60Co Gamma Influence on Transconductance in N-Channel MOS Device and its Revival under Isochronal Annealing Technique

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Abstract: N-channel depletion MOSFETs are exposed to 60Co gamma up to 60 Mega rad of radiation dose. Transconductance is one of the important electrical characteristics of MOSFET is studied before and after the impact of 60Co gamma on MOSFETs. It was found that transconductance to be decreased with increase in 60Co gamma radiation dose. After isochronal annealing the transconductance and peak transconductance are recovered about 90% at 300°C.

Keywords: MOSFET; transconductance; 60Co gamma radiation; isochronal annealing.

I. INTRODUCTION

N-channel depletion metal oxide semiconductor field effect transistors (MOSFETs) are used in many applications, including in integrated circuit industry, space, military and other radiation environments like in large hadron colliders (LHC). However, MOS devices are sensitive to radiation and even face functional damage [1-2]. The basic damage effects of radiation in MOS devices results from the generation of interface and oxide trapped charge [3]. This trapped charge degrades the important electrical properties of MOSFETs such as threshold voltage (V_TH), transconductance (g_m) and mobility of carriers (µ) in the channel. In order to use MOS devices in radiation present vicinity like in space, the devices need to radiation resist up to a few Mega rad of gamma dose. The main objective of this work is to explore the effect of 60Co gamma on g_m of the MOSFET and its revival by isochronal annealing.

II. EXPERIMENT

The devices used for this work are two serially connected N-channels with independent dual gate depletion MOSFETs (BEL 3N187) [1-3]. It is evident that, when high energy ion passes through a solid, it loses its energy by two processes namely, electronic energy loss, <dE/dx>e and nuclear energy loss, <dE/dx>n. Due to the lower elastic scattering cross section, nuclear energy loss in a material is significantly smaller (three orders of magnitude) than electronic energy loss. As a result, all of the energy deposited in the material is mostly owing to the electronic energy loss process during the substance’s early passage. Near the end of the ion range, nuclear energy loss becomes dominant. The N-channel MOSFETs are exposed to 60Co Gamma radiation using gamma chamber 5000 with a dose rate of 167 rad/s at Pondicherry University, Puducherry, India. MOSFETs are exposed to 60Co gamma radiation in a
dose range from 300 kilo rad to 60 Mega rad. The electrical characterization before and after $^{60}$Co gamma impact on MOSFETs are performed using computer interfaced 4155 HP Agilent Semiconductor Parameter Analyzer. The $V_{TH}$ and $g_m$ are determined from the $I_D-V_{GS}$ characteristics. Further, the mobility ($\mu$) of carriers in the channel of the device was estimated from the $g_{m\text{Peak}}$ (at constant $V_{DS} = 0.1$ V).

III. RESULTS AND DISCUSSION

In MOSFETs, the role of Si/SiO$_2$ interface is very important in determining the device performance. When MOS devices are exposed to radiation some of the radiation induced electron-hole pairs quickly undergo recombination and some of the positively charged holes make slow dispersive transport towards the Si/SiO$_2$ interface where they are trapped in deep hole traps [4-5]. It is well known that $^{60}$Co gamma produce radiation damage via the creation of Compton electrons, which results in the charge deposition at the oxide-semiconductor interface and the nearby oxide layer. In addition to the change in $V_{TH}$ due to build up of oxide trapped charge and interface states, the other major effect of $^{60}$Co gamma radiation on MOS devices is the degradation of transconductance ($g_m$) [6-7].

The behavior of $g_m$ for $^{60}$Co gamma impact MOSFET is shown in Figure 1. It can be seen from this figure that there is a significant decrease in $g_m$ after $^{60}$Co gamma exposure. From this graph the maximum or peak $g_m$ was noted for different doses and is shown in Figure 2. The peak $g_m$ decreases from $6.089 \times 10^{-4} \text{ S}$ to $0.87 \times 10^{-4} \text{ S}$ for 60 Mrad of $^{60}$Co gamma total dose. It can also be seen that, there is not much change in peak $g_m$ after 10 Mrad of total dose and the maximum degradation is observed only up to 10 Mrad.

![Figure 1. Decrease in transconductance after exposed to $^{60}$Co gamma radiation.](image)

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Figure 2. Decrease in peak transconductance verses $^{60}$Co gamma radiation dose.

The recovery in $g_m$ after $^{60}$Co gamma impact MOSFET is shown in Figure. 3. It can be observed from this figure that the $g_m$ increases with increase in temperature and there is about 90% recovery in the $g_m$. The recovery in peak $g_m$ with temperature up to 300°C for $^{60}$Co gamma impact MOSFET is shown in Figure. 4. It can be observed from figures 3 and 4 that, up to 150°C there is no much recovery in peak $g_m$. Only after 150°C there is a sharp recovery in peak $g_m$. It can be seen from this figure that about 90% recoveries in peak $g_m$ after isochronal annealing at 300°C.

Figure 3. Recovery in transconductance after isochronal annealing.

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