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Single Event Effects Accelerated Terrestrial Cosmic Rays on Ferroelectric RAM

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Abstract

Relatively new 4 MB Ferroelectric RAM (F-RAM) memory technology is exposed to Los Alamos Neutron Science Center (LANSCE) accelerated terrestrial cosmic ray spectra for soft error and failure in time (FIT) observations. In this poster the focus will be on work with [1]Los Alamos National Labs Neutron Science Center (LANSCE) accelerated terrestrial cosmic ray testing. This poster highlights the potential of advanced techniques and new materials in testing the reliability of critical applications of semiconductor and programmable logic devices.

LANSCE has excellent radiation test facilities that are used by engineers at METTOP to irradiate semiconductor devices to look for Single Event Effects (SEE), including Single Event Upsets (SEU), Single Event latchup (SEL), Soft Error Rate (SER) and device failure in time, (FIT). As a result, NMT is able to provide a dedicated testing facility which makes use of existing fixed facilities for stressing samples. The principal focus of the test facility is to support commercial, space and military microelectronics obsolescence testing and replacement with a focus on a combination of electrical and materials approaches towards maintaining device functional and parametric performance and radiation survivability in operational environments. The Los Alamos Neutron Science Center (LANSCE) facility was used for neutron irradiation of Ramtron FM22L16 4 MB F-RAM (ferroelectric RAM) devices under JEDEC 89 Measurement and Reporting of Alpha Particles and Terrestrial Cosmic Ray-Induced Soft Errors in Semiconductor Devices.

[1] This work has benefited from the use of the Los Alamos Neutron Science Center at the Los Alamos National Laboratory. This facility is funded by the US Department of Energy.

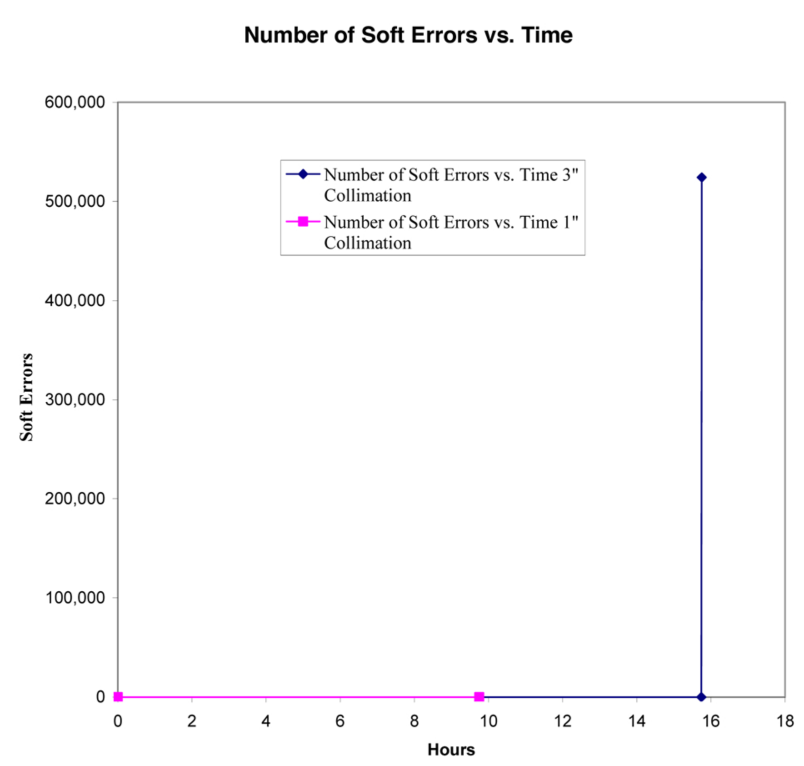


Figure 1. Number of Soft Errors vs. Time for 1" and 3" collimated beam.

