National Aeronautics and Space Administration

Avalanche ASV016204 (Pre-Production Samples)
40nm MRAM
Total Ionizing Dose Test Report

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1. INTRODUCTION

The purpose of this test was to characterize the Avalanche Technology ASV016204's total dose response. In the test, the device was exposed to high dose rate (HDR) irradiations using gamma radiation. Device functionality (in terms of memory cell upsets and read/write ability) as well as power supply currents during various modes of operations were recorded.

2. DEVICES TESTED

2.1. PART BACKGROUND

The ASV016204 is a pre-production sample (received from Avalanche Technology) of a 16Mb, 40nm serial non-volatile memory packaged in a SOIC-16 package. It uses Avalanche's proprietary perpendicular magnetic tunnel junction (pMTJ) Spin Torque Transfer Magnetic Random Access Memory (STT-MRAM) technology.

2.2. DEVICE UNDER TEST (DUT) INFORMATION

Six test samples were tested for TID. Specifications and descriptions are according to the datasheet (*Rev. 0.2*). More information can be found in Table 1.

Table 1. Part Identification Information

Part Number	ASV016204
Manufacturer	Avalanche Technology
Lot Date Code	1819
Additional Case Markings	FLB02-1W24
Quantity Tested	6
Part Function	Serial MRAM
Part Technology	CMOS
Package	SOIC-16

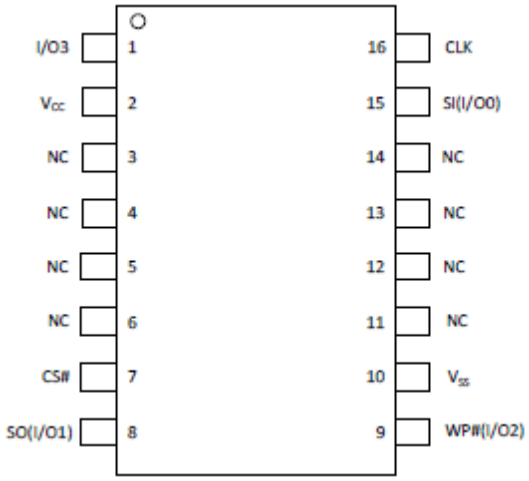

Fig. 1. Pinout of device in SOIC-16 package

3. TEST SETUP

The device was characterized with an ARM Cortex-M4 microcontroller that commanded the device's read/write functions over a serial peripheral interface (SPI). Power supply currents were monitored with a Keithley 2100 multimeter in series between a Keithley 2230-30-1 power supply and the device under test (DUT). Each memory was individually mounted to a two-sided printed circuit board adapter as shown in Fig. 2.

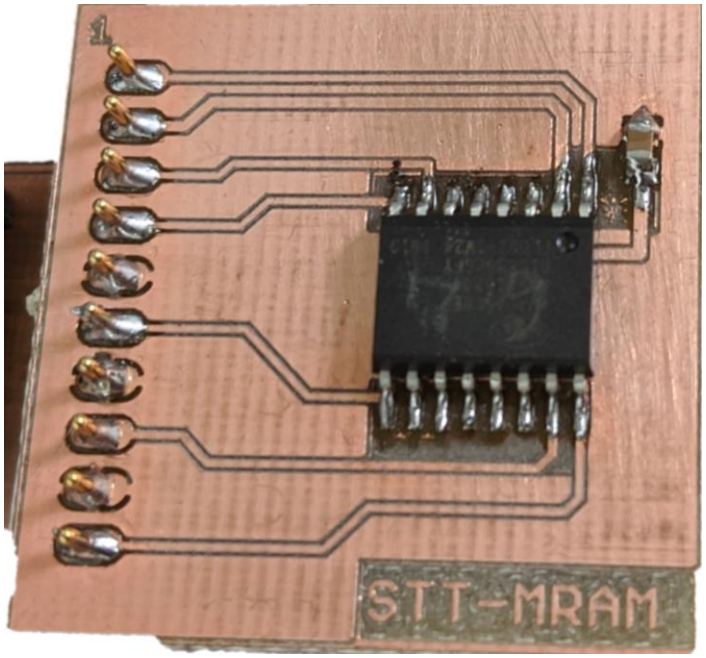

Fig. 2. Picture of DUT on test board

4. TEST DESCRIPTION

4.1. IRRADIATION CONDITIONS

The parts were exposed to gamma radiation at 50 rad(Si)/s. Six parts were tested, with all six exposed to radiation and none reserved as a control. Prior to the first radiation dose, all six parts were electrically tested and programmed. After each exposure level, the parts were tested again and returned to radiation within the time limits defined by MIL-STD-883, Method 1019. Three parts were actively biased (in a standby configuration) and three parts were grounded during irradiation. See Table 2 for more information.

