4 - 22 Anomalous Annealing of Floating Gate Errors due to High LET Heavy Ion Irradiation

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In our experiments, we studied the commercial Single Level Cell (SLC) NAND Flash devices manufactured by Micron Technology. The memories were irradiated at the Heavy Ion Research Facility in Lanzhou (HIRFL) in the Institute of Modern Physics (IMP), Chinese Academy of Sciences (CAS). We used two kinds of heavy ions(^{86}Kr and ^{209}Bi) to irradiate the Flash memories and the degraders with different thickness were used to get the different LET of ions.

All the tests were carried out in air at room temperature with normal incident beam. The peripheral circuitries of memory were protected with 100 μm thick Aluminum shields during ^{209}Bi ion exposure. During the irradiation, the devices were kept unbiased. An ion influence of about 10^6 ions/cm^2 was achieved so that sufficient amount of errors could be gathered. After the irradiation, we kept the devices unbiased at room temperature and measured the number of errors in the irradiated blocks/sectors for thousands of hours after exposure.

After the irradiation, we immediately measured the errors in all three kinds of NAND memories. The SEU cross sections for 1-Gb, 8-Gb and 16-Gb NAND flash memories as a function of ion LET are shown in Fig. 1. The SEU cross section increases with the increasing of LET. There is no noticeable difference between the 1-Gb and 8-Gb memories. The 16-Gb memories are more susceptible than the 1-Gb and 8-Gb memories.

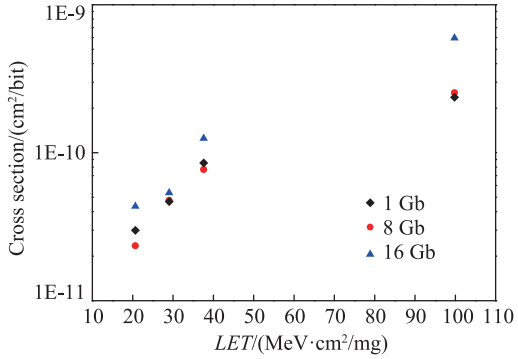

Fig. 1 (color online) The FG SEU cross sections for 1-Gb, 8-Gb and 16-Gb NAND flash memories.

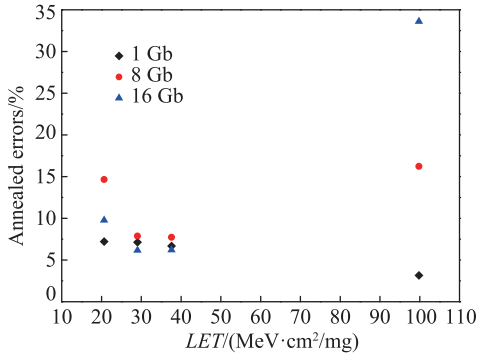

Fig. 2 (color online) The maximum percentage of annealed errors for 1-Gb, 8-Gb and 16-Gb NAND memories.

Then we kept the memories unbiased at room temperature and monitored the errors periodicity. We found that the number of errors decreases as a function of the time after irradiation for all three kinds of devices. In a few hundred hours after the irradiation, the errors show a decreasing trend with time in all cases. In addition, the error numbers prone to be a constant value after thousands of hours. This experimental phenomenon was discovered early in Ref. [1].

Fig. 2 shows the maximum percentage of annealed errors for 1-Gb,8-Gb and 16-Gb NAND memories as a function of the ion LET. The maximum percentage of annealed errors is calculated relative to the errors detected immediately after the exposure. For 1-Gb devices, the maximum percentage of annealed errors ranges from 3% to 7% and the higher the ion LET the lower the maximum percentage of annealed errors. The maximum percentage of annealed errors ranges from 7% to 16% in 8-Gb devices and from 6% to 33% in 16-Gb devices, but the maximum percentage of annealed errors isn't monotonic decreasing with the increase of ion LET in this two kinds of memories. For 8-Gb and 16-Gb devices, the maximum percentage of annealed errors decreases at ion LET increases initially and increases afterwards. When the particle LET is up to 99.8 MeV·cm^2/mg, the maximum percentage of annealed errors is the highest.

Reference

[1] M. Bagatin, S. Gerardin, G. Cellere, et al., IEEE Transactions on Nuclear Science, 55(2008)3302.