EEPROMs for Space Applications

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Several EEPROM device types have been considered for space use. We would like to show the sensitivity of these devices to single event effects (SEE), which has emerged as a partial result of the essential qualification tests in order to determine their suitability for space applications. For some device types we will compare the SEE sensitivity with other effects which should also be tolerated in space. The samples considered for testing are shown in Table 1.

Table 1 Microcircuits considered for SEE testing

Device Type	Memory Organization	Mfr	Technology	Gate
HN58C1001	128k x 8	Hitachi	CMOS	FG*
AT28C256	32k x 8	Atmel	CMOS	FG*
W28C256	32k x 8	NGC	CMOS	SONOS FG*

* FG = Floating Gate

SEE Test Method/Procedure

Devices are tested at the Lawrence Berkeley Laboratory 88-inch Cyclotron Facility using heavy ions ranging in energy from 4.5 to 32 MeV/n. We have observed test devices for single event upset (SEU), single event functional interrupt (SEFI), single event latchup (SEL), and single event gate rupture (SEGR) [1]. Some information for the total dose sensitivity may be obtained by integrating each ion dose for a test device.

Test Results

A. HN58C1001

We carried out testing while reading the memory device. The resultant cross-sections are shown in Figure 1. At LET of 63 and 87 MeV/(mg/cm^2)], the two lower data points represent the upper limits for the latchup cross-sections. Two data points at LET of 41 are upper limits for the SEU cross-sections. All SEU appeared to have been upsets in the output buffer area, since they were not permanent, and they were of “one-bit per byte” type errors. We looked for and did not find any sign of SEL as shown in Figure 1.

B. AT28C256

This device type is sensitive to SEL as well as SEU as shown in Figure 2. However, the SEL threshold LET value is above 41 MeV/(mg/cm^2), since we do not detect any sign of SEL at LET = 41 MeV/(mg/cm^2), yielding the SEL upper limit of 1.3 x 10^{-8} cm^2/device. SEU may be classified into roughly two groups for this device type. In one group, they are made up of “one-bit errors”, consistent with errors in the read out data buffer. In another group, upsets in many address locations take place. It appears that an upset in the control section of the device might have caused this type of errors. Even though errors at many different address locations may appear, we consider that all errors are caused by one ion strike in the control section. Therefore, the upset cross-sections in Figure 2 are calculated as such.

C. W28C256

This type is in the process of being tested for SEE. The devices belonging to an earlier generation of the same manufacturer were tested at LBL yielding errors during both the read and the write test cycles [2].

Consideration for Space Use

EEPROMs would not escape SEE in space. However, some have higher sensitivities than others. For example HN58C1001 appears to be superior to AT28C256 among COTS, since AT28C256 shows some sensitivity to SEL.

However, there are other issues which need to be considered. They are the leakage current, the burn-in, memory retention, and various functional test results over a wide range of temperature. HN58C1001 is used as an example while considering the above issues as follows:

It has been shown that some HN58C1001 EEPROM may not be written correctly at a low temperature even though they can pass the same “write test” at room temperature. Thus, it is necessary to carry out “write test” at various temperature settings. Another anomaly may occur while turning the power off/on the device. Unless the rest line is “grounded”, some devices ”write” an unwanted word at a location during the power turn on/off period. We do not encounter this type of problems with AT28C256.

The W28C256 type appears to be insensitive to both SEL and temperature effects. This device type utilizes SONOS gate material. Currently the SEGR sensitivity (for the programming voltage level below 8.25V) seems to be non-existent below LET = 41 MeV/(mg/cm^2). However, as the dimension of the gate thickness becomes smaller, the SEGR sensitivity may be expected to increase.

Summary

All of the device types considered here appear to be less sensitive to SEE than some other device types such as AT28C010 and X28HC256 EEPROMs [3]. Both of these have much higher sensitivities to SEE. However, other constraints such as the temperature effects need to be considered, while selecting a suitable device type. Qualification of COTS microcircuits for space use must include actual testing whenever there is no good evidence to support their adequate survivability.

References

[1] R. Koga, “Single-Event Effect Ground Test Issues,” IEEE Trans. Nucl. Sci., 43, 661-670, 1996.