General test procedures were in accordance with MIL-STD-883, Method 1019, Condition A. ESD procedures were followed during test and transfer of the devices between irradiation chamber and characterization. Exposures were performed at ambient laboratory temperature.

Table 2. Device Grouping

Group	Qty	Bias	Dose Rate	Exposure Level Steps (krad(Si))
1	3	Unbiased	50 rad(Si)/sec	0, 50, 100, 300, 500, 1000
2	3	Biased at 3.3 V	50 rad(Si)/sec	0, 50, 100, 300, 500, 1000

4.2. ELECTRICAL TESTS

Specification thresholds were set in accordance with the manufacturer's datasheet. Not all specifications were available in the preliminary datasheet provided. All data from the electrical tests in Table 3 were logged in Excel spreadsheet files. In addition, a series of memory tests were performed to detect any bit errors or functional failures.

Table 3. List of Electrical Tests Performed

Symbol	Parameter	MIN	TYP	MAX	Units	Test Conditions
Iwrite	Write Current			TBD		1 MHz SPI
Iread	Read Current			TBD		1 MHz SPI
ISB1	Standby Current		150	280	uA	Max at 85C
IDPD	Deep Powerdown Current		1	7	uA	Max at 85C

4.3. MEMORY TESTS

Prior to testing, each part was programmed with alternating checkerboard patterns (i.e. first 0xAA bytes, then 0x55 bytes) to verify functionality. Then, at each dose point, the following tests were run on the full memory space.

Table 4. List of Memory Tests Performed

Test Operation	Data Pattern	Objective
Read	0xAA	Count errors induced during irradiation step
Write	0x55	Flip every bit and measure write current at this time.
Read	0x55	Count incorrect bits after writing pattern and measure read current at this time.
Write	0xAA	Return memory array to 0xAA state.
Read	0xAA	Verify no errors prior to next irradiation step.

5. FAILURE CRITERIA

The parameter limits are defined as those listed in the datasheet where available. For these pre-production parts, characterization of change during irradiation is the primary objective.

6. SOURCE REQUIREMENTS

The total dose source is in a room air source gamma ray facility, which is compliant with MIL-STD-883, Method 1019. Dosimetry is NIST traceable.

7. RESULTS

7.1. MEMORY TESTS

After each dose point, the full device memory was exercised. The memory was first read to detect any bit errors that occurred during the actual irradiation. None were ever recorded. Then, the memory was written three times with a set of alternating checkerboard patterns to ensure that each bit could be written and read in both a 0 and 1 state. **No memory errors were ever recorded.**

7.2. POWER SUPPLY CURRENTS

When the memory was read or written at 1 MHz over a single-channel SPI link, the power supply currents remained unchanged at all dose points tested (Fig. 3 and Fig. 4). Similarly, standby mode and deep sleep mode currents all remained generally unchanged with radiation (Fig. 5 and Fig. 6).