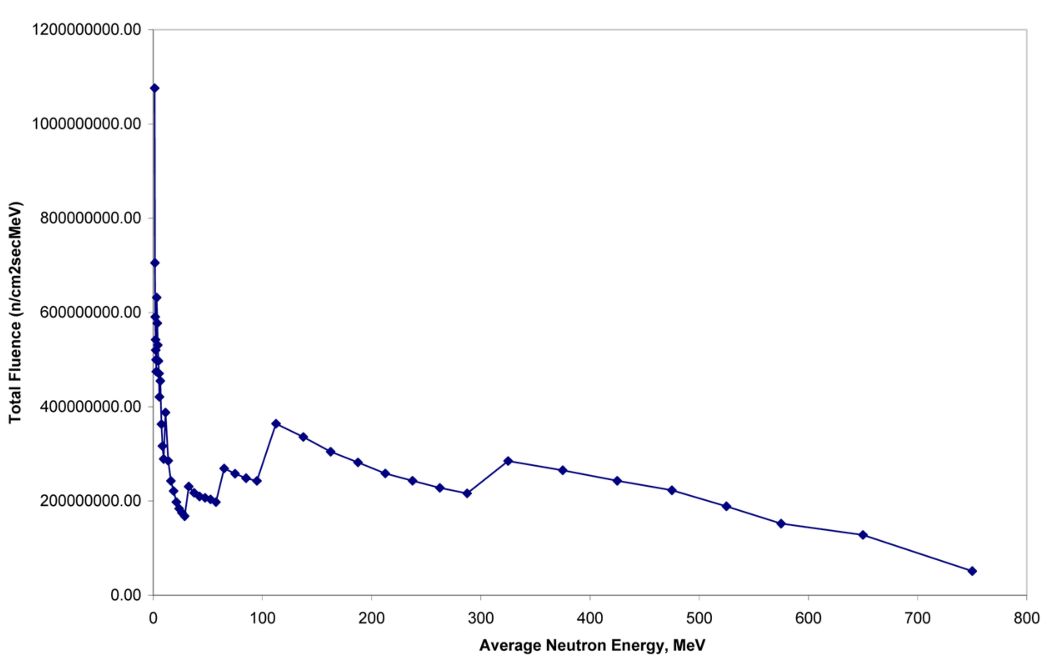


Figure 2. Total Fluence (neutron/cm²secMeV) vs. Average Neutron Energy (MeV)
3" Beam Collimation LANCE SPECTRA