[2] Sexton, F, et al, “SEU and SEL Response of the Westinghouse 64K EEPROM, Analog Devices AD7876 12-bit ADC, and the Intel 82527 Serial Communications Controller,” IEEE Data Workshop Record, 55-63, 1994.

[3] Koga, R, et al, “Single Event Functional Interrupt (SEFI) Sensitivity in Microcircuits,” RADECS97 Proceedings, 311-318, 1997.

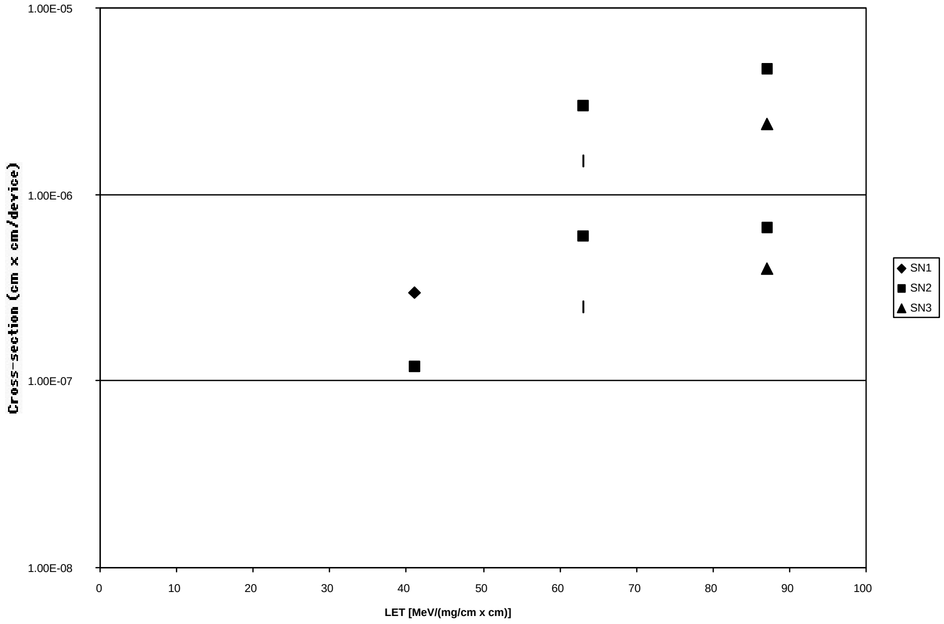

Figure 1. SEE Test results for HN58C1001

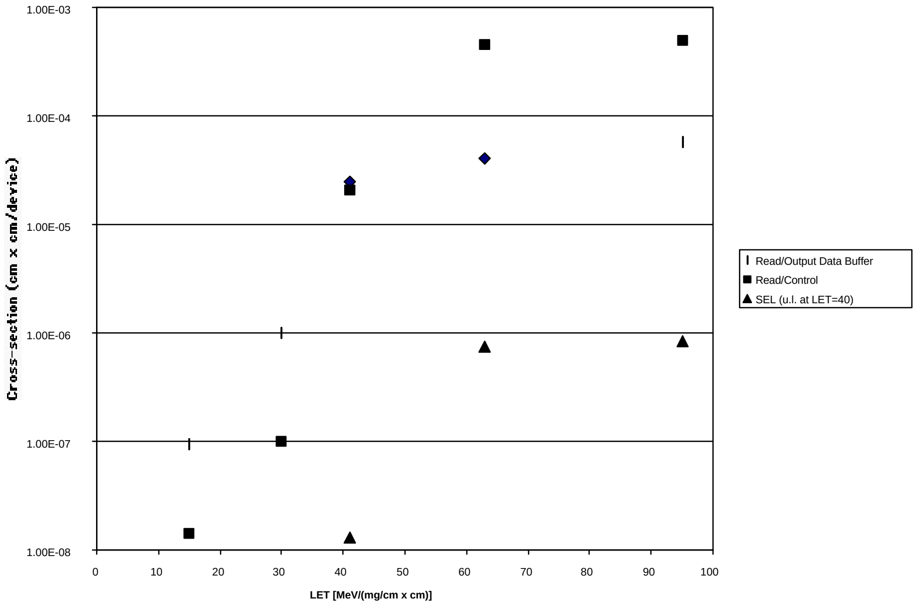

Figure 2. SEE Test results for AT28C256