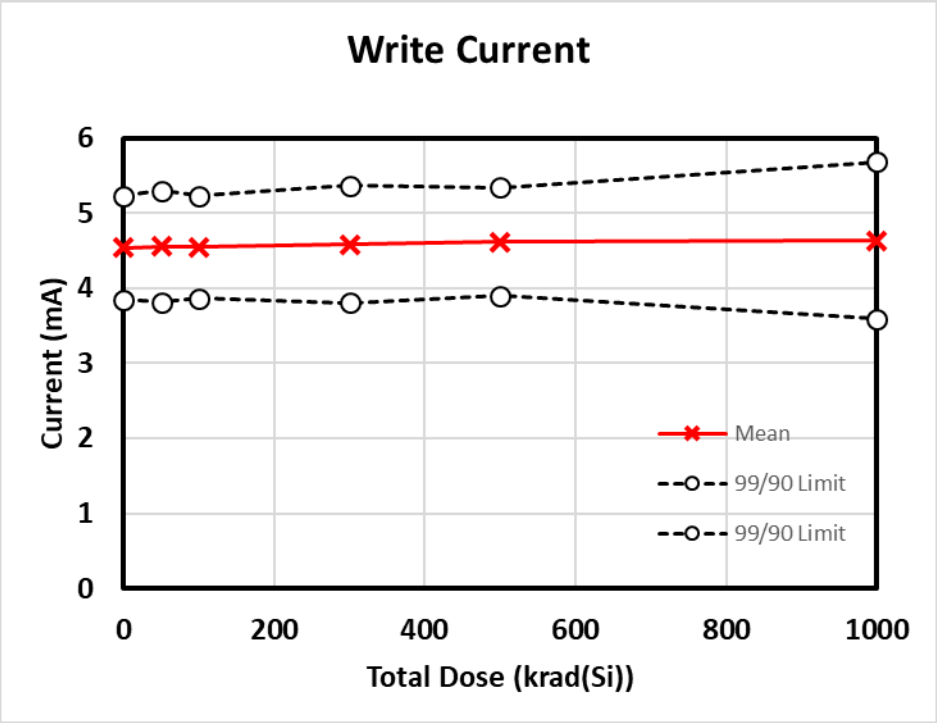

Fig. 3. Power supply current when actively writing to the STT-MRAM.

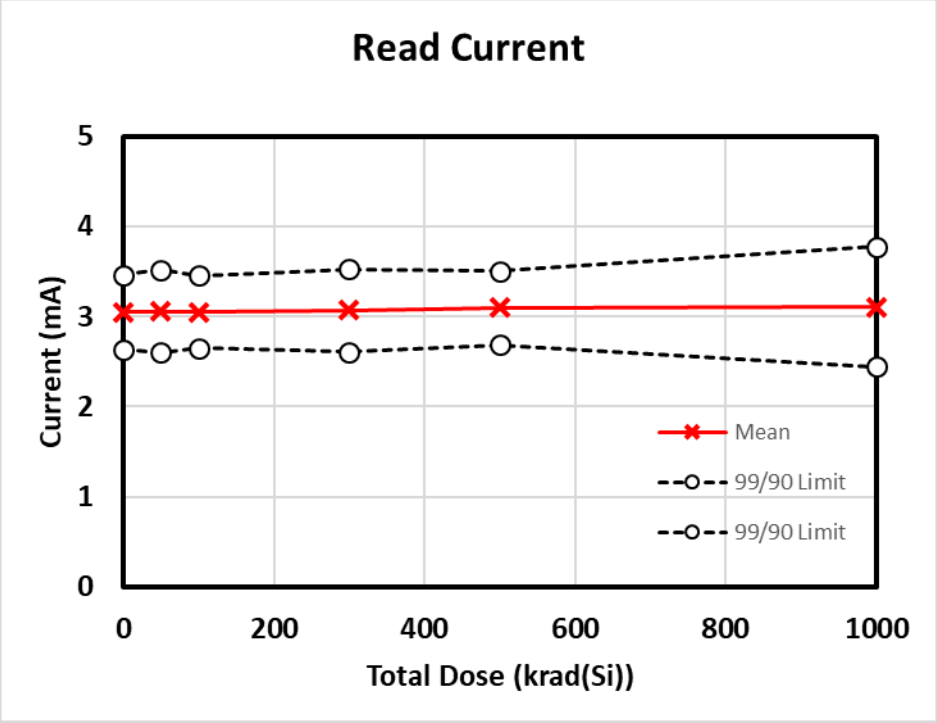

Fig. 4. Power supply current when actively reading from the STT-MRAM.