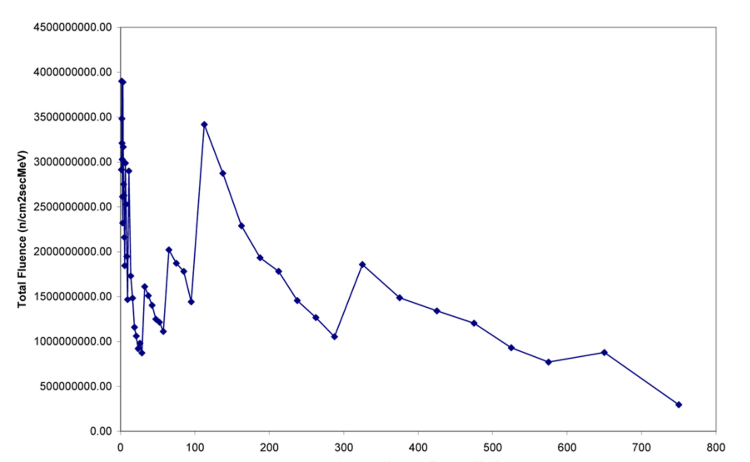
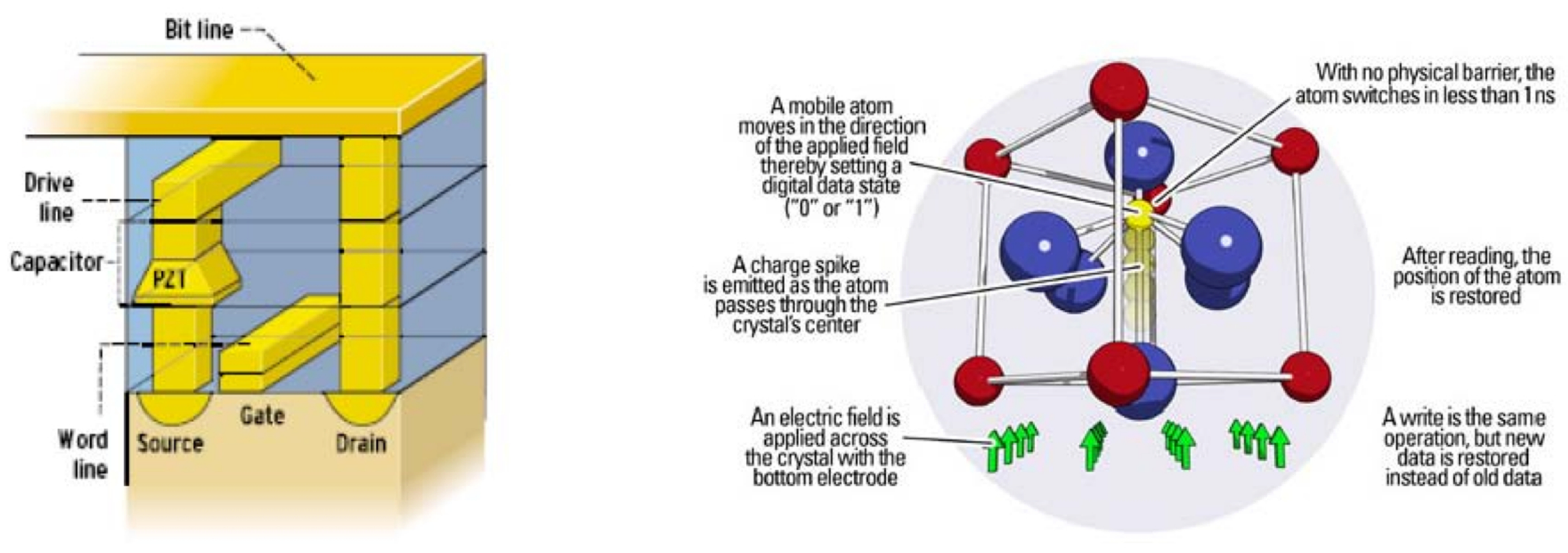


Figure 3. Total Fluence (neutron/cm²secMev) vs. Average Neutron Energy (MeV)
1' Beam Collimation LANSCE SPECTRA

Summary

The purpose of this research was to obtain soft error and failure in time data for Ramtron FM22L16 4 MB ferroelectric memory, under accelerated terrestrial cosmic ray spectra at Los Alamos Neutron Science Center (LANSCE). Soft errors due to terrestrial cosmic rays have always been a concern for spacecraft, high altitude aircraft as well as terrestrial telecommunications and systems. The New Mexico Tech Energetic Materials Research and Testing Center (EMRTC), Microelectronics Testing and Technology Obsolescence Program (METTOP) located in Socorro, New Mexico is a facility designed to test microelectronics components to various radiation effects including Single Event Effects (SEE) Soft Error Rate (SER) based on JEDEC/JESD 89. This includes semiconductor device technologies such as the newer F-RAM. A ferroelectric RAM cell relies on a capacitor containing a lead-zirconiumtitanate (PZT) insulator. Data is a 1 or a 0, depending on whether the ferroelectric domains in the PZT point up or down. To program the cell, an electric field pointing up or down between the capacitor plates orients the domains up or down. To read the cell, the bit and word lines are turned on and a short voltage pulse is applied to the capacitor through the drive line, creating an electric field. If the domains point in the same direction as the field, a small current pulse appears on the bit line. If they point in the opposite direction, a large current pulse occurs as the domains flip. Data is a 1 or 0, depending on whether the bit-line pulse is large or small[1].



