Neutron-Induced Soft Errors in Advanced CMOS SRAMs

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As the device density increases in VLSI, the soft error (SE) has become a serious problem [1]. The high energy neutron beam is powerful tool to investigate neutron-induced SEs [2]. Recently, an advanced neutron white beam was newly developed for SE investigations at RCNP. It is similar to that of LANSCE (Los Alamos Neutron Science Center) and has an energy spectrum similar to that of sea-level atmospheric neutrons (Fig. 1).

We investigated characteristics of multiple-bit (MB) SEs in CMOS SRAMs [3, 4], using the neutron beam of RCNP for neutron accelerated tests. Accurate estimations of MB-SEs are important for ECC (Error Correction Code) design [5]. Figure 2 (a) shows 4, 5, 6, and 7 bit error examples. We found that most MB-SEs with multiplicity > 4 occurred with SE cluster patterns. 4bit square (4b sq.) errors were 55% in 4bit errors and MB-SEs with SE clusters include 4b sq. were 71% in 5,6, and 7 bit errors (Fig. 2(b)). The occurrence possibility of SE chains (for example 4c and 5a in Fig.2 (a)) was smaller than that of SE clusters. Influence of SE clusters for ECC is rather small because 2-bit error distance in MB-SEs is rather suppressed.

We introduced the concept of "2bit correlation" in MB-SEs. We defined "2bit correlation" as the sum of specified 2bit error pattern in MB-SEs divided by all error counts. Figure 3 (b) shows 2bit correlation as a function of 2bit distance for12 patterns (Fig. 3 (a)). 2bit correlation decreases as the 2bit distance increases. Figure 3 (b) shows 2bit correlations along the word line, bit line and diagonal directions. 2bit correlations show different features along different directions. It is considered that the cell structure of the SRAM affects these features. 2bit correlation along word line is important for ECC design. For example, if we consider 8bit interleaving distance, only one event has observed in 90 nm SRAMs and the 2bit correlation is less than 1E-4. This probability implies the error rate for the 8 column SRAM with ECC.

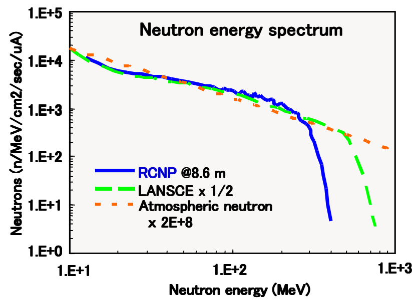

Fig. 1. Neutron energy spectrum of RCNP neutron beam compared with those of LANSCE neutron beam and of atmospheric neutrons.

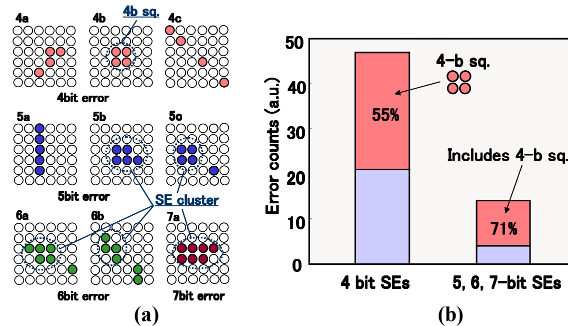

Fig. 2. (a) 4,5,6,7 bit error examples, and (b) component of 4bit square errors in 4bit errors and 5,6,7 bit errors.

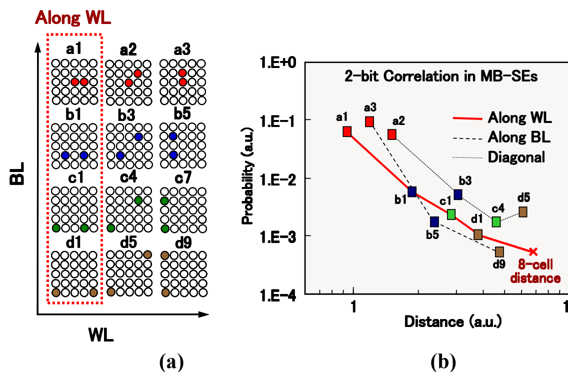

Fig. 3. 2bit correlations in MB-SEs in 90nm SRAMs. (a) 12 patterns and (b) their 2bit correlations.

Refferences

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