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Modelling the Field Soft Error Rate of DRAMs by varying the critical cell charge

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Abstract

The Field Soft Error Rate (FSER) has been determined by the Variation of the critical charge and the measurement of the charge collection volume determined by alpha-particle irradiation. The modelled FSER versus critical charge dependence agrees well to the one of the Field Soft Error measurements. The results futher show, that the irnpact of the on-chip Alpha-Particle flux can be neglected.

1. Introduction

Determining the Field Soft Error Rate of DRAMs is a major problem for manufacturers of memory products. Reliable data can only be gained in the field by the evaluation of large numbers of memory chips. This problem can be avoided by using an Accelerated Field Soft Error Rate test (AFSER) (Fig. 1). The flux of secondary particles of the cosmic radiation is currently modelled by high energy neutrons or protons (Fig. la) and the on-chip alpha-particles are modelled by use of an alpha-particle source (e.g. Thorium) (Fig. 1b).

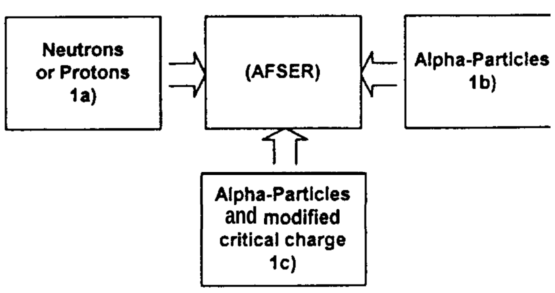

Fig. 1: Accelerated Field Soft Error Rate tests.

To our knowledge, the only reliable cosmic radiation modelling is performed by the use of neutrons or protons [1] at the disadvantage of high cost. Therefore, there is a need to come up with a new, inexpensive and simple method.

2. Modelling the impact of cosmic radiation by varying critical cell-charge

The proposed method (Fig. lc) uses a single energy alpha-particle source and simultaneously a variable dummy-cell- and cell-charge. The Variation of the dummy-cell charge is performed by varying the dummy-cell voltage V_{DC} and the charge of the cells by injection of light (Fig. 2). The measurement setup is shown in Fig. 3.

The purpose is to generate a defmed critical charge Q_c. This charge Q_c is used to determine the Charge-sensitive area of the memory chip by using an extemal alpha-source. The Charge-sensitive area σ is defmed by the ratio of the measured Accelerated Soft Error Rate (ASER) as a function of the critical charge Q_c with respect to the alpha-flux I_α of the alpha-particle Source.

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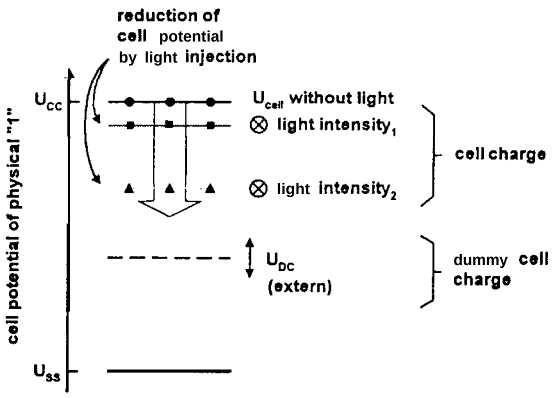

Fig. 2: Variation of the critical charge Q_c.

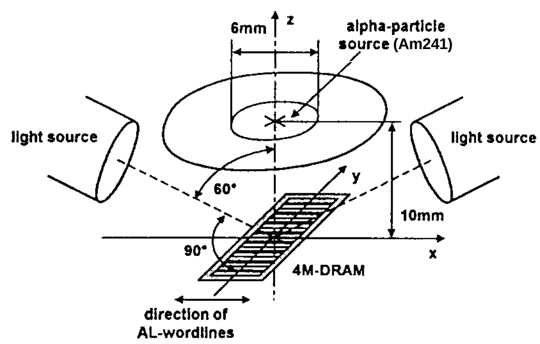

Fig. 3: Measurement setup.

$$\sigma = \frac{\mathrm{ASER}(Q_c)}{I_\alpha} \qquad (1)$$

This sensitive area increases if Q_c is reduced (Fig. 4) and can be described by a Weibull-distribution.

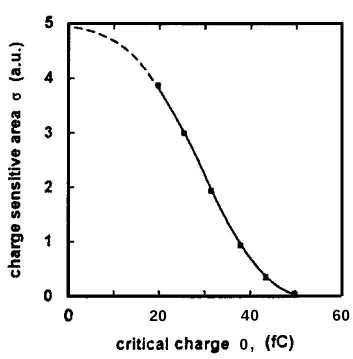

Fig. 4: Charge sensitive area.

Since Q_c is known, the minimum charge collection depth d_{col}^{mi} for the respective sensitive area can be determined by

$$d_{col}^{\min} = \frac{Q_c}{LQT_\alpha} \qquad (2)$$

which includes the linear charge transfer of an alpha-particle $LQT_\alpha \approx 60 \cdot 10^3$ charge carriers per micron. This results in an effective collection volume of

$$V_{col} = \int_0^\infty d_{col}^{min} \cdot \left(\frac{\partial \sigma(d_{col}^{min})}{\partial d_{col}^{min}} \right) \cdot \partial d_{col}^{min} = \int_0^\infty \sigma(d_{col}^{min}) \cdot \partial d_{col}^{min}$$

$$V_{col} = \frac{1}{LQT_\alpha} \cdot \int_0^\infty \sigma(Q_c) \cdot \partial Q_c \qquad (3)$$

Using this volume and the critical charge Q_c under normal Operation conditions the FSER can be calculated by

$$SER = V_{col} \,.\, \mathrm{IBR}(Q_c) \qquad (4)$$

where $\mathrm{IBR}(Q_c)$ is the Integrated Burst Rate, depending on the critical charge Q_c and can be found in Ziegler [2].