(a) (b)

Figure 1. (a) A Ferroelectric RAM memory cell. (b) Internal PZT crystal structure, Ramtron.

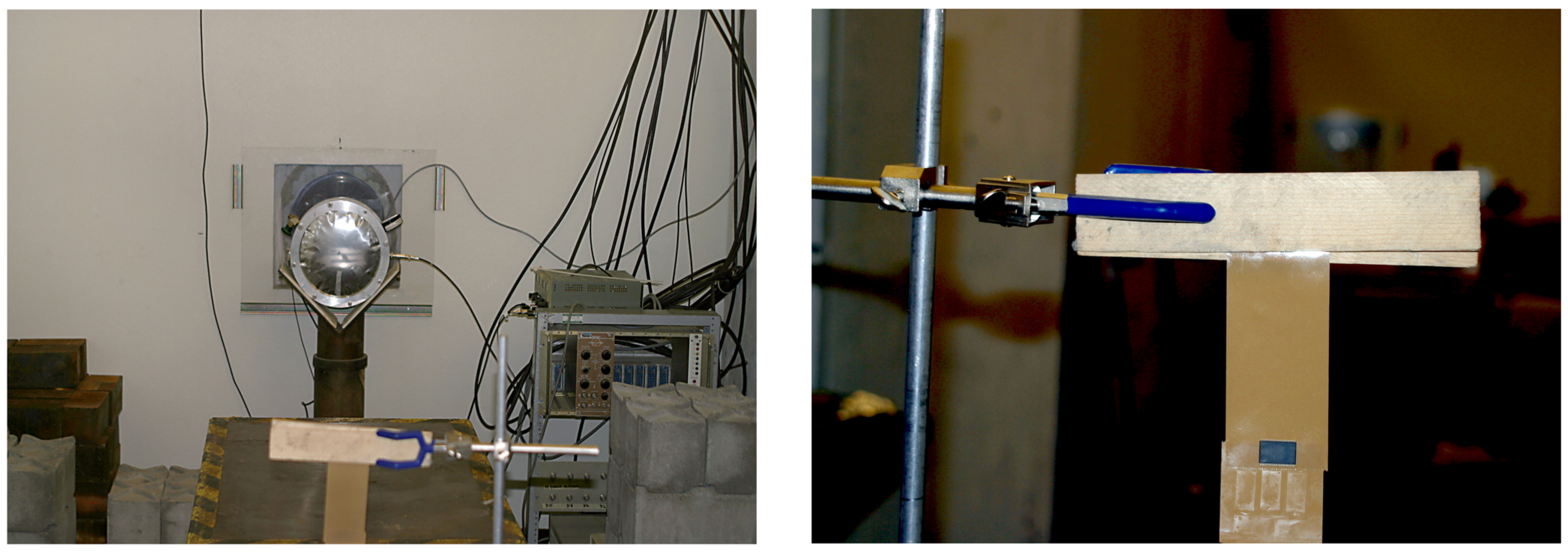
In this particular experiment, it was observed that for the 1" diameter collimated terrestrial cosmic ray beam no soft errors were observed in the FM22L16 over 9.75 hrs of continuous beam of LANSCE WNR Spectra. However for the 3" diameter collimated beam, all bits programmed as zero changed state to ones after 15.75 hrs of continuous beam. There were no hard errors and the devices recovered to programmed values shortly after removal from the beam. It was observed that the soft errors occurred almost simultaneously, indicating the possibility of gradual charge buildup due to secondary gamma, beyond maximum voltage threshold producing all soft errors in all registers of the devices.

A BK Precision Instrument 865 Universal Expandable Programmer was set up with a 5' ft extender cable and adapter to the DUT daughter card and placed in the radiation chamber at the Los Alamos Neutron Science Center LANSCE WNR L 30 flight path ICE House Facility as shown in Figure 4 below. The average standby current was 73.48 uA at nominal voltage of 3.3 Volts for all six device samples. A device programmer self-test was then performed to verify instrument operation. Every register in the devices under test was programmed with value: DFF7 [hexadecimal] = 1101111111110111[binary] = β [ASCII]. The programmed value was verified by the programmer and the device registers monitored.

