Study of Neutron-Induced Soft Error Rate on Advanced DRAM

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Terrestrial neutron-induced soft-error or single event upset (SEU) in semiconductor devices is one of the most crucial reliability-issues in the cutting-edge memory devices[1-3]. In the case of DRAM, Cell-data inversion from high-state to low-state mainly occurs. Designers of electronic systems such as high-end servers, therefore, need the soft-error rate (SER) data of the electronic components in order to architecht the system reliability securely. We have intensively developed the SER estimation method for memory devices mainly using monoenergetic and quasi-monoenergetic neutron beams generated by accelerators, which is well reflected also in JEDEC Standard/JESD89A [4] published in Dec. 2006. The essential concept of the method is summarized as follows: the inherent excitation function of a device $\sigma(E)$ is described as the Weibull-type function[1-4],

$$\sigma(E) = \sigma_\infty \left[1 - \exp\left\{ -\left(\frac{E - E_{th}}{W} \right)^S \right\} \right], \tag{1}$$

where σ_∞ is the saturated value of the SEU cross section, E_{th}, the threshold neutron energy for SEU, W, the scale factor, and S, the shape factor of the Weibull function, respectively. The SER of the device is estimated in the unit of FIT (failure in time; a number of errors in 10^9 hr) by the formula

$$\text{SER [FIT]} = 3.6 \times 10^{12} \int_{E_{th}}^{\infty} \sigma(E) \frac{\partial \phi_v(E)}{\partial E} dE, \tag{2}$$

where $\phi_v(E)$ means the flux of terrestrial neutrons at a specific place on the ground, for example, at sea level (0 m) in New York City.

Neutron irradiation experiments concerning DRAMs with stacked capacitors from

250-nm to 110-nm process were performed using monoenergetic and quasi-monoenergetic neutron beams of peak energy from 5 to 174 MeV at FNL (Fast Neutron Lab.) and CYRIC of Tohoku Univ. in Japan, and at TSL (The Svedberg Lab.) of Uppsala Univ. in Sweden [5,6]. Neutron energy dependence of SEU cross sections of each device is acquired by using monoenergetic and quasi-monoenergetic neutron beams[7]. Neutron irradiation experiments of DRAM beyond 100 nm process were performed using quasi-monoenergitic neutron beams of peak energy 70 MeV at CYRIC of Tohoku University. Typical neutron spectra, which were used in this experiment, are shown in Fig. 1. The experiments were performed using a special evaluation tool. The setup of evaluation tool in 32 neutron course is shown in Fig. 2. The estimated SER of each device from monoenergetic and quasi-monoenergetic neutron irradiation tests is shown in Fig. 3. According to Fig. 3, the SER of the DRAMs was effectively suppressed as its down-sizing from 220 nm to 150 nm. This is estimated the effect of the shrinking of junction-volumes and the securing of constant storage capacitance. However, the SER beyond 150 nm process was found constant. This is estimated the offset of the scaling effect and the gradual decreasing of storage capacitance by the lower voltage to capacitor. The securing of storage capacitance may be becoming difficult on advanced DRAM because of the reduction of the Cell area and the lower voltage to capacitor. The soft-error estimation of DRAM should be continued. A high intensity neutron source with a neutron flux around 1.5×10^6 n/cm^2/s is needed for estimating the soft-error on advanced DRAM.

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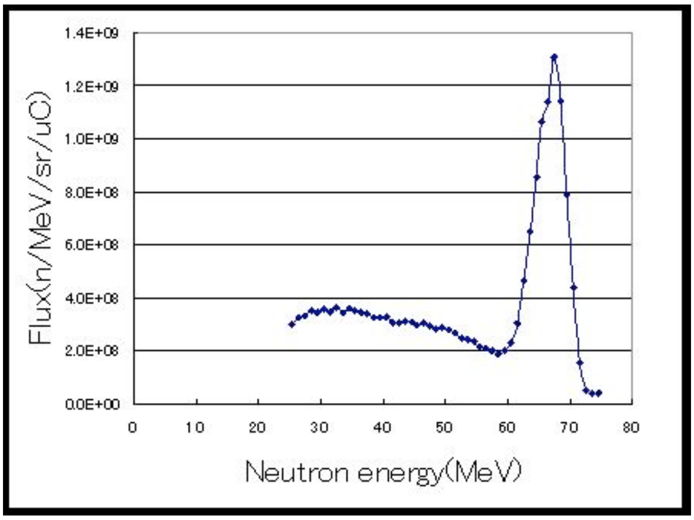

Figure 1. Typical energy spectra of quasi-monoenergetic neutron sources.

