# INVESTIGATION OF NUCLEAR REACTIONS ROLE IN SEU FORMATION IN SEMICONDUCTOR MEMORIES

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During last decade the large number of papers devoted to Single Event Upset phenomenon was published. Some new experimental results were presented in our preprint [1]. Besides, we have developed two parameter model for predicting Single Event Upset rate in semiconductor memories under nucleon irradiation.

It was supposed that upset occurs when additional amount of energy exceeding the threshold one $E_{thr}$ is deposited in a volume $V$ of a memory cell. So, $E_{thr}$ and $V$ are parameters under discussion. Considering the stopping power of nuclear fragments and recoils as a main reason of the deposited energy we obtain for SEU rate:

$$q = n \cdot V \cdot \sigma_{in} \cdot \varepsilon(E_{thr}) \tag{1}$$

In (1): $n$ — number of $Si$ nuclei in cubic centimeter, $\sigma_{in}$ — inelastic cross section of the projectile $+Si$ interaction, factor $\varepsilon(E_{thr})$ takes into account that not all reactions lead to upset, but only those in which energy deposition is greater than $E_{thr}$.

Using results of two experiments $q_1$ and $q_2$ one is able to determine two unknown parameters $V$ and $E_{thr}$. The essential part of our approach is calculation of deposited energy spectra. We use Monte-Carlo method. During the first stage we calculate the characteristics of nuclear reaction products and then we trace these products in a volume of a memory cell. The result is the energy deposited in volume under investigation. Repeating such process many times one obtains the deposited energy spectrum. It is a base for determination of factor $\varepsilon(E_{thr})$. Then we are able to calculate dimension of a cell in the next iteration. Usually the process converges after 2–3 iterations. The details of our approach can be found in preprint [2].

