ON-CHIP p-MOSFET DOSIMETRY

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ABSTRACT

The dosimeter consists of a p-MOSFET that is operated in a constant current mode, allowing the temperature effects on channel mobility and threshold voltage to cancel each other. The objective of this design is to minimize temperature effects and emphasize the dose dependence. The p-MOSFET's have. a closed geometry gate eliminating the source to drain bird's beak leakage path. The dose dependence of transconductance is shown to be small, and can be ignored.

SUMMARY

‘Ibis paper describes the “m-chip” p-MOSFET radiation dosimeter proposed for usc on all flight CMOS ASIC chips. Dosimetry measured via p-MOSFET threshold voltage shifts is influenced by two second order effects: (a) the temperature sensitivity of the transconductance factor, KP, and the threshold voltage, V’I’, and (b) the. source to drain bird’s beak leakage current [1,2.,3]. The goal in developing the advanced P-MOS101’1” dosimeter was to minimize or eliminate these effects.

The p-MOSFETs were measured in chip form using an hp4062 parametric test system with a hot chuck. Data for chip 1, dosimeter PR1, is shown in Table 1. The p-MOSFET 10 be flown on the Space Technology Research Vehicle (STRV) is operated in the saturation region which is insured by connecting the gate to the drain as shown in Figure 1, In the saturation region, drain current is given by:

(1) $I_p = (\beta/2)(V - V_T)^2/[1 - O(V - V_T)]$

where, $\beta = KP \bullet W/L$, $KP = \mu \bullet C_o$, and VT is the absolute value of the p-MOSFET threshold voltage. The other parameters are W and L, the as drawn channel width and length respectively, μ is the channel mobility, Co is the gale oxide capacitance per unit area, O is the mobility electric field dependence, and V is the gate, or output, voltage. Applying the Taylor series expansion to the. O term and letting $\theta \bullet V_T$ terms vanish, a linear equation is derived for the. square root of the drain current.

(2) $\sqrt{(I_p)} = \sqrt{(\beta/2)}[-V_T + V - (0/?)(V?'')]$

This equation, and the data from “J’able 1, is plotted in Figure 2, identifying the temperature independent drain current. The temperature dependence of the IV curves shown in Figure 2 indicate that temperature effects on p-MOSFET dosimeters can be minimized by operating the p-MOSFET at a certain fixed current value., termed 10. The above square-law relationship, Equation 1, with O = O, is rewritten in terms of the output voltage:

(3) $V = V_T + (2I_p/\beta)^{1/2}$

The output voltage temperature sensitivity is found by differentiating Equation 3 with respect to temperature and evaluating at To:

(4) $V_{To} = VT_T - (I_o/2)^{1/2} \bullet \beta_{To}/\beta_o^{3/2}$

where $V_{To} = \partial V/\partial T|_{To}$, $VT_T = \partial VT/\partial T|_{To} = -1.752$ mV/°C, $\beta_{To} = \partial\beta/\partial T|_{To} = -n \bullet \beta_o/T_o$ and $n = 1.549$. β_o is the. value, of β at T = To. Solving Equation 4 for Io at $V_{To} = O$ dc.fine.s the temperature independent operating point:

(5) $I_o = 2\beta_o^3(VT_T/\beta_{To})^2$

For the data given in Table 1, for To = 303 K or 30 °C, 10 = 189.9 μA and √I = 13.78 √μA as shown in Figure 2. The temperature independent drain current, 10, depends on the as drawn geometry because $\beta = KP \bullet W/L$.. The design space for these pMOSFET dosimeters is shown in Figure 3. The closed geometry gale is shown in Figure 4, The calibration curve, or damage factor, V’]]), curve, for the p-MOSFET dosimeter on the proton detector chip is shown in Figure 5 [4]. The damage factor is given for the line connecting O krad and the 8 day anneal point at 100 had.

REFERENCES

[1] A. Holmes-Siedle, L. Adams, S. Marsden, and B. Pauly, "Calibration and Flight Testing of Low-Field pMOS Dosimeter" IEEE Trans. on Nuclear Science, Vol. NS-23, 44?.5-4429 (1985).

[2] M, O’Sullivan, A, Kelleher, J. Ryan, B. O'Neill, and B. Lane, "Temperature Compensation of PMOS Dosimeters," Proceedings ESA Electronic Components Conference, Noordwijk, The Netherlands, 12-16 Nov. 1990, ESA SP-313, pp 281-285

[3] G. A. Soli, 11.1<, Blaes, M. G. Buehler, K. P. Ray, and Y-S Lin, "CRRES Microelectronic Test Chip Orbital Data 11," IEEE Trans. Nuclear Science, Vol. NS-39, xxxx-xxxx (1992).

[4] G. A. Soli, B. R. Blaes, and M. G. Buehler, "Proton-Sensitive Custom SRAM Detector," IEEE Trans. Nuclear Science, Vol. NS-39, 1374-1378 (1992).

