SENSITIVITY OF THE SREM RADFET DOSIMETERS FOR STRV-1C TO VARIOUS PROTON AND GAMMA RADIATION ENVIRONMENTS

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Abstract

Standard Radiation Environment Monitor (SREM) – see Figure 1, was designed in a cooperation between ESA-ESTEC, PSI and Contraves Space – the manufacturer. The monitor will detect cosmic particles using 3 direction sensitive Silicon detectors. Total dose measurement will be performed with internal and external RADFETs located at selected positions of the satellite. Their sensitivity towards protons and gammas was characterised for various energies, dose rates and exposure geometry.

I. GENERAL

The SREM monitor on board of the STRV-1c satellite will be equipped with a set of RADFET dosimeter [1] positioned in several locations on board. Their very small dimensions and weight as well as low power consumption and simple operation and read-out makes them attractive for simultaneous dose monitoring at remote places of the spacecraft. The STRV-1c radiation environment will consist mainly of electrons and protons. A purpose of this work is to characterise the dosimeter's response to protons of various energies, fluxes and fluences at representative working conditions and exposure geometry.

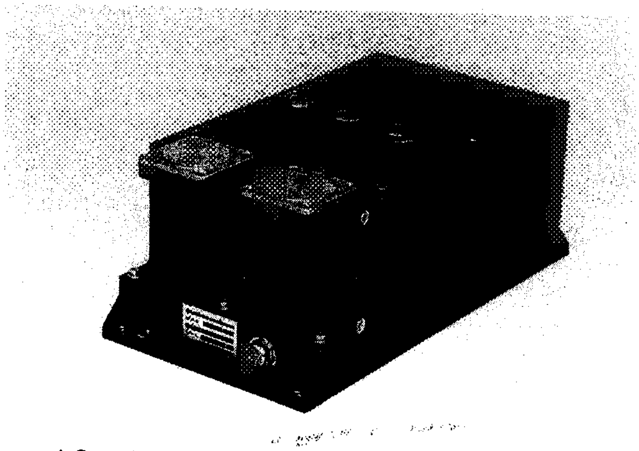

Figure 1 Standard Radiation Environment Monitor.

II. RADFET SPECIFICATION

The RADFETS solid state dosimeters were produced by National Microelectronics Research Centre in Cork (Ireland). Each one consists of two P-MOS transistors with 4000 Å implanted gate oxide thickness. The transistors have different geometry: a W/L value of 300/50 for type 1 and a W/L value of 868/11 for type 2. During operation in space the type 1 P-MOS will be used. Its threshold voltage V_{th} sensitivity towards radiation was initially determined to be 0.463 mV/rad (at temperature of 27ºC). This value was obtained from exposures to the gamma radiation in a low field mode in which the gate bias was equal to 0 V and all pins were tied together. In flight however the operation mode and thus the RADFET response will be different. A power and read-out system for gamma sensitivity determination and for STRV-1c measurements and/or calibrations is similar to one described below.

III. READOUT SYSTEM

During the mission, the RADFET dosimeters are connected to the SREM read-out circuit for permanent monitoring of the threshold voltage signal (read mode operation) and temperature. The circuit used for the device read-out during irradiation in PSI is fully equivalent to one that is used in the SREM – see Figure 2. The threshold voltage is measured using a constant 10 μA source to drain current. The S1, G1, D1 and B1 symbols shown in Figure 2 denote the source, gate, drain and bulk of the RADFET type 1 P-MOS transistor, respectively.

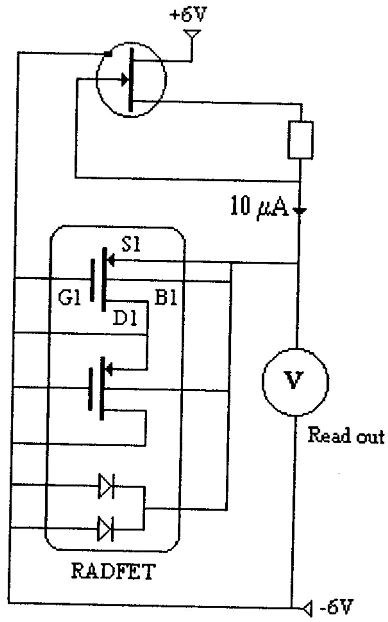

Figure 2 RADFET readout circuit used during the test.

IV. EXPERIMENT

All irradiation tests were performed in PSI using the following facilities:

1) Proton Irradiation Facility PIF in Nucleon Area
2) Proton Facility in the low energy OPTIS area
3) Gamma Irradiation Facility.

