Single Event Latch Susceptibility Test of Different Circuit Areas of Numonyx Phase Changing Memory A33

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1. Introduction

This study is being undertaken to determine heavy ion induced Single Event Latch-up (SEL) susceptibility of different areas of the Phase Changing Memory (PCM) A33 from Numonyx. Previous Single Event Error (SEE) test of the PCM at the Texas A&M University (TAMU) Cyclotron Single Event Effects Test Facility showed device's SEL sensitivity with heavy ions of LET 2.9 MeV•cm^2/mg. It was also determined that storage cell element of the device did not suffer any Single Event Upset or permanent failure suggesting that all the SELs originated from controls and peripheral circuitries. In this study, various areas with different circuitries of the device were exposed to a heavy ion beam at the TAMU to examine their SEL vulnerability. Latch-up event of each area was monitored by observing device current.

2. Devices Tested

The PCM A33 is a 90 nm technology based nonvolatile memory manufactured by Numonyx that uses a reversible structural phase change property in a chalcogenide material, an alloy of Germanium, Antimony and Tellurium. The tested devices have a Lot Number of T9300051 and Date Code of 0930 and the sample size of the testing was nine devices. The sample devices were prepped for test by Cliff Smith of Numonyx by etching the plastic encapsulation. Table 1 lists the device information.

Table 1 – **PCM A33** Device

Part Number:	PCM A33
Manufacturer:	Numonyx
Lot Number:	T9300051
Date Code:	0930
Quantity Tested:	8
Total number of parts supplied	9
Part Function:	Nonvolatile Memory
Part Technology:	90 nm chalcogenide PCM
Package Style:	56 pin TSOP II

Each etched device was mounted on a TSOP to DIP adapter from Ironwood Electronics (Part number: PC-SOIC/DIP56-06). Figure 1 depicts an etched DUT and its mount on the adapter.

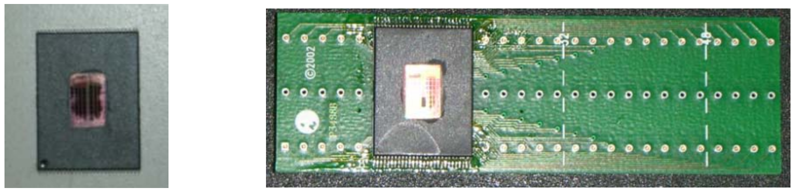

Figure 1. PCM A33 Device Mounting

Masking technique was used to expose an isolated region of the PCM die. An L-T-80 aluminum masking tape with 3mil backing and 1.5mil adhesive was used to mask the die of the DUT. Then a small pinhole sized opening was cut to expose the area of interest. Figure 2 depicts this arrangement. Nine devices were prepared, each with one or two pinholes, size ranging from 0.06 mm^2 to 0.62 mm^2 in various rectangular shapes. Devices were labeled as 1A, 1B, 1C, 1D, 2A, 2B, 2C, 2D and 3 for identification purpose of exposure areas. Of nine devices, one (DUT 3) was damaged while cutting the pinhole and it was excluded from the test.