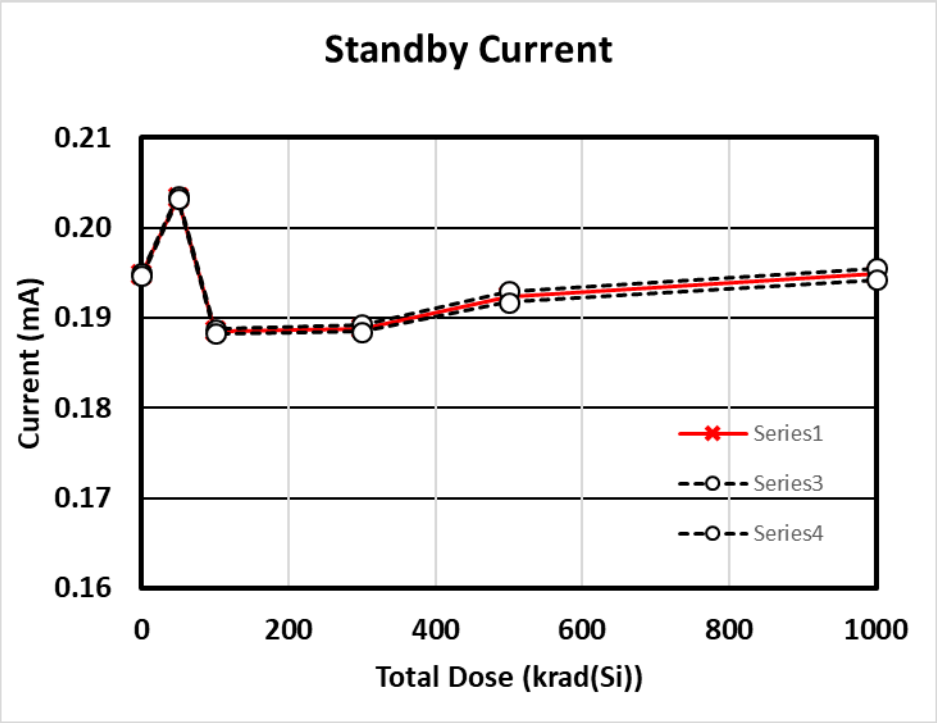

Fig. 5. Power supply current when the STT-MRAM is in standby mode (CS deactivated).

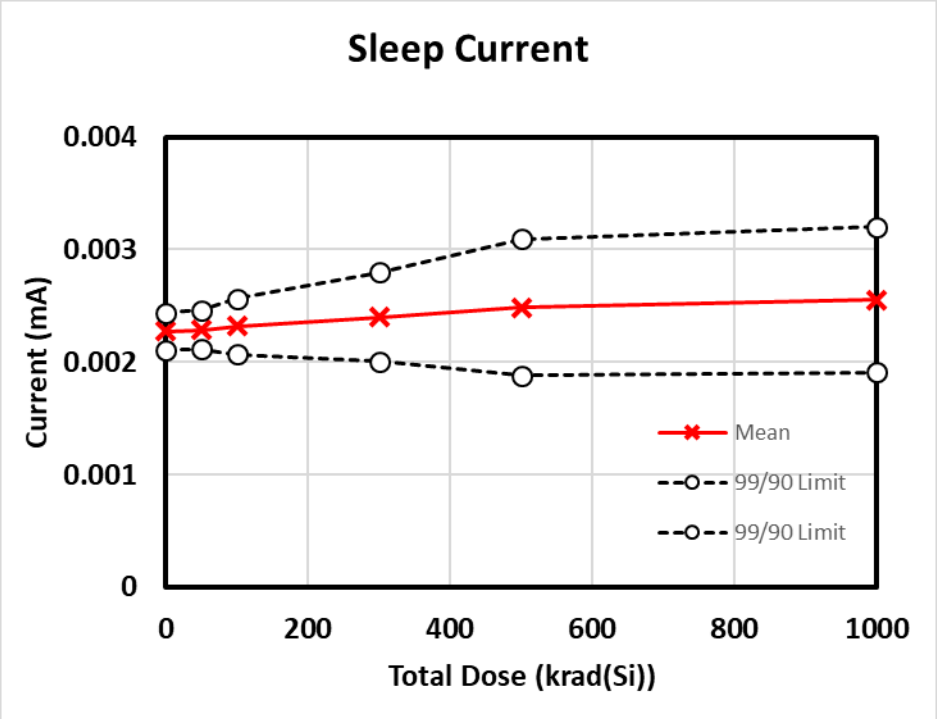

Fig. 6. Power supply current when the STT-MRAM is commanded to deep power down/sleep mode.

8. SUMMARY

No notable changes were observed to the electrical parameters tested up to at least 1 Mrad(Si) of total ionizing dose. No memory errors were induced during irradiation, nor were any reading or writing functional failures noted. Timing parameters and maximum read/write speed were not evaluated in this work.

9. REFERENCES

1) Department of Defense "Test Method Standard Microcircuits," MIL-STD-883 Test Method 1019.9 Ionizing radiation (total dose) test procedure, June 7, 2013, https://landandmaritimeapps.dla.mil/Downloads/MilSpec/Docs/MIL-STD-883/std883.pdf.
2) "1Mb/4Mb/8Mb/16Mb/32Mb High Performance QSPI 40MHz SPnvSRAM," Avalanche Technologies Preliminary Datasheet, Rev. 0.2AHP.