Submitted for presentation at the Nuclear and Space Radiation Effects Conference (July 1996)

Stacked p-FET Dosimeter for the STRV-2 MWIR Detector: A Joint US-UK Project

Martin Buehler
Microdevices Laboratory
Jet Propulsion Laboratory, MS 300-329
California Institute of Technology
Pasadena, CA 91109
Tel 818-354-4368
FAX: 8'18-393-4820

Andrew Holmes-Siedle
Radiation Experiments and Monitors (RE M)
Eynsham, Oxford, OX8 1PD England
FAX: +44 1865880030

Chris Caines
Defence Research Agency
Farnborough, GU14 6TD, England
FAX: +44 1252 377121

Christine Carmichael and Dennis Martin
Halcyon Microelectronics, Inc.
Irwindale, CA
FAX: 818-960-8133

ABSTRACT: A stacked p-FET dosimeter consisting of a RADMON mother chip with three p-FETs and multiplexer and an attached RADFET has been developed for the STRV-2/MWIR detector, a joint US-UK project. Calibration of the (it]:.irli{ler, using an Am-241 source, indicates that the RADFET is about 20 times more sensitive to radiation than the RADMON.

INTRODUCTION: This dosimeter is intended to be used to monitor the dose inside the Space Technology Research Vehicle (STRV-2) Medium-Waveband Infra-reel (MWIR) detector to be launched in 1998. The dosimeter consists of a thin-oxide RADMON mother chip [1] with three p-FETs, multiplexer, and other devices as seen in Fig. 1. A thick-oxide RADFE"T [2, 3] is attached to the mother chip as seen in Fig. 2 and consists of four p-FETs. Only one type K is used. Since the RADFET is 20 times more sensitive to radiation than the RADMON, this dosimcter is capable of measuring both low and high doses. The objective of Ibis effort is to develop a stacked p-FET dosimeter for the STRV-2/MWIR detector and to calibrate the dosimeter using a low-cost bench-top radiation Am-241 source.

CHIP DESIGN: I-he p-MOSFET mother chip, shown in Fig. 1, consists of an 8-bit multiplexer (MUX) that addresses four p-FETs (PG0, PG4, PK6, PG7), two n-FETs (NG1 and NF3), a resistor (RM2), and a user selected device (EP5) which can be the on-chip diode (DP5). The RADFET was attached to the mother chip as shown in Fig. 2 using 1-mil thick non-conductive epoxy. The RADFET is 21-mils thick and shields the MUX NG1, NF3, and PG4. The mother chip was die attached with a AuGe preform to a 16-pin flat pack. The package has a I-roil thick aluminized mylar lid that minimizes shielding effects of the lid. In the following calibration experiments, unlidded devices were used.

THRESHOLD DISTRIBUTIONS: Integral to the dosin-retry process is batch calibration. That is, a few devices must be selected from a batch and destructively tested with radiation with the assurance that the resulting calibration curve is applicable to the rest of the batch. This requires fabrication of p-FETs with tight electrical parameters. The threshold voltage, VT, is used to determine if a p-FET is part of the main population or an outlier. The threshold voltages were measured at room temperature with the FET in saturation. Five points IV curves were measured around the temperature-independent point [4]. The threshold voltage was determined from a least squares fit to the data extrapolated to I = O. The VT distributions, shown in Figs. 3 and 4, indicate that the VT for the RADMONs is 0.85 ± 0.003 V and for the RADFETs is 2.15 ± 0.03 V.

Am-241 CALIBRATION: A low-cost bench top approach was used to calibrate the devices using a 1-µCi Am-241 source. The p-FE 1 voltage was measured at 100-µA . The RADFET (PK6) was determined directly from this voltage and the RADMON (PG0, PG4, and PG7) voltage was amplified 10 times. Typical results in fig. 5 show the linear time dependence of the voltage for PK6 and PGO measured every 30-min.

To compare RADFET and RADMON results, the differences in the device-to-source distance must be determined. This was done using the dose rate, D_t in rad/sec expression [5]:

$$D_t = K_0 \cdot \varphi \cdot L \tag{1}$$

where K_0 is in rad·mg/MeV), φ is the flux in #/cm^2·sec, and L is the linear energy transfer in MeV·cm^2/mg. The flux for a point source is [5]:

$$q \quad S/4\pi R^2 \tag{2}$$

where S is the source strength in #/sec and R is the? distance in roils from the source to the p-FET. The distance is ill-defined and so was determined by making dose measurements at different heights, h, above a reference point above the p-FETs. Thus R is defined as:

$$R = H + h + A \cdot h^2 \tag{3}$$

where H is the offset distance from the reference point from which h is measured and A is a fitting parameter used to account for the deviation of the source from a point source. Finally, the p-FET output voltage rate, V_t, is related to the dose rate by:

$$V_t = V_D \cdot D_t \tag{4}$$

where V_D is in mV/rad. The combination of the above results leads to the fitting algorithm:

$$V_t = K/(H + h + A \cdot h^2)^2 \tag{5}$$

where $K = V_D \cdot K_0 \cdot S \cdot L/4\pi$.

