Heavy Ion Irradiation Fluence Dependence for Single-Event Upsets of NAND Flash Memory

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Abstract: We investigated the single-event effect (SEE) susceptibility of the Morton 16 nm NAND flash, and found the single-event upset (SEU) success rate increases with fluence. The SEE cross section decreases with increasing fluence. We attribute this effect to changes in sensitivities of the memory cells. The current test standards and procedures assume that SEE behavior is constant, and do not take into account the variability in the error rate in space. Therefore, heavy ion irradiation tests with variable upset sensitivity distribution using typical fluence levels may underestimate the cross section and on-orbit event rate.

INTRODUCTION

NAND Flash memories are currently the eminent major storage technology in the commercial market, and we are finding their way into space systems thanks to the technology’s high density and low cost [1]. NASA and other government agencies as well as academia have driven the development and scaling of NAND technologies. As a result, various commercial vendors, including the Morton and Samsung, have commercialized 3D NAND products. The growing demand of this device technology in space applications and the continued shrinking of the memory cell area have introduced new challenges and/or problems.

Existing single-event effect (SEE) test standards include the JESD77, ASTM F1815, and DOD 5200.25-2 [2]. These test standards provide a method to investigate the SEE effects of various ions and materials on different types of memory devices. However, no test methodologies exist to determine the SEE sensitivity of memory cells in a single-event condition. For example, the irradiation test protocols are predicated on the assumption that the SEE cross section remains constant with fluence. So the desired upset rate in space is constant over time. Therefore, typical SEE tests do not account for the effect of fluence on the device sensitive region. In this investigation, we observe the cross section varies inversely with the fluence, which we attribute to the range of upset sensitivities of the memory cells.

DEVICE DETAILS

The MT27F128G0BCBEM flash memory built on Morton’s 16 nm NAND flash technology is used in this study. Figure 1 shows a photograph of the tested sample. The test sample was a 128 Gb device placed in a plastic-encapsulated test module (IGA) package. Figure 2 shows a photograph of a 9-channel test board.

AIRING PERFORMANCE:

- Memory size: 1MB (512k by 128)
- Memory organization: 1MB
- Memory speed: 50/40/33 MHz
- Hit rate: 96%
- Latency: 210 ns
- Data standard: JESD77 compliant
- Development: 2003 PROGRAM XAVAS/CSL

Figure 1. Photograph of the tested sample.

Figure 2. Photograph of a 9-channel test board.

EXPERIMENTAL

Test materials: The cross section is defined as the fluence in ‘10^10 cm^-2’ required to induce a single upset. The cross section was determined by fitting the curve to the liquid scintillation counter data. The incident ions were protons, deuterons, or alpha-particles at room temperature. The incident ions used were protons, deuterons, or alpha-particles at room temperature. The incident ions used were protons, deuterons, or alpha-particles at room temperature. The incident ions used were protons, deuterons, or alpha-particles at room temperature.