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MEASUREMENT OF PROTON INDUCED RADIATION DAMAGE TO CMOS TRANSISTORS AND PIN DIODES

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Abstract

As part of our program to develop a silicon tracking device for the SSC we have exposed radiation-hard CMOS transistors and PIN diodes to the 800 MeV LAMPF proton beam. The fluences accumulated in a week corresponded to the expected radiation levels of about 10 SSC years. We determine the leakage current constants for PIN diodes and threshold voltage shifts for CMOS transistors under different biasing conditions.

One of the main requirements for detectors and front-end electronics at the SSC is to be radiation-resistant. The SSC Workshop on Radiation Levels in the SSC [1] found that, for example, a silicon tracking device at a radius of 10 cm has to survive a yearly dose of about 0.3 MRad due to charged particles and a yearly neutron fluence of a few times 10^{12} neutrons/cm² at the design luminosity of 10^{33} m⁻²sec⁻¹.

For our program to develop a large tracking device based on Si μ strip detectors for the SSC [2], an important part is the identification of radiation hard VLSI technologies for the front-end electronics and the testing of the radiation damage of silicon detectors. The pipe lining of the data requires a low power technology and thus we are

building a digital time slice chip (DTSC) in the form of a SRAM in CMOS [3]. There is a question as to the radiation hardness of MOS transistors under irradiation by ionising particles [4] and neutrons [5]. On the other hand, radiation-hard CMOS processes have been developed in the last years and are now commercially available [6].

To compare different CMOS technologies, we have tested the radiation resistance of various VLSI technologies at Los Alamos National Laboratory. We have reported [7] before on the irradiation of *n* and *p* transistors on 2 μ m CMOS test structures with neutrons in the LAMPF neutron spallation source. We have now extended our measurement to 800 MeV protons in the HRS line at LAMPF. To determine the proton fluence [8], the activation of an aluminum foil covering the active area of each test structure was measured. Both ⁷Be and ²²Na production were determined from their respective γ decay rate as measured by a 17% hyperpure Germanium detector. The fluences obtained from both isotopes agree well after a correction for the different lifetimes. The radiation damage effects have been determined from measurements of current-voltage characteristics employing the Hewlett-Packard Model 4145B Semiconductor Parameter Analyser.

For digital application the radiation damage to CMOS transistors is characterised by a shift of the threshold voltage V_{th} , i.e., the gate voltage at which the transistor turns on. We have tested transistors of 1.2 μ m feature size pro-

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Table 1
Average Leakage Current Constants

FLUX	BIASED	α (A/cm)
Low	Yes	$(4.57 \pm 0.63) \cdot 10^{-17}$
Low	No	$(4.36 \pm 0.69) \cdot 10^{-17}$
High	Yes	$(3.94 \pm 0.30) \cdot 10^{-17}$
High	No	$(3.86 \pm 0.37) \cdot 10^{-17}$

volume and Φ the proton fluence. In Table 1, we show the average leakage current constants for the diodes. Note that we find the same leakage current constant for the biased diodes and for unbiased ones. Moreover, we find that the average leakage current constants for high flux [$\alpha_H = (3.91 \pm 0.29) \cdot 10^{-17}$ A/cm] agree with the ones for low flux [$\alpha_L = (4.51 \pm 0.62) \cdot 10^{-17}$ A/cm] within the errors. These leakage current constants are somewhat lower than for 1 MeV neutrons [12].

We have measured room temperature annealing of diodes without further biasing after 29 days and 58 days for low flux and 21 days and 50 days for the high flux samples. Parametrising the annealing by the function

$$i(t) = i_i \exp(-t/\gamma)$$

we find that the average annealing time factor γ is $\gamma_L = (124 \pm 28)$ days for the low flux and $\gamma_H = (139 \pm 36)$ days for the high flux sample. We also find that the annealing stops after the current reaches about 50% of the initial current i_i . Both observations are in agreement with data of Ref. 13.

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