The results in Fig. 6 show the voltage shift relationship between the p-FETs as a function of R. The parameters determined from the least squares fit to the data are listed in Table 1. The ratio of the dose response for the p-FETs is K(PK6)/K(PG0) = 1.72 and when adjusted for the amplification factor used with PG0 the dose ratio, is 17.2. Figure 6 can be scaled in terms of dose using Eq. 4. For RADMON V_D is about 5 mV/krad [1]; thus, for the RADFET V_D = 86 mV/krad. Previous response [3] of the type K RADFET using CO-60 gamma rays was 200 mV/krad at zero bias. The data in Fig. 6 will be used to set the amplification factor for the ST RV-2/MWIR dosimeter so the sensitivity of the RADMON after amplification will be close to the sensitivity of the RADFET before amplification.

Table 1. RADFET and RADMON calibration parameters.

PARAMETER	RADMON (PG0x10)	RADFET (PK6x1)
A (1/mil)	0.0017	0.0006
H (mil)	249.1	199.5
K (mV·mil^2/min)	1873.2	3223.6

ACKNOWLEDGMENTS: This research was carried out by the Center for Space Microelectronic Technology, Jet Propulsion Laboratory, California Institute of Technology, and was sponsored by the Ballistic Missile and Defense Organization, Materials and Structures Project Office and the Defence Research Agency. The RADMONs were fabricated through MOSIS and the RADFETs by the Southampton University Microelectronics Centre. File: MWIR6202.DOC.

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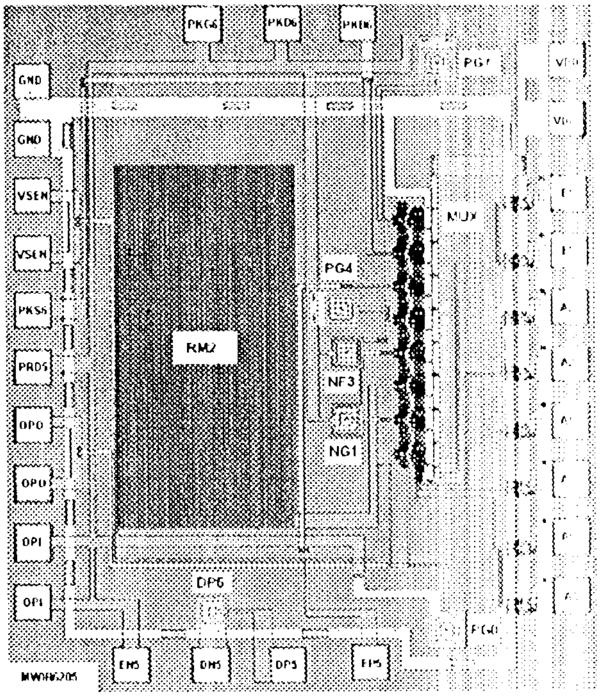

Figure 1. RADMON mother chip 1.8 mm x 2.2 mm.

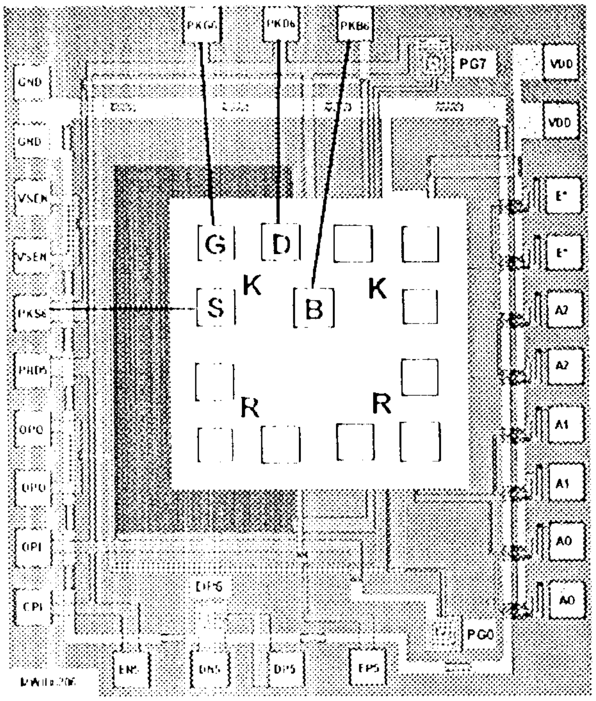

Figure 2. Stacked p-FET dosimeter with the RADMON mother chip and attached RADFET 1 mm^2.

