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# SMART SENSOR FOR SAFETY APPLICATIONS ON ELECTRONIC EQUIPMENTS IN RADIATION ENVIRONMENT

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*Abstract* — **This paper presents an integrated system for on-line monitoring of ionizing radiation in safety-critical applications. First, radiation sensors are briefly reviewed. Next, basic principles of an integrated system (Integrated Dosimeter) including such sensor are detailed. The main idea is to integrate the sensor with the appropriate circuitry so that a high-performance system is obtained. An integrated dosimetry system is proposed including microprocessor interface for remote monitoring. The primary advantage of the proposed dosimeter is that it is a compact design and provides continuos read out of the total dose.**

*Keywords* — **Smart Sensor, Measurement Integrated System, Instrumentation, Dosimetry, Ionizing Radiation**

## I. INTRODUCTION

When an electronic device is exposed to ionizing radiation, the total dose absorbed by the device may cause parametric shifts leading to failure or malfunction. Those effects are very important in safety-critical applications such as: medicine, nuclear plants, laboratories and spacecraft.

The simplest circuit used in radiation sensors is based on the pMOSFET sensitivity to the ionizing radiation (Kelleher *et al.*, 1992).

The concept of MOS dosimetry involves measuring the changes on the electrical characteristics of a MOSFET device when it is exposed to the radiation. These changes are threshold voltage shift, carrier mobility reduction and subthreshold current increase. Basically, the increase in the oxide charge causes the MOSFET's threshold voltage to change, and this change is used to estimate the absorbed dose (Buelher *et al.*, 1993). This type of dosimeters can be used in scenarios with radiation hazard, like hospitals or nuclear power plants, indicating involuntary radiation. But, they can also be used in radiation hardened circuits, such as those used in space missions, to detect fault induced by ionizing radiation.

## II. RADIATION EFFECTS ON MOSFETS DEVICES

When a MOSFET device is irradiated, three mechanisms within the silicon dioxide layer (sensitive region) predominate: a build-up of trapped charge in the oxide, an increase in the number of interface traps and an increase in the number of bulk oxide traps. (Soubra *et al.*, 1994).

Electron-hole pairs are generated within the silicon dioxide by the incident radiation. Electrons, whose mobility in $SiO_2$ at room temperature is about four orders of magnitude greater than holes, quickly move out of the gate electrode. Holes move in stochastic form towards the Si/ $SiO_2$ interface where some of them are captured in trapping sites. This causes a threshold voltage shift ($\Delta V_{TH}$) that can persist for long time.

The voltage shift ($V_{TH\ \text{before exposure}} - V_{TH\ \text{after exposure}}$), whose magnitude can be experimentally measured, is proportional to the total quantity of trapped charges which, in turn is proportional to the dose.

Threshold voltage in irradiated MOS transistor is related to the increase of the trapped charges in the oxide (Qot) and in the interface state (Qit) by:

$$\Delta V_{TH} = -\frac{\Delta Q_{ot} + \Delta Q_{it}}{C_{ox}} \qquad (1)$$

The net charge trapped in the oxide layer after radiation is always positive. The interface state can exchange charge freely with the silicon substrate, and thus the sign of the trapped charge depends on the bias of the device. In normal operation trapped charge is positive in a pMOS and negative in the nMOS. Therefore, the threshold voltage of a pMOS transistor shifts monotonically to negative values, as the radiation dose increases. The shift in a nMOS transistor can be more complicated; depending which contribution is dominant. Due to this fact pMOS transistors are preferred against nMOS to build sensors (Ma and Dressendorfer, 1989). The mobility of carriers in the transistor channel is degraded as the radiation dose increases (Sun and Plummer, 1980). This leads to a reduction in transistor transconductance. The mobility degradation correlated very well with the radiation-induced interface-trapped