Comparative Study of the Proton Beam Effects between the Conventional and Circular Gate MOSFETs.

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Whereas the electronic devices have been incorporated in the design for space applications, the investigation of the radiation effects in semiconductor devices has increased in order to understand the possible electrical failures that can occur in space ICs[1]. One of the many effects that have been vastly studied is the Total-Ionization-Dose (TID), that causes a cumulative damage of the semiconductor lattice and consequently in a shifting in the threshold voltage (V_{TH}), and an increase in the subthreshold slope (S) and off-state current (I_{OFF}). This effect is mainly caused by the interaction of high-energy photons or charged particles within the semiconductor structure [2]. However, hardening techniques such as guard rings and enclosed layout transistors (ELTs) [3] can be used to reduce the TID effects. The focus of this paper is to presents the experimental results of the comparison between conventional nMOSFETs (RGM) and circular gate nMOSFETs (CGM), manufactured with conventional CMOS fabrication process (On Semiconductor 0.5 µm) and irradiated with proton beam radiation doses. It is expected that due to the absence of the bird's beak, the CGM is more adequate for the space applications. During the experiment, several I_{DS}xV_{GS} curves were extracted, for V_{DS}=100 mV and varying V_{GS} from 0 V to 3V. This study demonstrated that the RGM I_{OFF} presented a degradation of 2 decades, a reduction of threshold voltage in 48.5 % and a variation of 36.3 % in the subthreshold slope. Reciprocally, the CGM presented practically no variation at I_{OFF}, reduction of threshold voltage in 51.5 % and variation in the subthreshold slope of 39.7 %.The Total-Ionization-Dose effects were studied, for different dose rates, beam currents and total doses, for protons beam irradiations. The protons beam irradiation was done, using an electrostatic accelerator-tandem Pelletron of 1.7 MV, at the Physics Institute of Universidade de Sao Paulo, for beam energy of 2.6 MeV and a total accumulated dose of 3.2 Grad. Figure 1.a presents an example of the RGM and CGM layouts. Where L is the channel's length, W is the channel's width, R_1 is the internal radius of the CGM and R_2 is the sum of the R_1 and L. Figure 1.b presents the I_{DS}xV_{GS} curves for V_{DS}=500 mV of the RGM and CGM counterpart, before and after exposure to protons total dose of 3.2 Grad. The experimental results presented that the RGM and CGM had practically the same variation in the threshold voltage and in the subtreshold slope. However, the CGM had pratically no variation in the off-state current, while the RGM presented a two decade variation, suggesting that the circular gate geometry is more robust to ionizing radiation than the one found in the rectangular gate geometry.

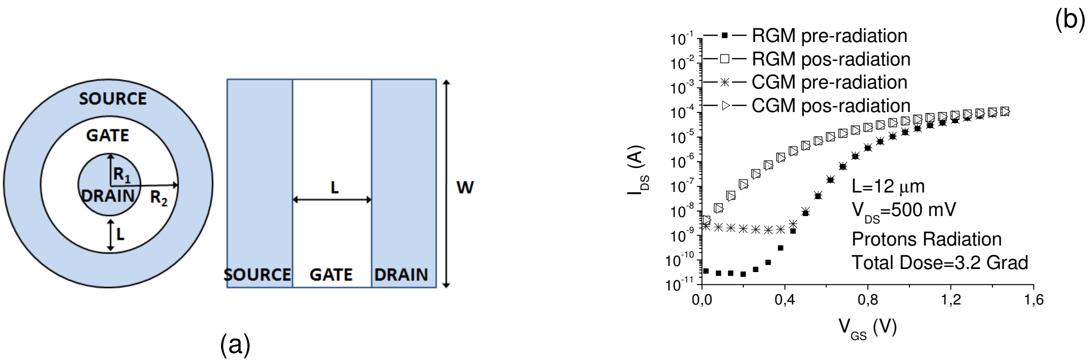

Figure1. Example of the CGM and the RGM layouts (a). I_{DS}xV_{GS} curve comparing CGM and RGM performance, before and after the protons irradiation (b).

[1] J. R. SROUR, **Basic Mechanisms of Radiation Effects on Electronic Materials, Devices, and Integrated Circuits**. Proc. 1983 IEEE NSREC Short Course, 1983.
[2] H. J. BARNABY, **Total-Ionization-Dose Effects in Modern CMOS Technologies**, IEEE Trans. Nuclear Science, vol. 53, n. 6, December 2006.
[3] MAVIS, D. G. and ALEXANDER, D. R.; **Employing Radiation Hardness By Design Techniques with Commercial Integrated Circuit Processes**, 16th Digital Avionics Systems Conference, 1997, AIAA/IEEE.