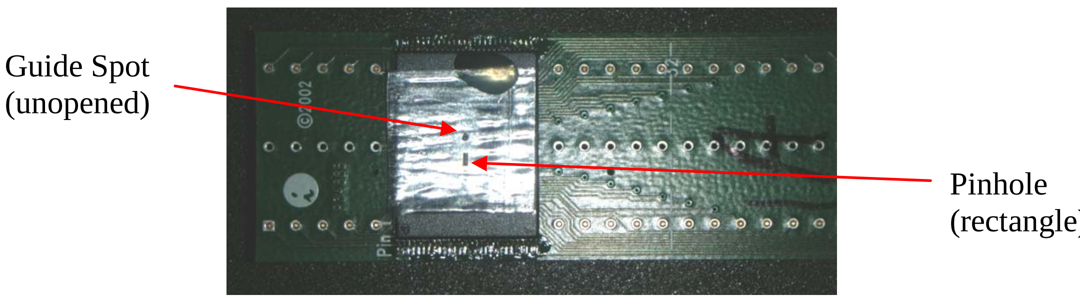

Figure 2. PCM Device with Aluminum Tape Mask with Micro-Pinhole

3. Test Setup

Test circuit, as shown in Figure 3, consisted of Power Supply, Low Cost Digital Tester (LCDT), and a computer with RS232 Communication and GPIB Controller. LCDT is a FPGA based tester. A VHDL code was developed to exercise the Device Under Test (DUT). The computer sent commands to LCDT and receives data from LCDT via standard RS232 communication channel. Command and data process was to examine the functionality of the DUT, not to collect error data. The power supply was controlled by the computer via GPIB and current consumption was recorded.

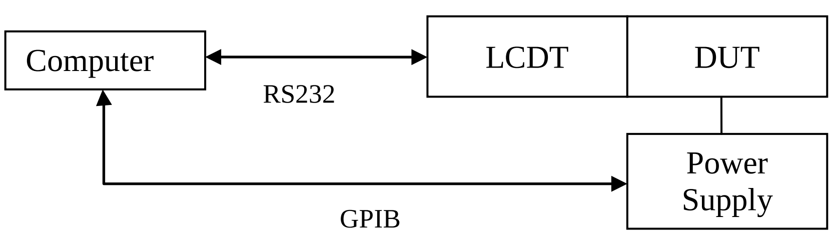

Figure 3. Overall Block Diagram for the testing of PCM A33.

4. Test Description

4.1 Irradiation Conditions

The experiment was performed at TEXAS A&M with Xenon ion beam at 25 MeV/amu and Krypton ion beam at 15 MeV/amu . The parts were irradiated in air. The distance between the beam output and the device under test (DUT) was 5 cm. The ions used and their characteristics are described in Table 2. The LET and range values given in Table 2 were the LET and ranges on the DUT after the 25.4 μm Aramica window and 5 cm of air.

Table 2 – Ion and LET values used

Ion	**Energy (MeV/amu)**	**LET at target (MeV-cm^2/mg)**
^{84}Kr	15	31.9
^{129}Xe	24.8	56.8

4.2 Test Parameters and Bias Conditions

The device was biased at 3.0V for both Vcc and Vccq. Of two power sources, Vcc was of particular interest since it has shown susceptible to SEL in previous test at TAMU. The nominal current of Vcc without reading or writing operation (i.e., static mode) was below 100 uA. All tests were performed at ambient temperature.

4.3 Test Procedure

The device was tested only in static mode since it was determined that static mode was sufficient to induce a SEL from the previous SEE test. In static mode, a known pattern (AA throughout the test) was written to the masked device prior to an irradiation. All readings and writings were suspended and the device was exposed to heavy ion and its static current was monitored during the irradiation. The irradiation terminated when desired fluence (1E6 particles) was reached or when a high current event was recorded. After each run, the device power was cycled and it was read back for its functional and data integrity.

5. Result

All devices but one resulted SEL before it reached 1E6 Xenon particles. The lowest number of particles need for SEL was 2.2E4 with DUT 1B and the highest number of particles was 7.4E5 with DUT 2A. Latch current was as high as 750mA. DUT 1D did not latch with 1E6 particles. Figure 4 shows an example current trace with SEL.

