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Experimental Study of Fast Neutron Irradiation on n-Channel MOSFET

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1. Introduction

Field Effect Transistor (FET) is a majority carrier device, and is therefore often called a unipolar transistor. The Bipolar Junction Transistor (BJT), on the other hand, operates by injection and collection of minority carriers [1][2][3]. Since the action of both electrons and holes is important in the BJT, it is called a bipolar transistor. Like its bipolar counterpart, the FET is a three terminal device in which the current through two terminals (source and drain) is controlled at the third (gate). Unlike the BJT, however, FET are controlled by a voltage at the third terminal rather than by a current. Metal Oxide Semiconductor (MOS) FET is commonly used, which is made using silicon for the semiconductor, SiO_2 or other oxides for the insulator, and metal or heavily doped polysilicon for the gate electrode.

This study will investigate the electrical characteristics of an n-channel MOSFET for the fast neutron irradiation.

2. Experimental Studies

MOSFETs are extensively used because of their faster switching speeds and simple drive requirements compared to bipolar transistors. However, MOS devices are sensitive to radiation in space and in other radiation environments [4][5]. MOS devices, when subjected to nuclear radiation, suffer from damage in oxide as well as in the bulk semiconductor. Displacement damage in the semiconductor devices as well in the bulk silicon of the MOS devices has been well reported as an increase of leakage current, carrier removal effect, degradation of carrier mobility and the reduction in the minority carrier lifetime etc.

The basic damaging effects of ionizing radiation result from the generation of electron-hole pairs in the gate oxide [6]. When positive bias is applied to the gate, electrons drift rapidly under the influence of the applied electric field and most flow out into the external circuit. In this case, holes have been shown to have lower mobility and to drift slowly to the Si/SiO_2 interface; a fraction become trapped and thus form the radiation-induced oxide trapped charge. These negative charge induce a negative shift in the threshold voltage and increase the leakage current, which leads to increased power consumption. During the hole transport and trapping process, hydrogen is released within the oxide, and may transport to the interface and react with silicon dangling bolds, forming interface traps. The density of these interface states is greatly enhanced by the positive bias voltage applied during the irradiation, and they too can modify the overall charge-dependent properties of MOS devices including the decrease in transconductance and the mobility. In many application of mixed signal and digital technologies, an important parameter is transconductance, which can affect the speed and output drive.

The lattice damage arises from the displacement of silicon atoms because of the bombardment by fast neutron irradiation [2]. A uniformity of damage can be obtained from the fast neutron irradiation method.

2.1 Fast Neutron Irradiation

In this experiment, n-channel MOSFETs, used for switching application, were applied. The maximum ratings of the MOSFET are given in Table 1. Fast neutron irradiation is performed using the MC-50 cyclotron in KIRAMS (Korea Institute of Radiological & Medical Sciences). The irradiated fast neutron fluence is 1 x 10^{10} n/cm^2.

Table 1. Maximum ratings of MOSFET at 25 °C

Characteristic	Symbol	Rating
Drain-Source Voltage	V_{DSS}	650 V
Gate-Source Voltage	V_{GSS}	±30 V
Drain Current	I_D	7 V
Drain Power Dissipation	P_D	44.6 W

2.2 Experimental Results

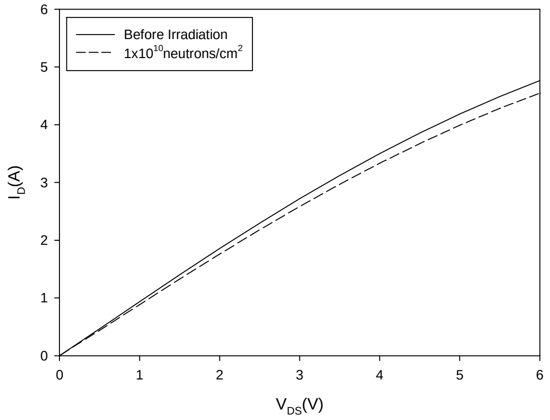

Fig. 1. Drain currents versus drain-source voltage for the case

of before and after fast neutron irradiation.

Figure 1 shows the experimental result of the drain currents (I_D) versus the drain-source voltage (V_{GS}) for before and after fast neutron irradiation when the gate-source voltage is 7.5 *V*. The drain current is decreased for the case of after fast neutron irradiation compared with before irradiation case.

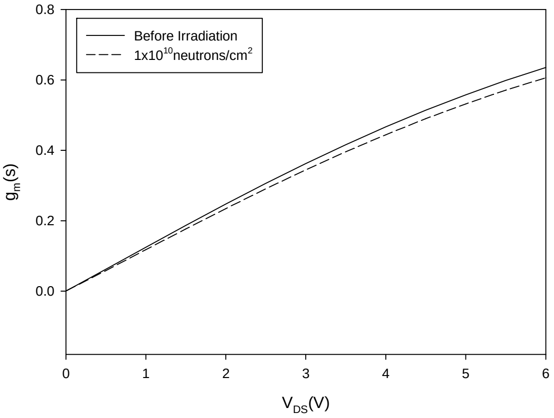

Fig. 2. Transconductance versus drain-source voltage for the case of before and after fast neutron irradiation.

Figure 2 shows the experimental result of the transconductance ($g_m=I_D/V_{GS}$) versus drain-source voltage for before and after fast neutron irradiation when the gate-source voltage is 7.5 V. The transconductance is decreased for the case of after fast neutron irradiation compared with before irradiation case.

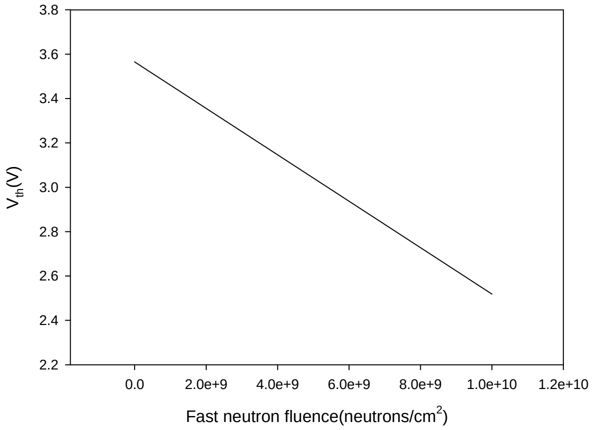

Fig. 3. Threshold voltage versus fast neutron fluence.

Figure 3 shows the threshold voltage (V_{th}) for before and after the fast neutron irradiation. The threshold voltage is decreased with increasing of fast neutron fluence.

3. Conclusions

In this paper, the electrical characteristics of an n-channel MOSFET such as the drain current and transconductance are investigated for fast neutron irradiation. The experimental results show that the drain current and the transconductance were decreased for the case of fast neutron irradiation. And the threshold voltage was decreased for the case of fast neutron irradiation.

Acknowledgement

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