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# Effect of the active mode NMOS-transistor irradiated on formation of surface defects

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**Abstract.** The results of experiment on irradiation CMOS integrated circuits are presented at dose rate 0,1 rad/s with in electric and passive modes. Two stages of surface defects formation in both cases were observed.

## 1. Introduction

The two stages of surface defects formation in *n*MOS-transistors of CMOS integrated circuits at low dose rate described in [1, 2]. These integrated circuits were irradiated by the gamma-rays of Cs<sup>137</sup> at passive mode of *n*MOS-transistors. The first stage of surface defects formation is described by an exponential dependence and have any saturation [ 3 ]. The second stage has some delay and saturated too [1]. Also, some useful information is presented in articles [6-8]. The purpose of this paper is the investigation of surface defects formation at Si-SiO<sub>2</sub> interface under active mode and low dose rate gamma irradiation.

## 2. Metod

The density of surface defects (interface traps) at the *Si-SiO<sub>2</sub>* interface was calculated from the slope value drain-gate characteristics *I-U* [4]. As for the experiment were used measurements *I-U* curve on sloping plot drain-gate character transconductance *n*MOS, consequently equation was used:

$$I_d = k(U_G - U_0)^2, \quad (1)$$

where  $I_d$  is the drain current;  $k$  is the effective transconductance;  $U$  is the gate voltage and  $U_0$  is threshold voltage.

The linear dependence can be written as:

$$\sqrt{I_d} = \sqrt{k} (U_G - U_0), \quad (2)$$

Because the parameters *n*MOS are not known, we analyzed relative changes transconductance:

$$\frac{\sqrt{k(0)}}{\sqrt{k(D)}} = \frac{\sqrt{\frac{\mu_s(0)}{2} * \frac{W}{L} * C_{ox}}}{\sqrt{\frac{\mu_s(D)}{2} * \frac{W}{L} * C_{ox}}}, \quad (3)$$



where  $k(0)$  and  $k(D)$  is s transconductance before and after irradiation at dose  $D$ ,  $W$  and  $L$  is width and length of the channel NMOS,  $C_{ox}$  is the gate capacitance per unit area.

Of the relative change transconductance, has been described relative value surface electron mobility  $\mu_s$ , in channel  $n$ MOS-transistors:

$$\sqrt{\frac{k(0)}{k(D)}} = \sqrt{\frac{\mu_s(0)}{\mu_s(D)}}, \quad (4)$$

where  $\mu_s(0)$  and  $\mu_s(D)$  are values surface carrier mobility before and after irradiation dose  $D$ .

Surface mobility depends on the change interface trap concentration, and is described [5]:

$$\mu_s(D) = \frac{\mu_s(0)}{1 + \alpha \Delta N_{it}}, \quad (5)$$

where  $\Delta N_{it}$  is change interface trap concentration;  $\alpha = (7,0 \pm 1,3)10^{-13} \text{ cm}^2$ . Thereby, change interface trap in this paper, defined as equations:

$$\Delta N_{it} \cong 1,43 \cdot 10^{12} \left( \frac{\mu_s(0)}{\mu_s(D)} - 1 \right). \quad (6)$$

### 3. Experiment

In this experiment three CMOS integrated circuits *CD4069UBCN* in which characteristics of 9 MOS transistors were measured were used. This integrated circuits was irradiated by  $\text{Cs}^{137}$  gamma source at dose rate  $P = 0,1 \text{ rad/s}$ . The irradiation was in active and passive modes. In case of using active mode it was given at input and supply voltage  $U=12 \text{ V}$ . In passive mode all pins of the integrated circuit were grounded during irradiation.

Characteristics  $n$ MOS-transistors were measured before and after each step irradiation. During experiment were obtained the average values of the changes of the electrons mobility, which have been determined by statistical techniques. The function of the normalized electron mobility on the dose irradiation is presented in fig. 1.

During the experimental study, the calculated values of the density interface traps after each stage of irradiation was received. The experimental results are presented in fig. 2, where interface trap density as a function of dose is shown.