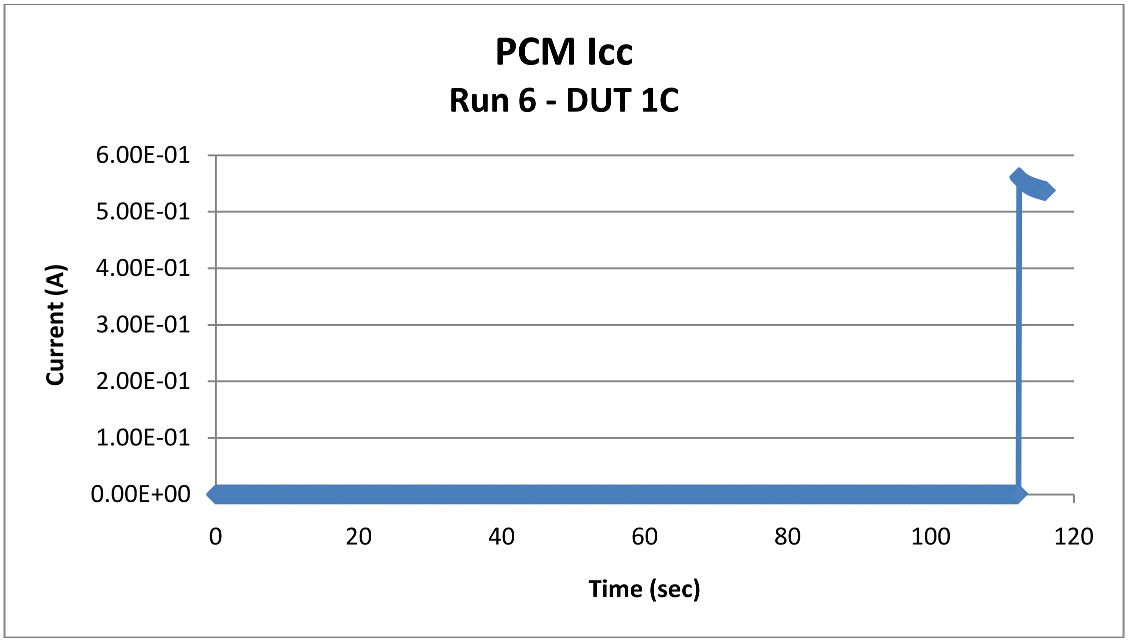

Figure 4. PCM Heavy Ion Test - Icc Trace

Different areas showed different SEL sensitivity to the Xeon beam. The SEL cross-sections varied by more than an order of magnitude ranging from 1.6E-6 to 2.6E-5 cm^2. Figure 5 shows the SEL cross-section of each circuitry with Xenon meam.

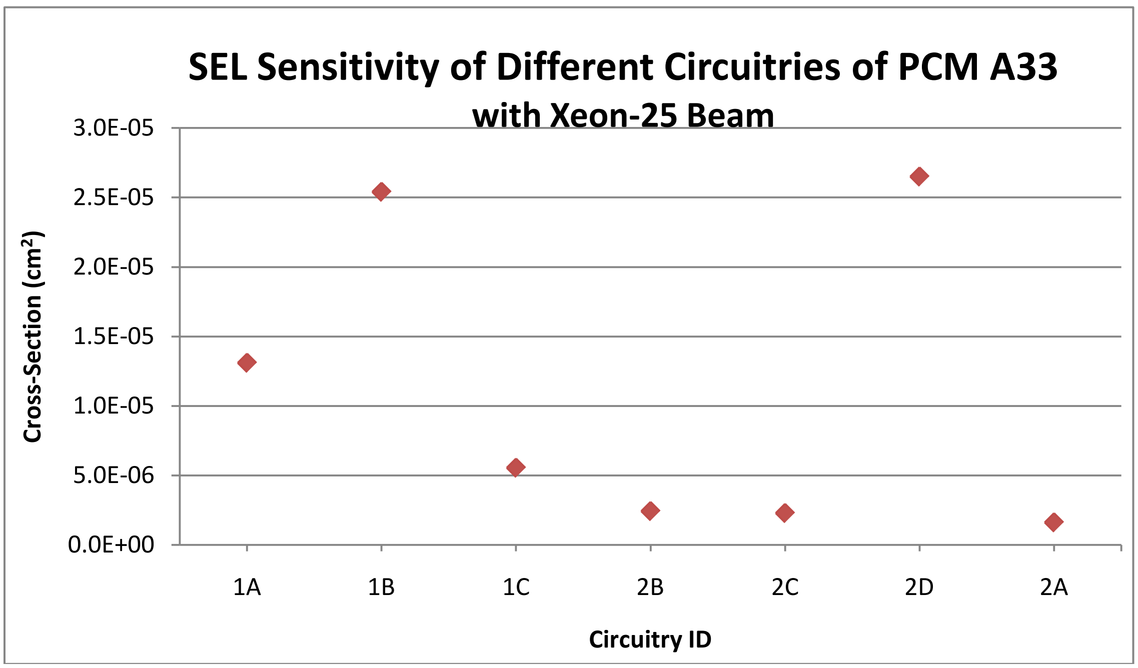

Figure 5. SEL Cross-Section of Different Circuitries of PCM A33*

* Runs combined for the same circuit

Krypton beam with lower LET was used to study the sensitivity of areas that showed SEL with Xenon beam. Only limited number of runs was performed due to unavailability of the beam. The complete list of run by run results of the SEE testing is shown in Appendix A.

