HEAVY-ION AND RADIATION HARDNESS IN MAGNETORESISTIVE RANDOM ACCESS MEMORIES

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I. INTRODUCTION

Magneto-resistive Random Access Memories (MRAMs) have been developed, qualified, and made available as standard products for radiation-hardened, space, and aerospace applications. These MRAMs are also non-volatile, indicating they retain data even when unpowered. These MRAMs include single-die MRAMs in single-chip packages (SCPs) with capacities of 16 Megabits (16Mb), and four-die MRAMs in multi-chip modules (MCMs) that have capacities of 64 Mb. These 16Mb and 64Mb MRAMs are specified to operate across a temperature range of -40 °C to +125 °C; are QML-qualified for classes V and Q; and use Magnetic Tunnel Junctions (MTJs) fabricated on radiation-hardened 150nm silicon-on-insulator (SOI) CMOS to achieve desired functionality in radiation, space, and aerospace environments. The MTJs in these 16Mb MRAMs use inductive Savtchenko toggle-bit writing and tunneling magneto-resistance (TMR) readback. These 16Mb MRAMs were subjected to heavy ion irradiation, and to total ionizing dose (TID), dose rate upset (DR-U), dose rate survivability (DR-S), and neutron exposure testing, to determine and to confirm radiation hardness and to identify failure mechanisms and the physics of failure. These 16Mb MRAMs were demonstrated, for example, to be robust to irradiation and radiation effects, meeting 1Mrad(Si) TID levels, DR-U thresholds of 10^{10} rad(Si)/s, DR-S levels of 10^{12} rad(Si)/s, and neutron (N) levels of 10^{14} N/cm^2 (1 MeV equivalent). No latch-up was observed in DR-U or heavy-ion testing. Heavy ion irradiation testing was performed on 16Mb MRAMs. For the heavy-ion species and cumulative fluence and LET conditions that were tested, the MTJs exhibited no hard errors for cumulative fluences exceeding 10^9 ions/cm^2 and approaching 10^{10} ions/cm^2 for heavy-ion species with Linear Energy Transfer (LET) values up to approximately 55 MeV-cm^2/mg. Such performance supports use in radiation-hardened, space, and aerospace applications. When Ta is used as a heavy ion at an LET of 81.1 MeV-cm^2/mg, hard errors were induced in MTJs at a cumulative fluence level of approximately 10^7 ions/cm^2. As the cumulative fluence is increased to approximately 10^8 ions/cm^2 and then to levels approaching 10^9 ions/cm^2, and as the irradiation angle becomes more oblique, and away from normal incidence to increase the effective LET value to approximately 150 MeV-cm^2/mg, additional hard errors in MTJs were induced. While hard errors were induced in MTJs at what in practice are extreme conditions, the use of error correction with MTJs that exhibit sufficiently low magnetic bit-error rates supports operation of these 16Mb MRAMs with quantifiably low overall error rates.

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REFERENCES

1) SMD 5962-13212, "Microcircuit,Memory,Digital,CMOS/SOI,16Mbit,Radiation-Hardened, NonVolatile Random Access Memory (NVRAM), Monolithic Silicon," https://aerospace.honeywell.com, (2014).

2) R. R. Katti. "Heavy-Ion Device Cross-Section Response in Magnetic Tunnel Junctions for a Radiation Hardened 16Mb Magneto-resistive Random Access Memory (MRAM)," *NSREC REDW*, (2017).

3) N. Rizzo, et al. "A Fully Functional 64 Mb DDR3 ST-MRAM Built on 90 nm CMOS Technology," *IEEE Trans. Magn*., 49(7) 4441-4446, (2013).

4) R. R. Katti, et al. "Heavy Ion Bit Response and Analysis of 256 Megabit Non-Volatile Spin-Torque-Transfer Magneto-Resistive Random Access Memory,STT-MRAM," *NSREC REDW*, (2018).

5) M. J. Gadlage, et al. "Extended Life Testing of Previously Heavy-Ion Irradiated MRAMs," *GOMAC*, (2015).