation techniques are proposed to improve further the radiation hardness of future Rad-Hard CIS developments for extreme TID applications (e.g. for nuclear power plant monitoring/dismantling, experimental reactors (e.g. ITER) or next generation particle physics experiments (e.g. CERN)).