6. Conclusion

Almost all control circuitries (seven out of eight) showed SEL susceptibility to heavy ion beam. It should also be noted that current recording showed similar readings obtained from the previous test confirming all PCM's SELs were indeed from control circuitries. More runs with different ions are needed to determine the SEL sensitivity of each circuit.

Appendix A - PCM A33 SEL Test Log

Run #	DUT #	Ion	LET	Fluence	Flux	Dose (rad(Si))	Vcc (V)	Icc (mA)	SEL	SEL Xect (cm^2) per run	SEL Xect (cm^2) [1]combined	Icc SEL (mA)	Note
1	1A	Ze	56.8	5.89E+04	9.81E+03	5.36E+01	3.00	~0.08	1	1.70E-05	1.31E-05	500	Icc Limited by PS
2	1A	Ze	56.8	9.41E+04	1.64E+03	8.57E+01	3.00	~0.08	1	1.06E-05		750	
3	1B	Ze	56.8	2.15E+04	1.67E+03	1.96E+01	3.00	~0.08	1	4.65E-05	2.54E-05	450	
4	1B	Ze	56.8	5.71E+04	1.56E+03	5.20E+01	3.00	~0.08	1	1.75E-05		720	
5	1C	Ze	56.8	2.02E+05	1.53E+03	1.84E+02	3.00	~0.08	1	4.95E-06	5.55E-06	530	
6	1C	Ze	56.8	1.58E+05	1.44E+02	1.44E+02	3.00	~0.08	1	6.31E-06		531	
7	1D	Ze	56.8	5.00E+05	1.35E+02	4.55E+02	3.00	~0.08	0	0.00E+00		n/a	
8	2A	Ze	56.8	5.00E+05	1.21E+03	4.55E+02	3.00	~0.08	0	0.00E+00		n/a	See note 2
9	2B	Ze	56.8	2.06E+05	1.08E+03	1.88E+02	3.00	~0.08	1	4.84E-06	2.43E-06	168	
10	2B	Ze	56.8	6.16E+05	2.01E+03	5.61E+02	3.00	~0.08	0	0.00E+00		n/a	Icc Jump to 37 mA
11	2C	Ze	56.8	7.53E+05	2.04E+03	6.86E+02	3.00	~0.08	1	1.33E-06	2.29E-06	460	
12	2C	Ze	56.8	1.20E+05	7.64E+03	1.09E+02	3.00	~0.08	1	8.37E-06		459	
13	2D	Ze	56.8	4.21E+04	6.71E+03	3.83E+01	3.00	~0.08	1	2.38E-05	2.65E-05	211	
14	2D	Ze	56.8	3.34E+04	1.87E+03	3.04E+01	3.00	~0.08	1	2.99E-05		211	
15	1D	Ze	56.8	1.02E+06	6.97E+03	9.29E+02	3.00	~0.08	0	0.00E+00		n/a	
16	2A	Ze	56.8	7.37E+05	6.70E+03	6.71E+02	3.00	~0.08	1	1.36E-06	1.62E-06	136	See note 2
17	1A	Kr	31.9	2.63E+04	8.96E+03	1.34E+01	3.00	~0.08	1	3.81E-05	2.08E-05	749	
18	1A	Kr	31.9	6.99E+04	1.40E+03	3.58E+01	3.00	~0.08	1	1.43E-05		527	
19	1B	Kr	31.9	3.12E+05	1.34E+03	1.60E+02	3.00	~0.08	0	0.00E+00		n/a	

Note 1: Combined cross-section was obtained by combing runs that the same device tested with the same ion.
2: Combined cross-section for DUT 2A was obtained by adding the results of run 8 and 16.