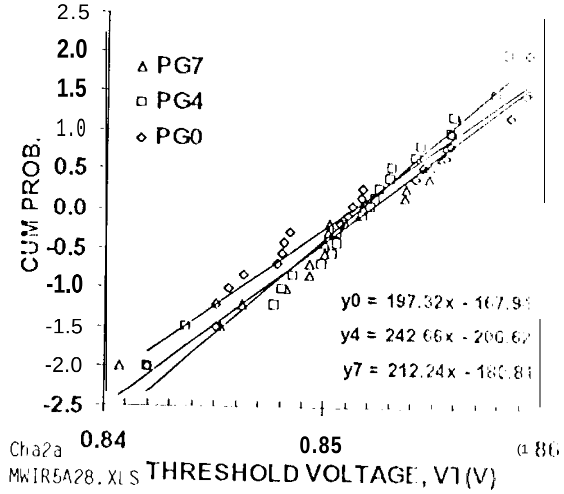

Figure 3. Threshold distributions for the RADMONS.

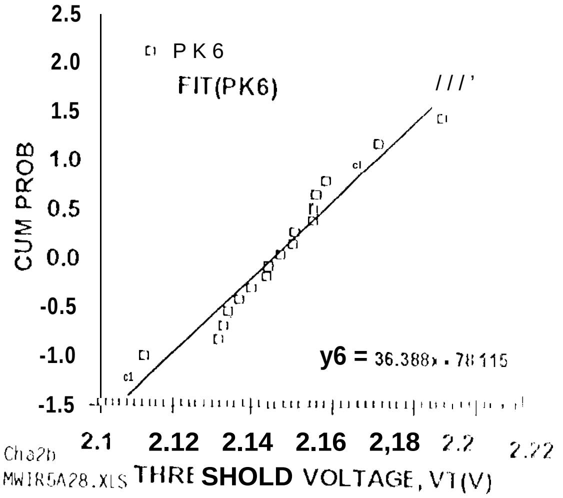

Figure 4. Threshold distributions for the RADFETs.

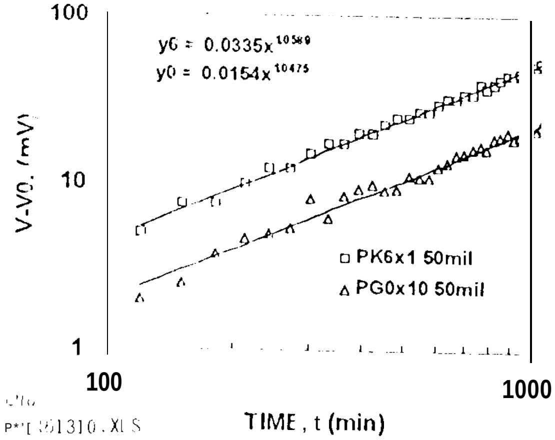

Figure 5. **RADFET (PK6) and RADMON (PG0) output voltage change due to a 1-μCi Am-241 source where the RADMON voltage is amplified 10 times and the source is 50 mils above the reference point.**

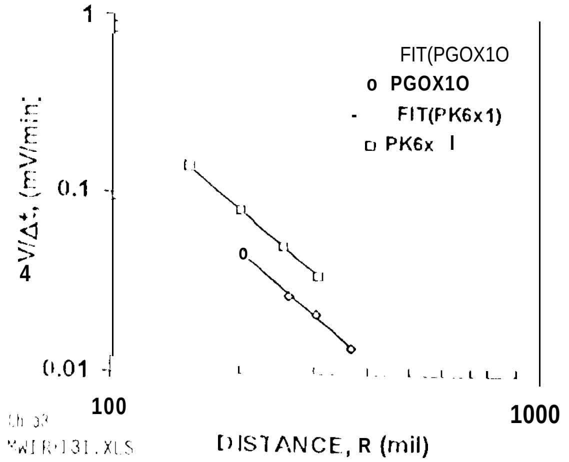

Figure 6. RADFET (PK6) and RADMON (PG0) output voltage shift as a function of the distance to a 1-μCi Am-241 source where the RADMON voltage is amplified 10 times.