Evaluation of LSI Soft Errors Induced by Terrestrial Cosmic rays and Alpha Particles

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It is well known that alpha particles cause soft errors in LSI. Recently, it has been found that cosmic ray neutrons also cause soft errors even at ground level [1, 2]. At present, high energy neutrons and thermal neutrons in terrestrial cosmic ray and alpha particles from radioactive decay of U, Th in mold resin are considered to be the three major causes of LSI soft errors. When a high energy neutron with energy of order of 100 MeV incidents to LSI, a spallation of Si nucleus can take place. In the spallation process, many particles such as protons, neutrons and nuclei (e.g. carbon) are generated, and they produce large number of electron-hole pairs in a short range of several μm [3]. If total electrical charge reached to a storage cell is larger than the critical charge (Q_c) to upset logic, a soft error takes place. A ^{10}B has a large cross section of thermal neutron capture. A 1.47 MeV alpha and a 0.84 MeV Li are emitted (fission) after the neutron capture, and these particles also produce electron-hole pairs. A conventional CMOS contains a large quantity of ^{10}B in BPSG dielectric layers. Alpha particles are emitted from radioactive decay of U and Th contained in mold resin, and they also produce electron-hole pairs. We have used refined mold resin, which has lower concentration of U and Th, to reduce alpha-induced soft errors. We have performed several field tests at sea level, high altitude and underground for SRAM devices. The purposes of this work are to obtain soft error rates (SER) of SRAM devices induced by high energy neutrons, thermal neutrons and alpha particles independently, and to find effective measures to reduce these soft errors.

We have performed field tests at sea level (Yokohama and Oita) and high altitude (California, a height of 2000 m) for 0.25 μm and 0.18 μm SRAM devices. Approximately 1000 devices have been tested for 1000 - 3000 hours. Since cosmic neutron flux at a height of 2000 m is approximately six times larger than that at sea level, field tests at high altitude are useful as accelerated tests. Neutron fluxes at each location were estimated taking account of altitude, geomagnetic effect and shielding effect of buildings, and all SER data have been corrected to be equivalent SER at New York City. Figure 1 shows summary of the field tests. It is shown that 0.18 μm SRAM has approximately twice SER than that of 0.25 μm SRAM, suggesting that the soft error problem becomes more serious with scaling down of LSI devices.

In order to measure only alpha-induced SER, it is necessary to test underground where cosmic rays are effectively shielded. We have performed field tests at Oto Cosmo

Observatory of RCNP. It is located at 470 m in depth and cosmic neutrons are shielded to be negligible level. 527 0.18 μm SRAM have been tested for more than 4000 hours. We found that the alpha-induced SER is less than 1 %, which is unexpected small value (Fig.1). This suggests that reduction of the U and Th concentration in mold resin by refining is very effective. This is the first measurement of the alpha-induced SER separated from the cosmic ray-induced SER.

The high energy neutron-induced SER and the thermal neutron-induced SER have been compared in high altitude field tests using thermal neutron shield sheets. We used BN contained silicon rubber sheets with thickness of 4 mm. ^{10}B in the sheets capture thermal neutrons, and the thermal neutron flux is reduced to less than 1/100 using these sheets. We have tested 252 devices (0.18 μm SRAM) with the shield sheets and 252 devices without them simultaneously for 2800 hours, and found that the thermal neutron-induced SER is approximately four times larger than the high energy neutron-induced SER in 0.18 μm SRAM.

Figure 2 summarizes the ratio of SER of 0.18 μm SRAM induced by high energy neutrons, thermal neutrons and alpha particles. The thermal neutron-induced SER is the largest at present, however, it will become negligible because the BPSG dielectric layer will be eliminated from 0.13 μm process and after. Therefore, the high energy neutron-induced SER will be most serious in the next generation of LSI. An intense neutron beam having similar energy spectrum as terrestrial cosmic neutrons is very useful to study the high energy neutron-induced SER. We strongly hope for the construction of a neutron beam line with a spallation target at RCNP.

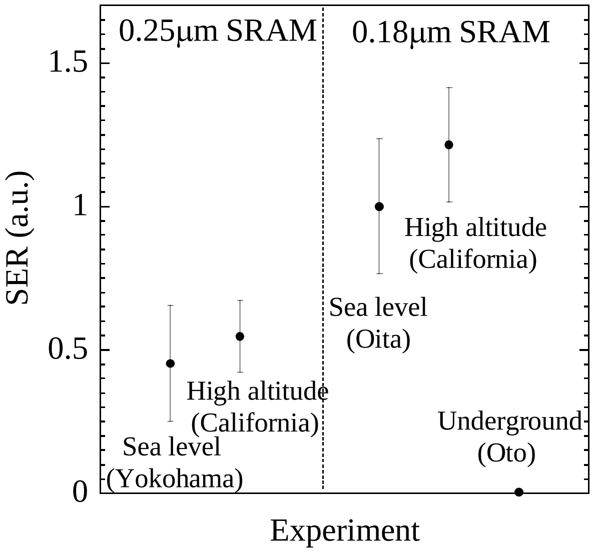

Fig.1 Summary of field tests

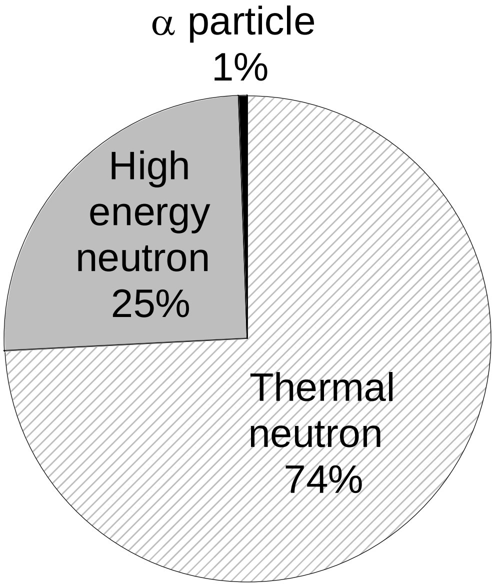

Fig.2 Ratio of SER of 0.18 μm SRAM induced by various particles

References

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