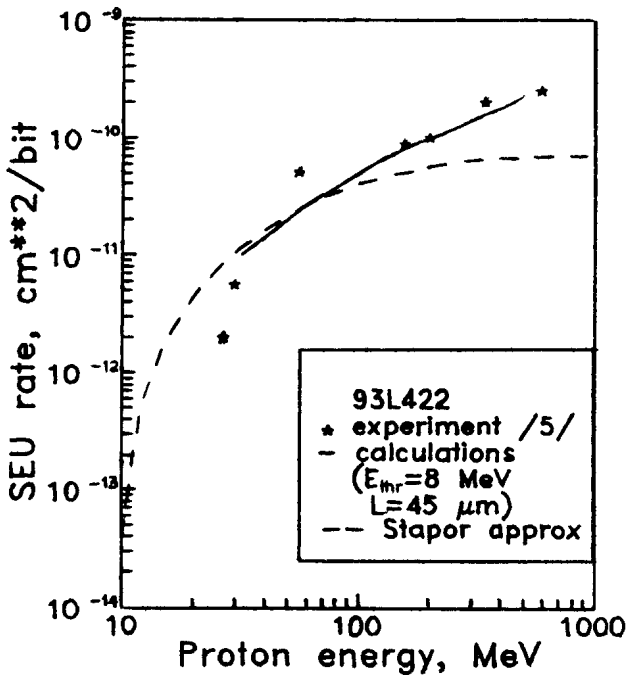


**Fig.1.** Comparison of experimental and calculated SEU rates for device 93L422. Dashed line — Stapor approximation

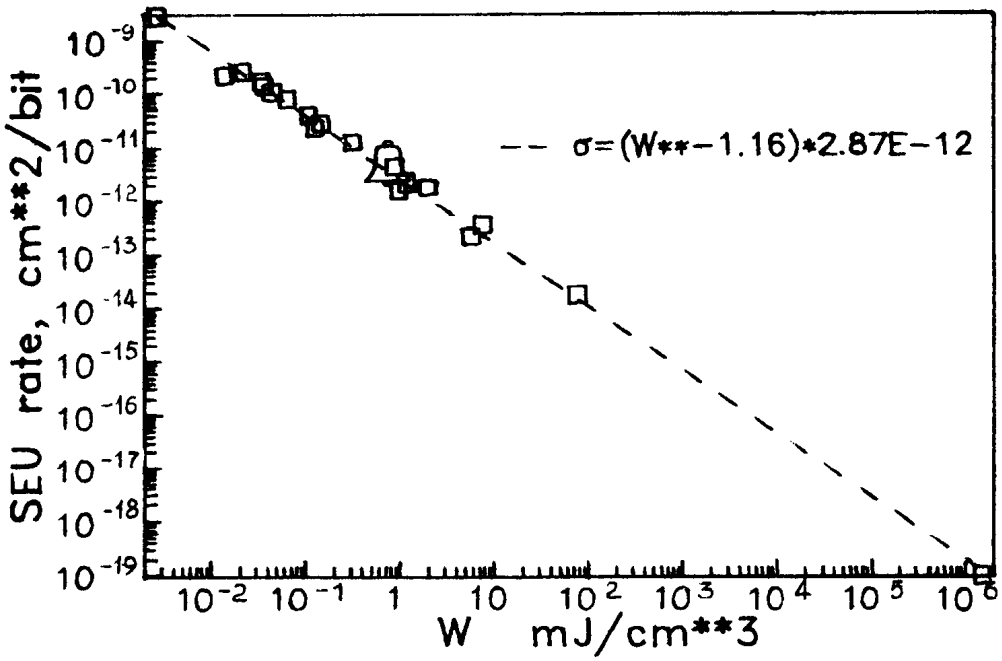


**Fig.2.** Dependence of SEU rate on specific energy deposition for proton energy 1000 MeV. Squares — results for microcircuits treated in [5]. Bell — result for IMS 1601 SRAM

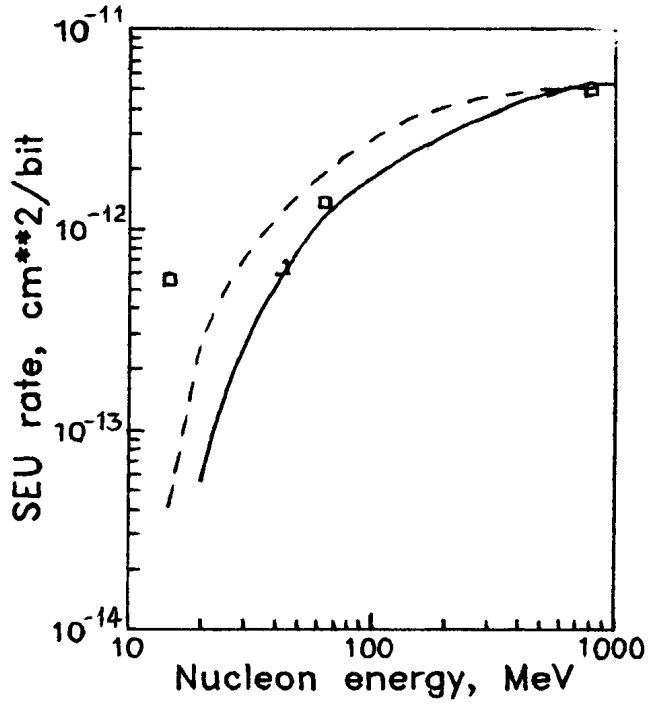


**Fig.3.** Comparison of experimental and calculated SEU data for IMS 1601 SRAM. Dashed line — Stapor approximation

We had checked the present code by comparing experimental and calculated energy spectra deposited in thin semiconductor detectors. Experimental data at 20–150 MeV [3] and 1 GeV [4] were used. It was found that agreement is quite good.

The developed procedure was applied to a number of experimental SEU cross sections. Mainly they are devices treated in [5] in the frame of Stapor approach. Obtained model parameters and curves can be found in our preprint [2]. It should be pointed out that we handle data presented mainly in graphic form. Fig.1 gives an example of such approach. Here one can see experimental data from [6] together with our calculations and those based on Stapor approximation. The obtained model parameters are given in box.

We tried to find a universal parameter for describing the sensitivity of microcircuits to SEU. We introduced a specific energy deposition $W = E_{thr}/V$. Dependence of $\sigma_{SEU} = f(W)$ for $E_p = 1000$ MeV is shown in Fig.2. It is seen that the data demonstrate linear dependence. The similar behavior is valid for $E_p = 100$ MeV (with their own line parameters). These results are in our opinion evidences of the basic features of semiconductor materials. They can be used as a universal characteristics of a memory cell.

The two parameter model for predicting SEU rate was applied to new neutron data [7]. We use at least two experimental SEU cross sections to obtain above mentioned parameters.

We took a neutron SEU cross section for IMS 1601 SRAM at 42 MeV and a proton one at 800 MeV as basic points. The data at 2.5 V in standby mode were analyzed. Obtained model parameters are: $E_{thr} = 3.84$ MeV and $V = 8E - 10$ cm$^3$ ($l = 9.3$ $\mu$m for cubic cell).

In Fig.3 our results (solid line) are shown together with the experimental data. The results of the calculations based on Stapor approximation with parameters determined in [7] are also shown (dashed line).

It should be pointed out that we couldn't reproduce the results at neutron energy 14.7 MeV. The calculated cross section is essentially less than the experimental one. We had observed the same behavior investigating the SEU rate at PNPI neutron generator. The reason of such discrepancy is connected in our opinion with the difficulties in the identification of "false" upsets in experimental environment at such accelerators.

The marked point (bell) in Fig.2 represents the result for microcircuit IMS 1601 SRAM under investigation. It is seen that the proposed characteristics reflect the basic properties of semiconductor material.

In conclusion we would like to point out that the proposed two parameter model should be considered as a good tool for predicting SEU rate at intermediate nucleon energies. That statement confirms principal proposition of our approach [8].

REFERENCES


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