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Stacked floating gate MOSFET as a passive dosimeter

Stefan D. Ilic[1,6], Marko S. Andjelkovic[2], Miguel Ángel Carvajal[3], Russell Duane[4], Milija Sarajlic[1], Srboljub Stankovic[5], Goran S. Ristic[6]

1 Center of Microelectronic Technologies, Institute of Chemistry, Technology and Metallurgy, University of Belgrade, Belgrade, Serbia
2 System Architectures Department, IHP - Leibniz-Institut für innovative Mikroelektronik, Frankfurt (Oder), Germany
3 Department of Electronics and Computer Technology, University of Granada, Granada, Spain
4 Centre for Micro and Nano Systems, Tyndall National Institute, University College Cork, Dyke Parade, Cork, Ireland
5 Department of Radiation and Environmental Protection at the Vinča Institute of Nuclear Sciences, Belgrade, Serbia
6 Applied Physics Laboratory, Faculty of Electronic Engineering, University of Niš, Niš, Serbia

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Introduction. The approach to increase the sensitivity of semiconductor radiation dosimeter with a stacked design was presented for the thick oxide pMOS transistors, also known as RadFETs (A. Kelleher et al., IEEE transactions on nuclear science 42, 1995). The sensitivity is increasing with the number of RadFETs in stacked structure, but there were limitations because of the diode reverse breakdown voltage during readout current (B. O'Connell et al., In Proceedings of the Third European Conference on Radiation and its Effects on Components and Systems, 1995). Further improvement of the stacked RadFETs device enables detecting a minimum absorbed dose of less than 50 μGy for a 20 V power supply (B. O'Connell et al., Fifth European Conference on Radiation and Its Effects on Components and Systems, 1999). Floating gate MOSFET is a modified structure of MOSFET with another polysilicon gate surrounded by oxide. The advantages of the floating gate MOSFET as a radiation dosimeter are that it does not require thick oxide fabrication and the highest sensitivity is for the zero-bias at the control gate during irradiation (S. Ilić et al., Sensors 20 (11), 2020).

Experimental setup. Commercial floating gate MOSFETs designed by Advanced Linear Devices Inc. were used in this paper. Four transistors were connected in the stacked structure (drain and control gate are shorted and connected to the source of the next stacked transistor), and their threshold voltage drift values were measured before and after each irradiation portion with the same conditions. The experiment was performed at the Institute of Nuclear Sciences "Vinča", Belgrade, Serbia. Radiation source Co-60 was used for irradiation of the components, with the following portions of the absorbed dose (Si): 10 μGy, 10 μGy, 10 μGy, 20 μGy, 50 μGy, 400 μGy, 500 μGy, 4 mGy, 45 mGy, 50 mGy, respectively (absorbed dose was 100 mGy in total). All measurements were performed in a test fixture with triax cables by Keithley 2636A Source Measure Unit. During irradiation, all stacked transistors were zero-biased.

Results. Observing the threshold voltage drift of the four stacked floating gate MOS transistors, we noticed that the stack of two transistors has the most stable reading values over time (smallest drift). Considering this, we analyzed only two stacked floating gate MOS transistors as a passive dosimeter for the low doses. The results show that it is possible to detect the first portion of 10 μGy at which the sensitivity of the two stacked transistors is 23 μV/μGy. For the next same portion, the sensitivity is 17 μV/μGy, while for the third, the value is 7 μV/μGy. However, for the next 20 μGy, there is a tiny shift, and the sensitivity is only 1 μV/μGy. Decreased sensitivity with absorbed dose is a feature of the floating gate MOSFET that has been observed before for much higher doses (S. Ilić et al., Sensors 20 (11), 2020). There is a large overlap in the threshold voltage drift values for the next four radiation portions. However, for the last two largest portions, 45 and 50 mGy, there is a significant threshold voltage shift with no overlapping, and thus it is possible to determine the sensitivity of 0.0226 and 0.0214 μV/μGy, respectively.

Conclusions. Using a floating gate MOSFET as a low-dose passive dosimeter is possible, but recharging the floating gate and reusing this device for higher total ionizing doses should be investigated.

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