CMOS INTEGRATED CIRCUITS TOTAL DOSE FUNCTIONAL UPSET SENSITIVITY TO OPERATION MODE

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Abstract

Both simulation and experimental research of CMOS ICs total dose upsets must take into account the operation modes of IC. Techniques are presented to determine the irradiation and test operation modes of CMOS ICs. Test and simulation results illustrate the specifics of operation mode influence on total dose upsets.

1. INTRODUCTION

CMOS ICs are widely used in LHC electronics and are often irradiated by gamma and neutrons. Total dose degradation of MOS transistors parameters under such irradiation results in both parametrical (supply current, output voltages and currents, leakage current etc.) and functional upsets of ICs. For digital LSI the functional upsets are often of primary interest.

Both radiation tests and calculating simulation can be used for total dose functional upsets of digital CMOS ICs investigation; and in both cases one must take into account the dependence of element dose degradation on operation mode under irradiation. It is well known that CMOS element is most vulnerable for total dose when logical "1" is applied to its input and n-channel transistor is turned on. In the same time the element total dose upset is characterized by output logical "1" degradation because of threshold voltage shift of the MOS transistors. Any CMOS logical element inverts input signal, that is why we can conclude that CMOS IC radiation test procedure should use two operation modes for worst case hardness estimation: (1) operation under irradiation and (2) test operation. It is very desirable for IC under test to have as many logical element inversions for these two operation modes as possible. This technique is applicable for numeric simulation as well.

2. EXPERIMENTAL AND NUMERIC SIMULATION TECHNIQUES

The experiments and simulations were carried out to investigate the influence of operation modes on total dose behavior and upset levels.

2.1. Experimental Technique.

Experimental technique we used for total dose investigation is based on the X-ray simulator. The simulation usage possibility and test results adequacy is discussed in many previous papers (see [1] for example). The "REIS-IE" X-ray simulator demonstrates 50 keV maximum energy, about 10 keV average energy and provides up to 1000 rad(Si)/s dose rate.

We used top-side irradiation in both X-ray and laser simulation tests. That is why all the parts were previously delidded.

The computer based test and measurement tools allowed to control a device under test (DUT) during irradiation and to measure its characteristics after irradiation. The basic version of the control system is also presented in [1].

2.2. Numeric Simulation Technique.

For calculating we used the system of functional-logic numeric simulation based on the criterion membership functions (CMF) method of the fuzzy logic sets theory.

Application of the CMF method for total dose functional failures simulation is based on the following principles:

1. The continuous character of processes in IC elements under irradiation brings to the parametrical character of their failures. It claims the transformation of Boolean logic model with set of signals {0,1} to logic model with signals which are belong to the continuous interval [0,1] for analysis of such processes.

2. The influence of irradiation on element is simulated by introduction of an additional CMF input signal $\mu(D)$ which is also within the range [0,1]. The value of this signal depends on the total dose.

3. The Boolean logic functions are transformed to contiguous functions. Thus, the system of Boolean logic equations of IC operation is transformed into the system of fuzzy logic equations.

The system and the simulation method were presented in detail in the last year Workshop [2].

3. NUMERIC SIMULATION DATA AND TEST RESULTS DISCUSSION

We took some simple CMOS ICs (logics, decoder, multiplexer, counter, parity check circuit) and multifunctional buffer VA1 (analogue of CP82C86 by Harris Semiconductor).

Both experimental and simulation results showed that usually there is no total dose upset if irradiation and test operation modes are same. Upsets take place if the modes are different. Some results allow to conclude that the more this difference (number of elements which change state) the lower total dose upset levels.

The experimental data and the numeric simulation results of CMOS multifunctional buffer VA1 are presented in Fig. 1. The output CMF's for two strategies are presented: (a) the test operation mode of the DUT is changed as compared to the irradiation mode and (b) the test mode and the irradiation mode of the DUT are the same.

One can see that there is no total dose upset when the operation mode was not changed for test. Both numeric simulation and experiment demonstrated the total dose failure only when the operation mode of VA1 was changed after irradiation for the test.

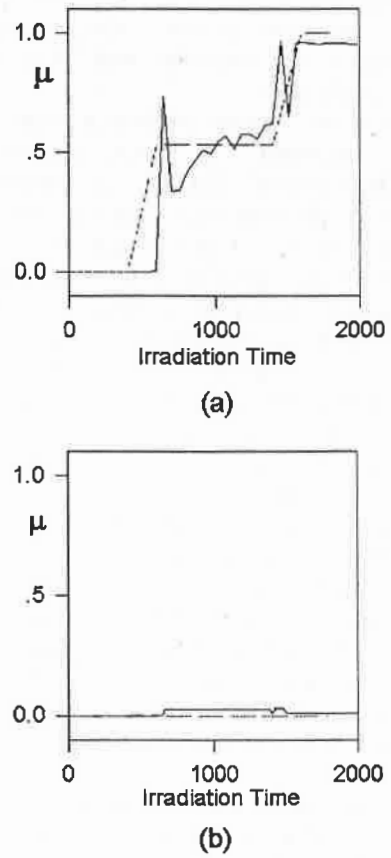

Figure 1. Output CMF's of VA1: a – test operation mode is changed as compared to irradiation mode, b – test mode and irradiation mode are the same.

The operation mode sensitivity of CMOS IC total dose upsets results in some problems in calculations. When an element of IC changes its state during simulating irradiation (because of input signals change or if "a previous" element failured) we have to switch a model of an element into another one. In many cases these moments can not be predicted in advance and we need to add some "intellect" into the calculation strategy.

4. CONCLUSIONS

One should take into account the CMOS ICs total dose upset sensitivity to operation modes in radiation test and simulation task preparation. The technique presented assumes to use two different operation modes - under irradiation and for functional test. This approach is proved to result in sufficient differences of CMOS ICs radiation hardness levels.

REFERENCES

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