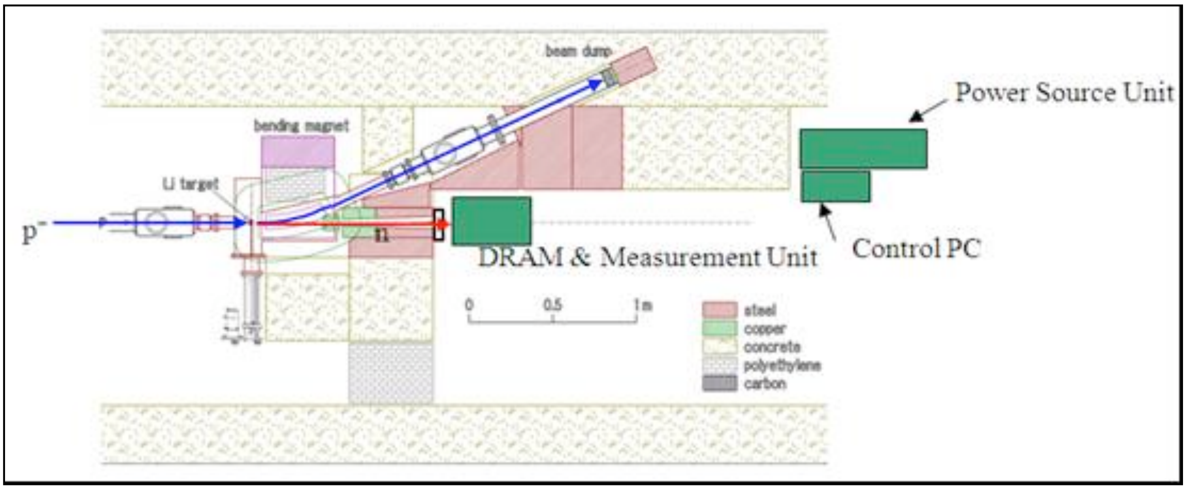

Figure 2. The setup of evaluation tool in 32 neutron course.

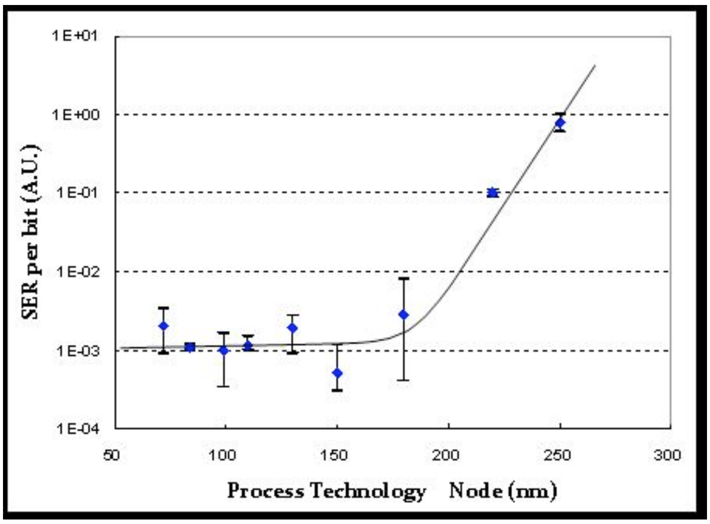

Figure 3. The SER-trend of DRAM with stacked capacitor from 250 to 70 nm process technology node. The solid line is an eye-guide for the trend. *The data form 110nm to 220nm quoted from references 7.