[1] Linda Geppert, IEEE Spectrum 2003, The New Indelible Memories

(a) (b)

Figure 4. DUT setup for testing under bias to LANSCE SPECTRA



(a) (b)

Figure 5. DUT removed from bias for testing to LANSCE SPECTRA

DEVICE UNDER TEST: FM22L16 4 MB TSOP44 Ferroelectric RAM
VDD= 0 Volts, **Average Room Temperature**= 25°C, **# of Neutrons/ cm²/ pulse** =1.7310.5 x 10^4,
# of Neutrons/ cm2 = 1.7310.5 x 104 * Neutron Pulse Count, Neutron Energy=LANSCE SPECTRA

Run #	LOT CODE	Beam Time	Start		Stop			
			Date	Time	Date	Time	Neutron Pulse Count	Neutron Flux (neutrons/cm²)
1	0731	Beam Off 10 min	112707	12:09p	1127 2007	12:19p	0	0
2	0731	3 hrs 53 min	112707	12:25p	1127 2007	4:18p	418,411	7.243 x 10^9
3	**0731 (6 devices)**	**15 hrs 45 min**	**112707**	**4:30p**	**1128 2007**	**8:15a**	**1,716,470**	**2.97 x 10^{10}**
4	0731	Beam Off 10 min	112807	8:16a	1128 2007	8:26a	0	0

Table 1. Beam Run where soft errors were observed is highlighted.

Calculation of Soft Error Rate [2] $SoftErrorRate = \#ofBits \times \int_0^{\infty} \sigma(E)F(E)dE$,

$$\sigma(E) = \frac{NumberofFails}{(NumberofNeutrons / cm2)*(NumberofBits)}$$

, where $\sigma(E)$ = bit fail cross-section and F is the differential neutron flux as a function of neutron energy, E.

Failure rate estimation from accelerated testing at WNR:

Assume in the terrestrial neutron environment, the neutron flux in the 1 - 10 MeV range, 4.0 x 10-3 n/cm²s (or 14.4 n/cm²h) is almost identical to the integral flux of all of the neutrons with energies above 10 MeV. 2 Thus, the terrestrial failure rate is estimated to be: Soft Error Rate, (SER) = 14 × σ (E) × # bits (upset/h), where failure in Time (FIT) represents one failure in 109 (1 billion) device hours.

Calculation $\sigma(E)$,SER, FIT	# of Bits	# of fails	# bits (upset/h)*	# of hrs	SER	FIT
$\sigma(E)$ = **4.209 x 10^{-12}**	4,194,304	524,288	33288	15.75	**1.962 x 10^{-6}**	**1962**

Table 2. Values of SER, FIT.

The F-RAM devices performed without any soft errors below 15.75 hrs under LANSCE Spectra both with and without bias and with both random and β (ASCII) patterns. There were no hard errors observed and the devices recovered their data after beam was removed. This experiment is the first of its kind for the 4 MB FM22L16 F-RAM under Accelerated Terrestrial Cosmic Ray environment. Additional lot testing is recommended based upon device intended usage application.

Acknowledgements

Thanks to Dr. Stephen A. Wender, Dr. John M. O'Donnell, Art Bridge, the Los Alamos LANSCE WNR spectra control and operations staff and ICE House flight path, Manuel Duran of NASA Space Alliance Technology Outreach Program (SATOP) for their support of this experiment and university research at New Mexico Tech. Thanks also to Ramtron for supplying the F-RAM device samples for test.

[2] JEDEC STANDARD, JESD 89, Measurement and Reporting of Alpha Particles and Terrestrial Cosmic Ray-Induced Soft Errors in Semiconductor Devices.