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Radiation Sensor Design and Applications: The 3N163

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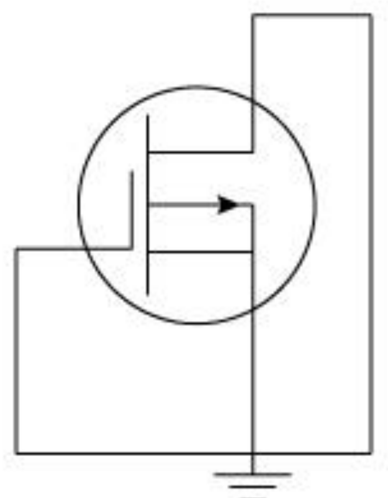
Wireless real-time radiation sensor networks offer the general public and those that work in high radiation areas greater protection against radiation hazards. Combined with real-time localized and global heat mapping of radiation levels, these radiation networks will help give government and environmental agencies the ability to understand the radiation landscape and respond quickly to radiation changes before they become life-threatening.

Low-cost, low-power and no-power radiation sensors, also known as RADFETS (Radiation Field Effect Transistors) or dosimeters, are necessary for the implementation of these networks. The RADFET is unique because it does not need a power source to detect radiation. The RADFET is also unique in that it records the amount of actual radiation exposure. The RADFET, as a non-volatile analog memory device, stores the level of radiation exposure as a change in threshold voltage. RADFET's are relatively simple circuits, consisting of only a PMOS transistor. The LS 3N163 PMOS transistor can be used to design a RADFETs to meet different design requirements like cost, sensitivity, linearity and power. The ability to optimize a RADFET for these different design requirements give network designers the ability to construct wireless radiation sensor networks that can also be optimized for cost and performance on a wide scale.

Radiation Detector Principles

PMOS (P-Channel) MOSFET radiation detectors work on the principle that electron-hole pairs form when radiation or an ionizing particle strikes the MOSFET. This in turn results in shifts to the threshold voltage and drain current parameters of the MOSFET device. Because the change in threshold voltage with radiation exposure is highly linear in a PMOS device, PMOS devices such as the LS 3N163 are commonly used as a radiation detector. In a typical application, the LS 3N163 is operated in unbiased mode (no-power mode) and exposed to radiation. The change in threshold voltage is then measured and the corresponding radiation exposure level determined. In another application, where higher levels of sensitivity are needed, the LS 3N163 is operated in biased mode (power mode).



P-Channel Transistor in No-Power Radiation Detection Mode

Figure 1 - Simple RADFET gate, substrate, drain and source connections

Radiation Sensor Parameters

Central to the design of a radiation sensor are sensitivity and sensitivity loss. Sensitivity is defined as the change in threshold voltage shift per accumulated radiation dose (measured in SI-Gray Units, 1 Gy = 1 J/kg = 100 rad)

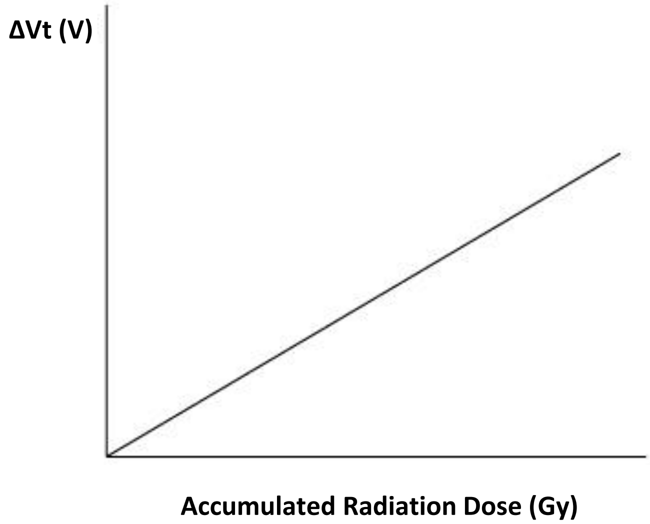


Figure 2: Threshold voltage shift in P-Channel transistors as a function of radiation dose

Sensitivity loss on the other hand, is the loss of sensitivity as a result of previous exposure to radiation events. Sensitivity loss levels can be in the order of 1 percent per kGy of radiation energy exposure (10). This requires that the detectors be recalibrated so as to accurately measure the radiation dose. Alternatively, because of the low-cost of the LS 3n163, the devices can be deposed when sensitivity falls below required levels.

Improving Sensitivity

Different design techniques have been studied to increase the radiation sensitivity levels of the LS 3N163 and other MOSFET devices. It has been shown that the biasing of the MOSFET effects sensitivity. Sensitivity to radiation is higher in the biased mode than the unbiased mode (non-power mode).

Data on sensitivity to 6MV photon beams data showed that the 3N163 has a sensitivity of 33 mV/Gy in the unbiased mode and 62 mV/Gy in the biased mode (9). In that study one and two-stacked transistor, biased and unstacked configurations were analyzed. Stacking PMOS transistors increases the effective oxide thickness of gate oxide, increasing its sensitivity.

Emerging Applications

Energy harvesters, used to convert vibrations to electrical energy, have been used to provide power to radiation sensors (2). In these applications, energy harvesters are used to power the read circuitry that measures the threshold voltage shift in the radiation sensor. Because wireless technology is ubiquitous, vibration energy is pervasive in factories and all types of vehicles, and the cost of RADFETs is low, the implementation of real-time wireless radiation sensors is a reality. These wireless networks are expected to be hierarchical. Cost-efficient, high performance networks could include radiation detectors with varying degrees of sensitivity based on biased and unbiased designs.

Citations

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