3. Modelling the impact of the alpha-particle flux

For evaluating the impact of the on-chip alpha-particles (Fig. 1b), that have there origin in trace amounts of radioactive isotopes (e.g. uran, thorium and other possible contaminations) as well as of bursts of atoms caused by energetic secondary particles of cosmic radiation, samples of each FSER test lot are analysed by alpha irradiation (ASER measurement). Fig. 5 ① shows the measurement results in dependence on the measured critical charge of the samples of the test lots, whereas Fig. 5 ② shows the dependence on the critical charge for a single device.

The contribution of the alpha-particles to the FSER is expected to be proportional to the measured ASER. Therefore a only alpha-particle caused FSER would be expected to change its value for the measured test lots over approximately 4 decades as shown on the right-side scale of Fig. 5.

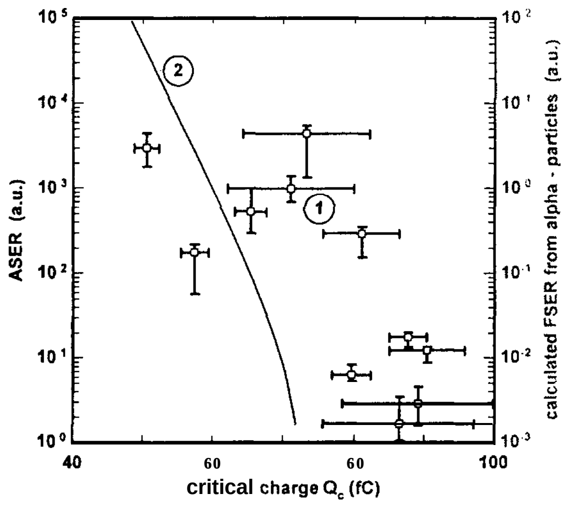

Fig. 5: ASER as function of critical charge.

4. FSER Measurement results

A field test has been performed with 11 lots of 3000 parts each for several weeks in order to determine the FSER. Samples of each lot were analysed by alpha-irradiation (Fig. 5). The results are compared in Fig. 6.

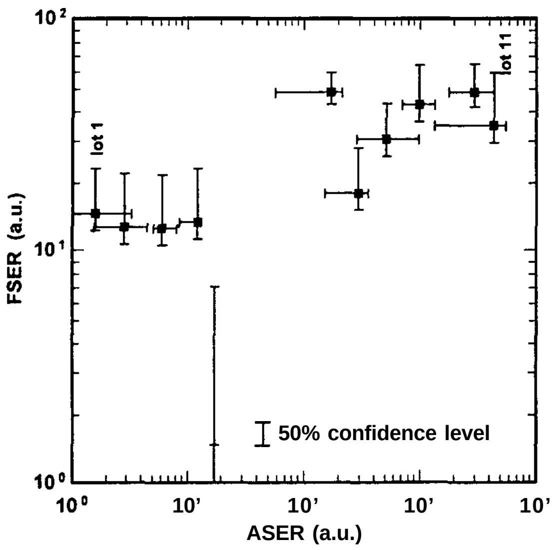

Fig. 6: Correlation between FSER and ASER.

The dots show the conelation between the measured FSER and the measured ASER. This figure shows furthermore a FSER spread of less than one decade whereas the ASER has a spread of approximately 4 decades. This means that the ASER measurement is not a useful model for predicting the FSER.

Therefore the FSER of the lots shown in Fig. 6 has been correlated to the critical charge Q_c (Fig. 7) and is shown as black dots. This result allows the comparison of the modeled FSER (Eq. 4) using the data of the critical charge.

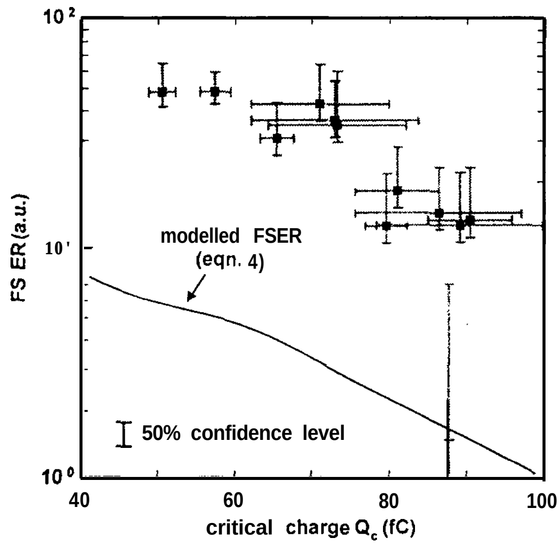

Fig. 7: FSER as a function of critical Charge.

The discrepancy between measurements and theory (Eq. 4) is due to the definition of the burst rate covering only bursts of less than about 200nm in diameter-

A comparison of the FSER results in Fig. 7 with the ASER results in Fig. 5 shows no impact of the alpha-particles on the FSER.

In summary it can be said that the theory derived allows the prediction of the FSER by simply measuring the critical charge and the charge collection volume and by using the point burst rate of [2].

References

[1] J. F. Ziegler, H. P. Muhlfeld, C. J. Montrose, H. W. Curtis, T. J. O'Gorman, J. M. Ross "Accelerated testing for cosmic soft-error rate," IBM J. Res. Develop., vol. 40, no. 1, 1996.

[2] J. F. Ziegler, W. A. Lanford, "The effect of sea level cosmic rays on electronic devices," J. Appl. Phys., 52(6), pp. 4305-43 12, June 198 1.