Table 1. p-MOSFET dosimeter data as a function of temperature using hp4062 with hot chuck for chip 4, transistor PR1, with W/L = 188,5/6 μm/μm.

T (°C)	VT (V)	β(μA/V²)	θ (1/V)
30	0.875	809	0.098
55	0.828	694	0.097
80	0.785	629	0.082

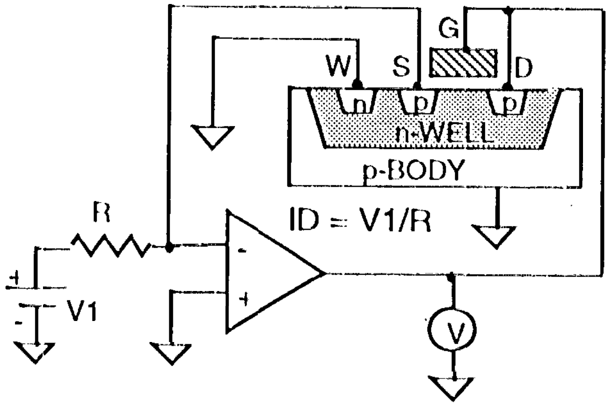

Figure 1. p-MOSFET dosimeter with a constant current source, ID = Io, set to minimize temperature variation. The gate voltage is proportional to the total dose,

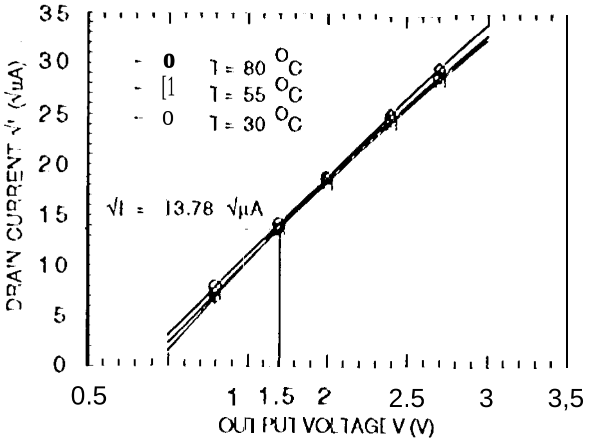

Figure 2. Current-voltage dependence of the p-MOSFET dosimeter showing the temperature independent point at √Io = 13.78 √μA.

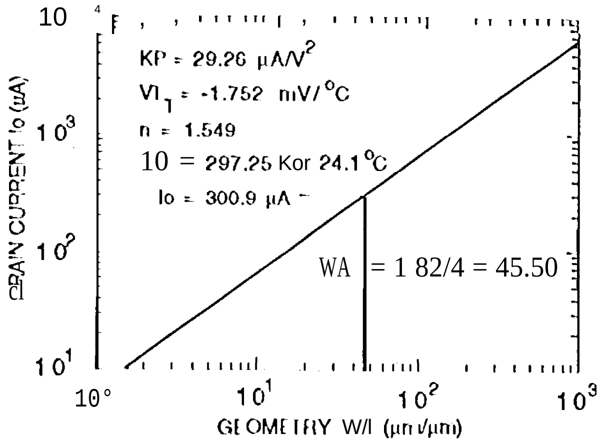

Figure 3. Design space for pMOSFET dosimeters showing the temperature independent drain current as a function of geometry,

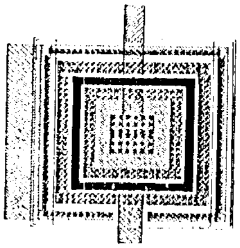

Figure 4. STRV SRAM proton detector ASIC p-MOSFET, MP4, layout, where W/L = 182/4 μm/μm, showing the closed-geometry gate.

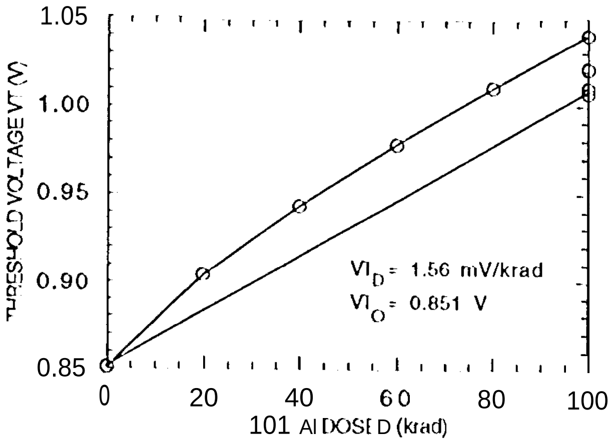

Figure 5. STRV ASIC p-MOSFET, MP4, calibration cur Annealing after 0, 2, 5 and 8 days at 100 krad is shown.