STUDY OF ENERGY DEPOSITION FROM NUCLEAR REACTIONS IN MICROVOLUMES OF MATTER

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During the longitudial operation of information system using semiconductor memory the possibility of upsets of an information (on single bit level) in memory devices under the fast particles bombardment is to be kept in mind. This effect is known as SEU-single event upset. We deal with the case when projectile is fast and possesses a low ionization capacity. It is shown that the reason of the effect is an addititional charge generated by stopping residual nuclei.

Considering the above mentioned, the necessity of the detailed study of energy deposition from nuclear reactions in the microvolumes corresponding to dimensions of an elementary cell in modern memory devices is obvious.

Memory devices are such objects under investigation whose irradiation can provide us with quantitative information about energy deposition discussed.

Even in 1968 [1] we reported about the possibility of the functional disturbunce in radioelectronic elements initiated by single nuclear reaction. This statement was confirmed later by the experiments with industrial transistors irradiated by 660 *MeV* and 1 *GeV* protons.

Following the process of miniaturization of electronic devices the investigation was applied to the semiconductor memories. It was supposed that nuclear reaction could be a reason of the upsets of information kept in memory in binary code.

In a number of experiments with memories irradiated by projectiles of different types and energies it was shown that upsets under consideration took place. Upsets were observed for all irradiated memories (145ИР1П, 565РУ1, 565РУ5, 565РУ6, 565РУ7 etc.) and for all projectiles: protons ($E_p = 1$ *GeV*), neutrons ($E_n = 14$ *MeV*), pions ($E = 150$ *MeV*) and quantum of bremsstrahlung ($E = 800$ *MeV*).

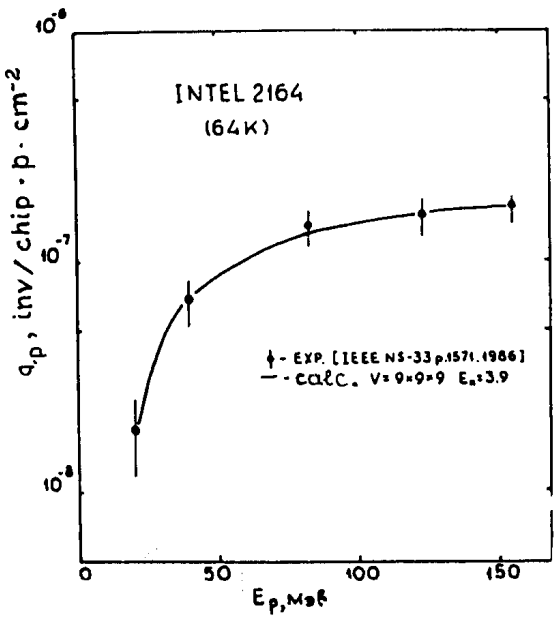

Fig. Forecast of upset probability of INTEL 2164 device under proton irradiation

The interpretation of experimental results (in particular the probability of upsets) required the development of phenomenological model of SEU [2]. The model includes two unknown parameters V and E_t that can be determined by the results of two experiments at different initial conditions (at different energies of projectiles, for example).

The method of calculation of V and E_t includes generation of spectra of the energy deposited in volume by nuclear reaction products. Deposited energy is a random value and therefore Monte-Carlo method is a useful tool for calculation of such spectra. The above mentioned method was realized in cascade-evaporation model of nuclear reactions. Developed code was tested with the help of the experimental deposited energy spectra from dE/dx-detectors. We used data [3] in the energy range up to 100 *MeV* and our results [4] at 1 *GeV* proton energy.

It was shown that our model of SEU is an effective tool for interpretation of the experimental results dealing with memories. The calculated dependence of the upset probability on the proton energy for the device INTEL 2164 [5] is shown in fig.1. Two out of five experimental points were used to establish V and E_t. It was found that $V = 740\,\mu m^3$ and $E_t = 3.9\,MeV$. These quantities are the characteristics of a memory cell. Now one knows the volume of a memory cell and threshold energy depositing of which in that volume leads to the upset and can forecast the behaviour of memories irradiated by different projectiles.

The developed model of SEU does not contain any special information about the technology of manufacture or feeding parameters of the memory devices with the exception of common information on atomic number and density of a cell matter, its stopping power etc. Parameters of the model are to be determined on the base of experimental data and then might be used for the forecast of the behaviour of memory devices in the other conditions of irradiation. Hence the model has a universal character and can be used for the description of the behaviour of different man-made and natural systems consisting of a large number of functional elements of small dimensions ($l \sim 10\,\mu m$) and corresponding characteristic energy ($E \sim 10^{-12}\,J$).

References

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