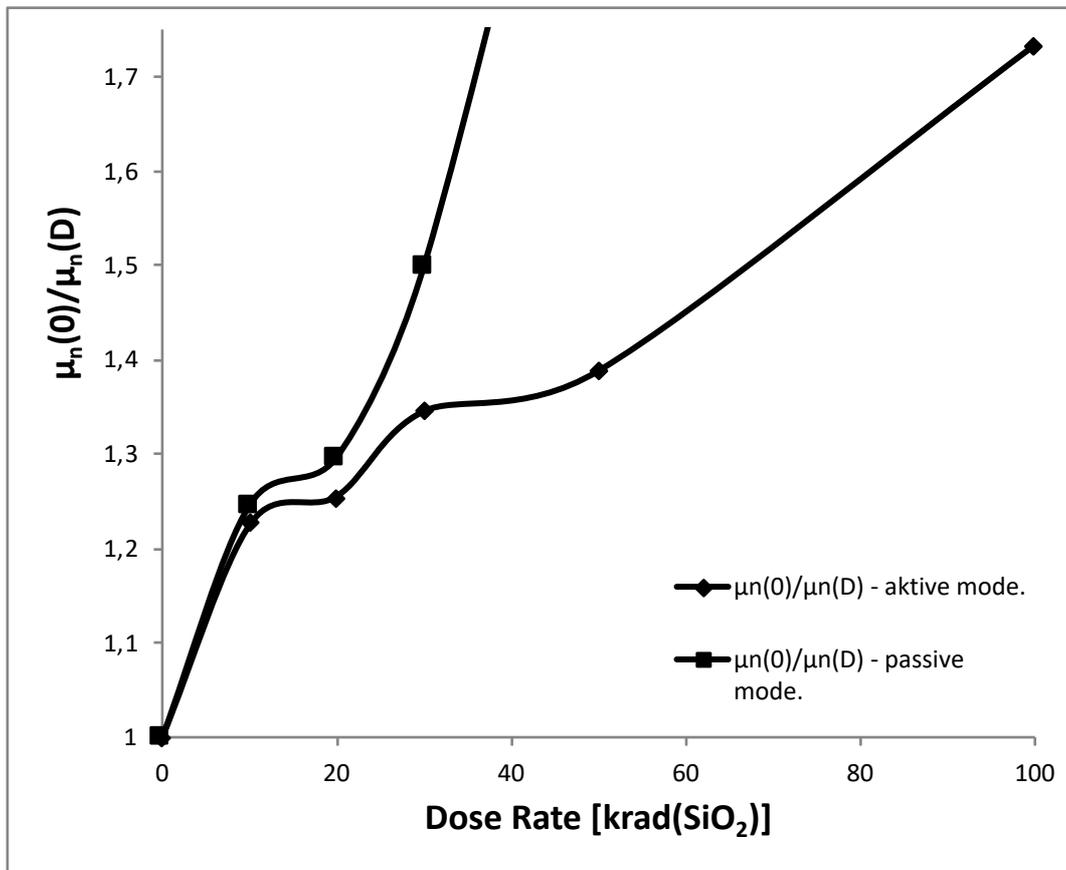


Figure 1. Dependence of normalized electron mobility versus dose irradiation.

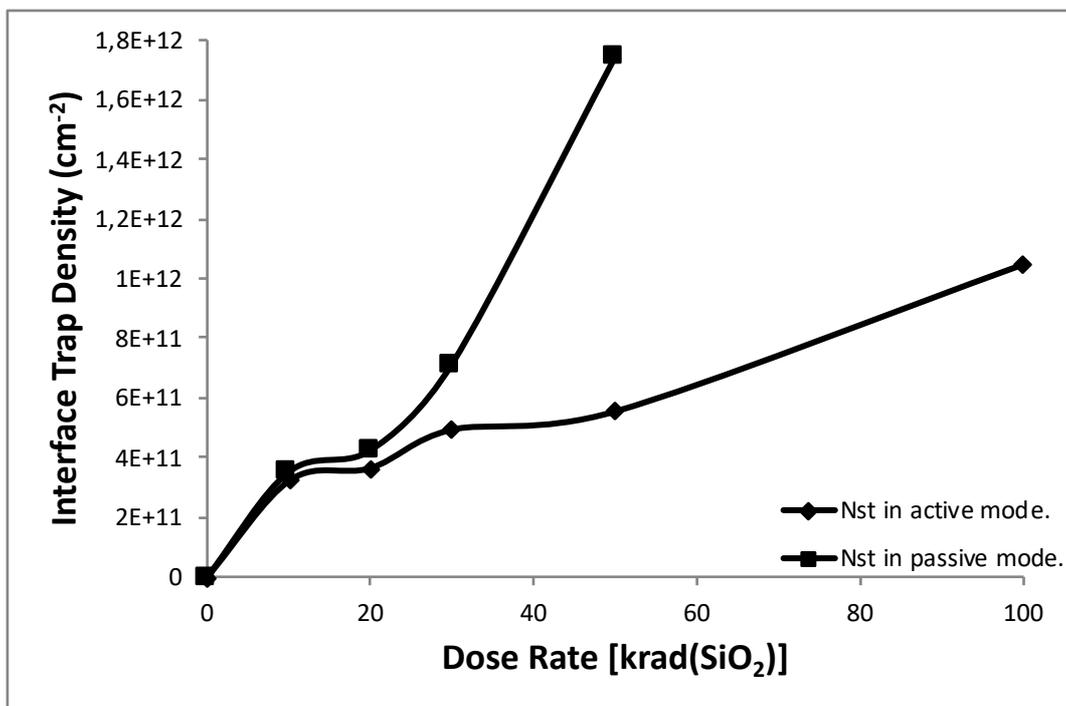


Figure 2. Interface trap density versus dose irradiation.

#### 4. Conclusion

Two stage of interface trap formation is observed in active mode and in passive mode irradiation. The first stage of the formation of surface defects is practically independent of the electrical mode and a true effect. In the second step this process becomes dependent on the dose rate and time. This leads to an additional increase in the density of surface defects. It is observed that in active mode the rate of formation of surface defects is reduced.

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