Radiation Response of SOI CMOS Transistors/4M SRAMs Fabricated in UNIBOND^{TM} Substrates*

S. T. Liu, W. Heikkila, K. Golke, B. Stinger, M. Flanery,
A. Hurst, G. Panning, G. Kirchner and W. C. Jenkins[1]

Honeywell SSEC, Plymouth, MN, U.S.A.
[1]Naval Research Laboratory, Washington, DC, U.S.A.

The radiation response of 0.35 µm PD SOI CMOS transistors and 4M SRAMs fabricated in new high quality UNIBOND substrates is evaluated and discussed for the first time. The new UNIBOND substrates used here were obtained from SOITEC [1]. The buried oxide of UNIBOND is 400 nm and the final top silicon thickness is approximately 210 nm. We have fabricated 0.35 µm PD SOI CMOS transistors and 4M SRAMs for measurements using a radiation hard SOI CMOS process. The processes used for fabricating these devices are similar to those of SIMOX based 256K SRAMs reported earlier [2]. An 8 nm gate oxide grown in wet ambient at low temperature is used.

The total dose response of individual 10/0.35 PD CMOS transistors was tested using an ARACOR model 4100 X-ray source. The front channel and back channel Vt's as a function of total dose up to 10Mrad(SiO_2) are shown in Figures 1 and 2 respectively. Front channel voltage shifts at 1Mrad(SiO_2) of less than 5mV for the NMOS and less than 20 mV for the PMOS were observed; implying the gate oxide is radiation hard. On the other hand, a large back channel V_t shift of NMOS was observed for the pass-gate irradiation bias (worst-case). This degradation is attributed to the radiation induced oxide and interface charges. The radiation-induced back channel threshold voltage shift can be estimated by the oxide charge:

$$\Delta V_{t2}\,(D) \approx -A\,[1-\exp(-D/D_0)] \qquad (1)$$

where D is the total dose in rad(SiO_2), A is the maximum radiation induced back-channel Vt shift in volts, D_0 is a fitting parameter in same units as D [2]. Since V_{t2} is much larger than 0V, no back channel leakage current was observed.

The SEU performance of 4M SRAMs is usually evaluated by the response to a heavy-ion hit. The upset induced by high-energy heavy ions is usually discussed in terms of the effective linear energy transfer (LET). Heavy ions will deposit charge directly through ionization in the active device silicon during a transient hit and may cause upset. Experimentally, five high-energy heavy ions (Ne, Ar, Kr, Xe, and Bi) were used to cover LET, ranging from 5.5 to 95 MeV-cm^2/mg at normal incidence. The effective LET was extended by adjusting the angle of incidence of the heavy ion by $LET(\theta) = LET(0)/\cos(\theta)$.

The results of upset cross-section per bit are shown in Figure 3 for a 4M SRAM at 3V and 125C. The overall cross-section data of Figure 3 are fitted with a Weibull function:

$$\sigma = \sigma_{max}\,[1 - \exp(-\{(LET - LET_0)/W\}^S)] \qquad (2)$$

where σ_{max} is the saturated cross-section, LET_0 is an on-set parameter, W is a width parameter, and S is a dimension-less exponent [3]. The parameters fit to equation (2) are $\sigma_{max} \approx 0.1\text{x}10^{-8}$cm^2/bit, $LET_0 \approx 5$ MeV-cm^2/mg, $S \approx 2.4$, and $W \approx 330$ MeV-cm^2/mg.

Low LET_0 of 5MeV-cm^2/mg suggests that the SRAM might be sensitive to high-energy protons [4]. For these 4M SRAMs, a saturated cross-section of approximately 4x10^{-16}cm^2/bit and an onset energy of ≈ 25 MeV was observed at normal incidence. We are currently in the process to improve the LET_0 to improve the SEU performance of the 4M SRAMs. It should be pointed out that Equation (1) is a special form of the Weibull function given by Equation (2) by setting S=1, σ_{max} by -A, W by D_0, and the LET variable ($LET-LET_0$) by the total dose D.

In summary, we have discussed the two main radiation effects in 0.35 µm PD SOI devices fabricated in new high quality standard UNIBOND substrates. Both the worst-case total-dose radiation-induced back-channel Vt shift and the SEU induced upset cross-section can be described in terms of the Weibull function.

References

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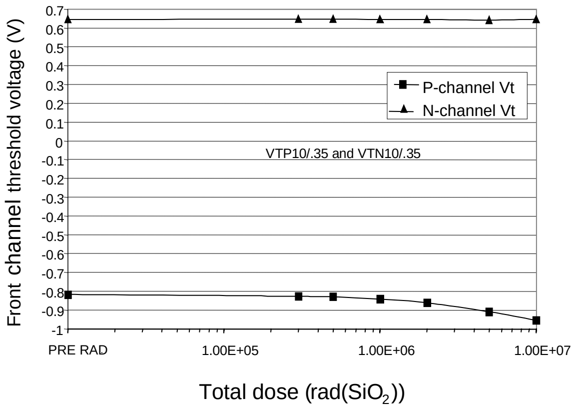

Figure 1. Front channel Vt as a function of total dose.

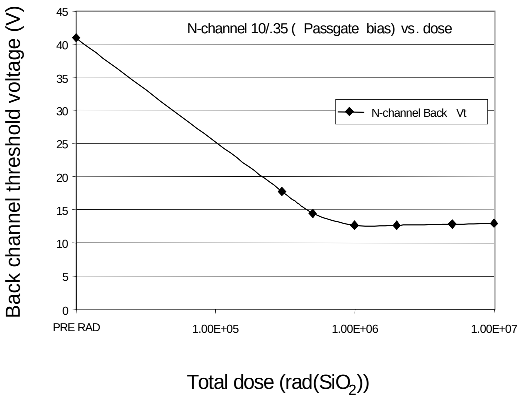

Figure 2. Back Vt as a function of total dose.

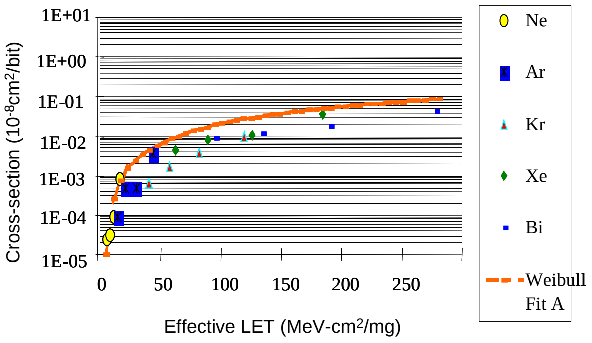

Figure 3 Heavy ion upset cross-section as a function of effective LET.

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