All RADFET exposures to radiation ware carried out in air. Dose rates varied between 2 and 80 rad/sec and the minimum deposited dose was equal to 50 Gy(Si) (5 krad(Si)). Proton energies covered the range from 9 to 300 MeV. The proton beam profiles were uniform over the entire exit window of 35 mm in diameter. Two transmission ionisation chambers mounted in front of the tested devices monitored the dose rate and total dose deposition. Small plastic counter mounted in place of the RADFETs was used to calibrate ionisation chambers for all proton energies applied during the test. The initial beam energy of 304 MeV for PIF and 64.5 MeV for OPTIS tests could be degraded to the desired value with a energy degrader. In OPTIS facility it allowed to select 8 energies between 6 and 63.5 MeV. The PIF degrader makes possible to select 255 energies distributed from ca. 30 MeV to 300 MeV. Experimental setup for PIF-OPTIS facility is shown in Figure 3. For consistency purposes two RADFETs were irradiated and measured simultaneously. The dose was applied in steps between 2 and 10 Gy(si) (0.2 and 1 krad(Si)) up to about 150 Gy(Si) (15 krad(SI)) per device.

Figure 3 RADFET experimental setup in low energy OPTIS area. Two devices are mounted on the plate and fixed to the test frame. On the left side there is an energy degrader and two ionisation chambers for dose monitoring.

V. MAIN RESULTS

A. Proton Response

As an example of the device response towards protons, two curves for 17.0 and 63.5 MeV proton energy are shown in Figure 4 using log-log scale. The linear fit of two sets of data points was performed using the function:

$$\lg(\Delta V_{th}) = A + B \bullet \lg(D) ;$$

ΔV_{th} is the threshold voltage shift /Volt
D is the dose /Gy (or krad).

The slopes (B) of two curves were found to be almost identical and located within values found previously in literature [2,3].

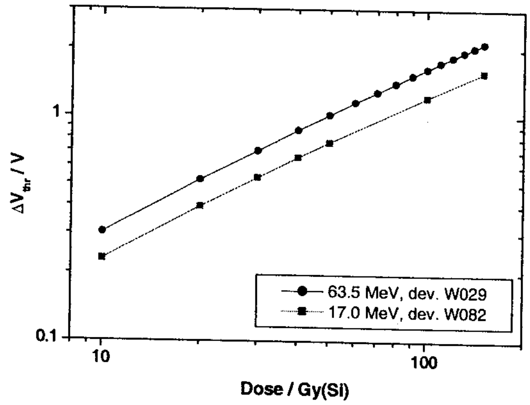

Figure 4 Threshold voltage shift versus deposited dose for two proton energies.

B. Proton Sensitivity Threshold

The sensitivity threshold of the RADFET for protons was determined in OPTIS facility with set of proton energies. Response changes of the threshold voltage shift as a function of the energy were measured down to 9 MeV. As one can see from results shown in Figure 5, the sensitivity threshold for proton detection is around 10 MeV. This value corresponds well to the thickness of the Ni-Au lid (entrance) of the RADFET.

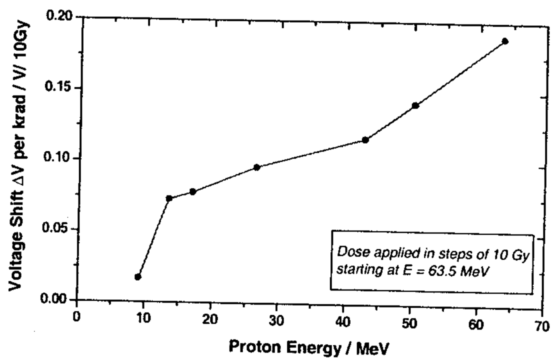

Figure 5 Response threshold of RADFET dosimeter.

C. Dose rate sensitivity

In the range of applied dose rates no sensitivity changes were observed. The same device irradiated at different dose rates didn't show changes of its response function.

D. Device specific sensitivity

Non-negligible response variations from device to device were seen as shown in Figure 6. Side effects like e.g. beam optics were excluded by careful monitoring of the beam profiles. A dependence on the device lid thickness was also excluded by irradiation of devices with and without the lid. Further studies of the device related effects are under way.

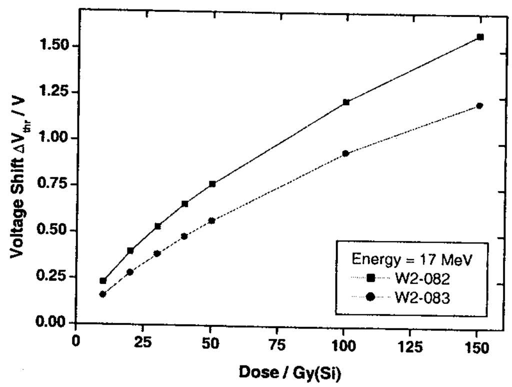

Figure 6 Response variations as a function of selected RADFET device.

E. Proton Energy dependence

Energy range of the proton beam varied from 9 to 300 MeV. Some devices were irradiated using a single energy while the others were exposed to protons with several energies. For the last tests the energy was changed in steps of 10 Gy of the applied dose. Despite of response variations as a function of the device, no strong energy dependence could be observed. Representative set of results is shown in Figure 7.

