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Radiation Sensitive Detector Based on Field-Effect Transistors

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Abstract—The possibility of developing radiation detectors based on field-effect transistors (FET) is investigated. Transistor saturation current is chosen as an informative parameter for modeling. Experimental results show that the drain saturation current of the FET with *p-n* junction as a gate is decreasing after irradiation. In metal-oxide-semiconductor (MOS) FETs during radiation-induced defect formation two effects are competing, therefore the result of radiation influence is highly dependent on the electro-physical properties of transistors before irradiation and on the absorbed radiation dose. It is shown that saturation current increases with absorbed radiation dose for all the transistors with low electron concentration in a channel above certain levels of absorbed radiation. While the opposite effect is observed for high electron concentration in a channel, i.e. the saturation current drops. Obtained dependences of the drain saturation current of FET on the irradiation dose facilitated development of simple detector design for low levels of radiation. The bridge circuit is used in the radiation sensor to minimize the effect of temperature fluctuations. The sensitivity of the detector is enhanced several times with the help of two pairs of FETs with the opposite sign of radiation sensitivity.

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Current progress of nuclear industry, medical radiology, research in high energy physics considerably prioritizes the development of high-sensitivity compact detectors of ionizing radiation. The influence of radiation triggers the changes in electro-physical parameters of all semiconductor devices [1], but field-effect transistors (FET) appear to be most sensitive to the ionizing radiation. Therefore they become used as radiation sensors almost immediately after the emergence of industrial mass production of FETs with *p-n* junction as a transistor gate (JFET) [2].

Current technological progress enables investigation of characteristics improvement of traditional metal-oxide-semiconductor (MOS) radiation sensitive FETs (RADFET) [3–5] as well as development of novel special designs such as floating gate transistors (FG-MOS) [6] or designs based on nanostructures junctionless gate-all-around radiation sensitive FETs (JL GAA RADFET) [7]. However such radiation detectors are rather expensive, difficult to fabricate and require additional elements, approved by radiation measurement. This is due to the fact that threshold voltage, used as a radiation sensitive parameter, needs to be measured in a specific setup.

The possibility of designing the radiation detectors based on the commercial, low-cost FET with low power consumption is experimentally investigated in this study. The drain saturation current is suggested as an informative parameter, since during the irradiation the defects are formed in the FET channel. These defects increase the resistance of the channel [8] and, therefore, decrease the transistor drain current.

The goal of this study is the design development of low-cost, highly sensitive radiation detector with minimum number of component parts and with FET as a sensitive element.

The drain saturation current of the FET with *p-n* junction as a transistor gate in case of two-pole connection, when the gate is short-circuited with source, is defined as:

$$I_s = A\mu n^2, \tag{1}$$

where A is a constant, n is electron concentration in n-channel, μ is electron mobility.

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