ESRF	**Experiment title:** **Spatially-resolved defect generation in metal-oxide-semiconductor transistors**	**Experiment number:** HE-443
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Report:

Over the past several years, only a few works have experimentally verified the impact of localized total-dose degradation in metal-oxide semiconductor (MOS) devices [1]. Ion beams were used to induce spatially-limited total-dose effects. The aim of this work is to investigate a new experimental approach based on the use of a x-ray focused micro-beam to irradiate, at the micrometer scale, the active area of a single MOS transistor. We studied the electrical response of generated defects as a function of their precise location in the device.

Experimental details

The devices used in this study were large area ($100\times100\ \mu m^2$) n-channel transistors manufactured using a 0.25 μm CMOS technology with 4.5 nm gate oxide thickness. They were mounted in Dil16 ceramic packages. The device under test was fixed on a goniometer head which can be translated along the two directions perpendicular to the beam with an absolute accuracy of ≤ 1 μm. Devices were irradiated at room temperature under +1 V gate bias (source, drain and substrate grounded) and with a dose rate of ~180 Mrad(Si)/s.

Results

A schematic top view of the transistor gate area is illustrated in Fig. 1. Two series of irradiation spots are identified on this map : a single spot (labeled A) in the middle of the gate and a series of 15 spots (labeled B1 to B15) distributed along the source size (B1 to B7) and along the transistor channel (B8 to B15). These two series refer to two distinct devices. Each spot corresponds to 180 s irradiation exposure. Fig. 2 shows the charge pumping response of a transistor before and after the spot A. The plateau of the characteristics is directly proportional to the number of interface traps at the Si/SiO_2 interface [2].

After spot A and by subtracting the two curves, an increase of ~2 pA in the charge pumping current is evidenced, which corresponds to the net creation of ~ 2500 active traps. These traps are created on a part of the interface which corresponds to the spot size, i.e. ~ 3 μm^2. Consequently, the spot induces an increase of the interface state density of ~8×10^{10} cm^{-2}. This level of density is rather moderated if we consider the total dose reached after 180 s exposure. But the combination of an ultra-thin gate oxide and a gigantic dose rate could explain such a result. During the experiments, we varied the position of this single spot (always performed on virgin devices). The influence of the spot position and of the total-dose on the electrical response of the device are discussed in Ref. [3].

Fig. 3 shows the increase of the maximum charge pumping current as a function of cumulative degradation caused by series of spots B1 to B15 on a transistor initially virgin. We evidence here the fact that the step-by-step increase is approximately constant when varying the spot position, excepted near the transistor drain. This aspect has been explored throughout complementary experiments (when disconnecting source or drain contacts) and by numerical simulations of the charge pumping response [3].

Finally, the impact of local irradiation on the gate oxide breakdown under high electric-field has been investigated by performing emission spectroscopy measurements after irradiation. Fig. 6 shows the spatial emission map of the transistor submitted to spots B1 to B15, as obtained with an Hamamatsu dual mode cooled CCD camera C4880-06. No direct correlation between irradiation and oxide breakdown is revealed here. These results suggest that, in this particular case, the radiation-induced defects may not play any significant role in the oxide breakdown phenomenon.

[1] M. Koh et al. Appl. Phys. Lett. 68, 1552 (1996). See also references therein.
[2] J.L. Autran et al. in *Instabilities in Silicon Devices*, Vol. 3, chapter 6 (1999, Elsevier North-Holland).
[3] J.L. Autran et al. Submitted to IEEE Trans. Nucl. Sci. (1999).

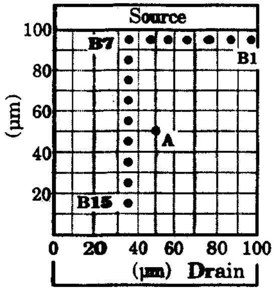

Figure 1

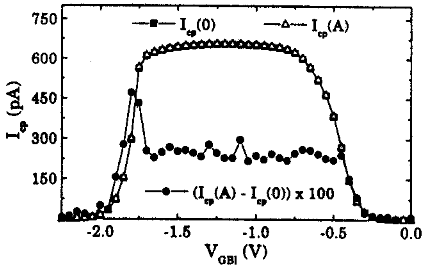

Figure 2

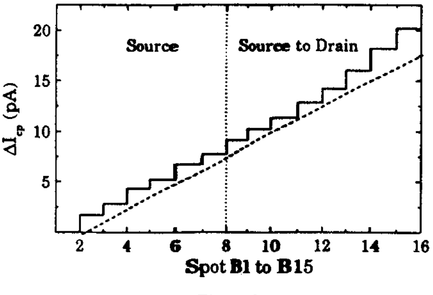

Figure 3

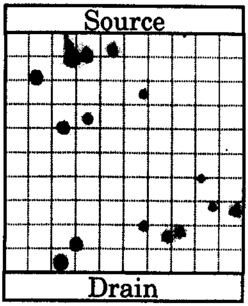

Figure 4