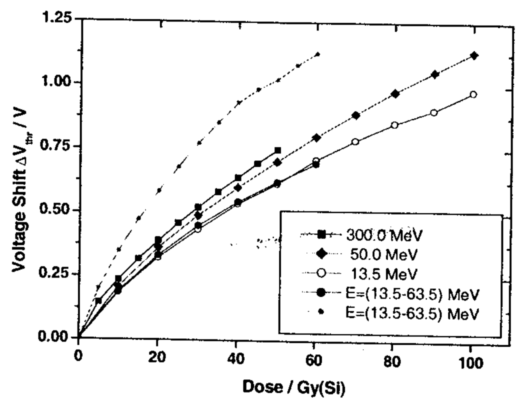

Figure 7 Threshold voltage shift as a function of proton energy. Each curve represents another device.

F. Angular dependence

Angular sensitivity of the RADFET was measured by irradiating the dosimeters using different angles of incoming protons. The irradiation angles were equal to 0°, 45°, 60° and 180°. Response functions are shown in Figure 8. The response curves obtained for three devices are parallel and vertical shift can be attributed to the devices itself.

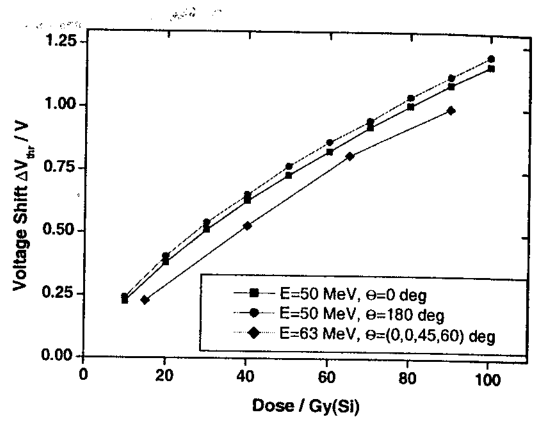

Figure 8 RADFET sensitivity as a function of proton incoming angle.

G. Proton versus gamma sensitivity

In order to test RADFET response dependence as a function of the irradiation type, several devices were exposed to ^{60}Co source in PSI. The dose rate was of about 1.4 rad/sec. Dosimeter powering and read-out was identical as for proton exposures. Comparison of proton and gamma response curves for two devices is shown in Figure 9.

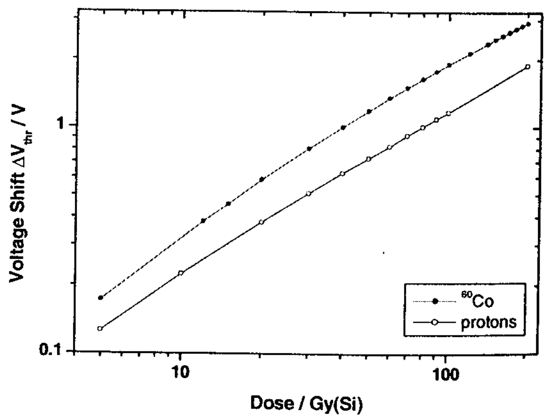

Figure 9 Voltage threshold shift vs dose for proton and gamma-ray irradiated devices.

In addition, the same device was tested using protons and gamma rays. In the first step the RADFET was exposed to the proton beam to the dose of 25 Gy(Si) (2.5 krad(Si)). Then the gamma irradiation was performed up to the total dose of 55 Gy(Si) (5.5 krad(Si)). Experimental data are shown in Figure 10. From Figures 9 and 10 can be seen that RADFET response toward protons and gamma rays are slightly different. Further studies of this disparity are planned for the next future.

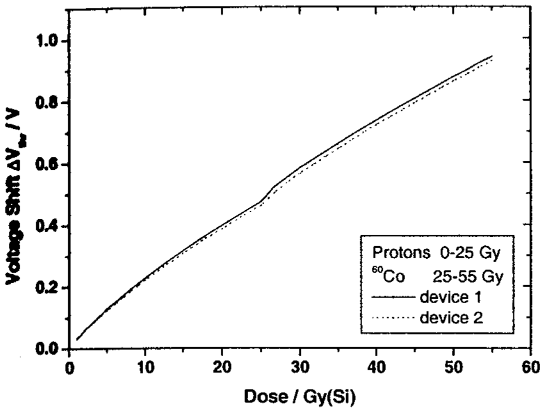

Figure 10 Threshold shift as a function of deposited dose for devices irradiated both with protons and gamma rays.

VI. CONCLUSIONS

RADFET dosimeters for SREM radiation monitor on board of the STRV 1c satellite were tested with protons and gamma rays. Irradiation conditions and power/read-out of the devices were as expected in space. The RADFET response exhibits no relevant sensitivity to proton energy or incoming angle. Certain dissimilarity of the response function towards either proton or gamma radiation was observed. Further studies of this issue are currently under way. A noticeable variability of response was found between different devices irradiated in similar conditions. It requires a calibration of each RADFET dosimeter before using it in space by proton/gamma pre-radiation to a small dose.

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