Soft Error Rate

Summary

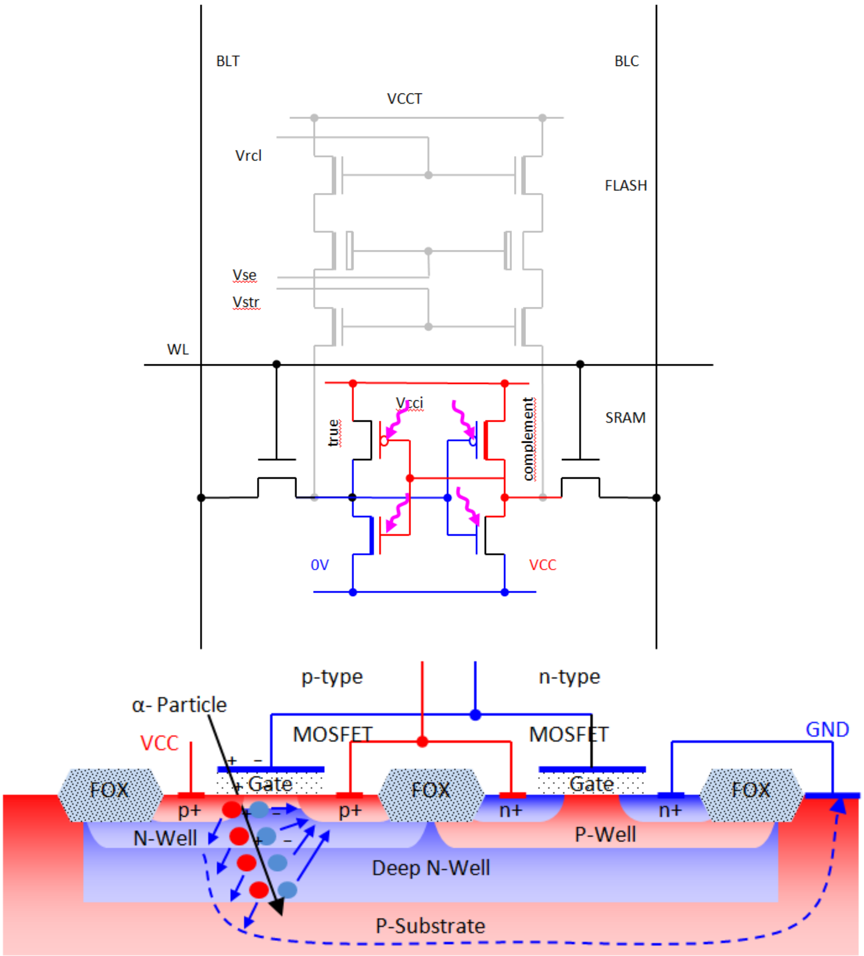
Application Note to inform ANVO Customers about the Soft Error Rate Phenomenon which could potentially occur in our nvSRAMs.

Contents

Introduction

SER Failure Mechanism

Uranium and Thorium impurities found in trace amounts in the various production and packaging materials emit alpha particles. Alpha particles are strongly ionizing, so those that impinge on the active device create bursts of free electron-hole pairs in the silicon. [12]



The holes drift to the substrat and the electrons drift to the nodes. If the current is too high, the SRAM cell may flip. This is called a Soft Error or single-event upset.

The rate at which a device is hit or might be hit by such an event is called Soft Error Rate (SER).

Accellerated SER Assessment

$$SER = \mathrm{N}_{flux} * C_S * \exp\left(\frac{-Q_{critical}}{Q_S}\right)$$

N_{flux} …intensity of the particle flux
C_S …area of the cross section of the node
Q_S …charge collection efficiency
$Q_{critical}$ …necessary charge for a bit flip [9]

Since SER is directly proportional to the particle flux, the flux can be increased to accellerate the measurement.

$$\mathrm{SER}_{(natural)} = \mathrm{N}_{flux(natural)} * Constant$$

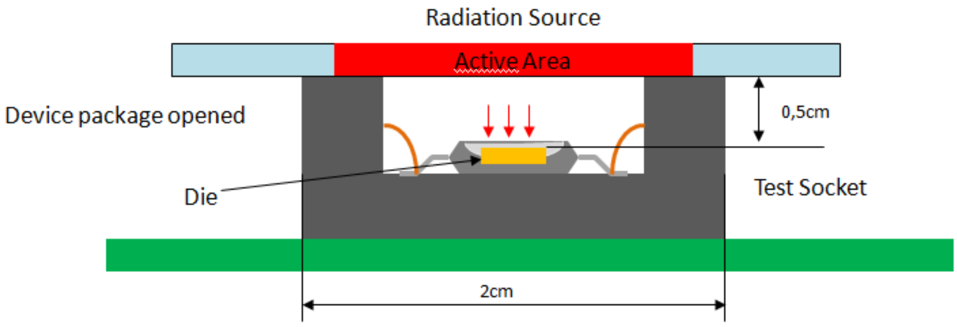
$$\mathrm{SER}_{(accellerated)} = \mathrm{N}_{flux(accellerated)} * Constant$$

$$\frac{\mathrm{SER}_{(natural)}}{\mathrm{N}_{flux(natural)}} = \frac{\mathrm{SER}_{(accellerated)}}{\mathrm{N}_{flux(accellerated)}} = Constant$$

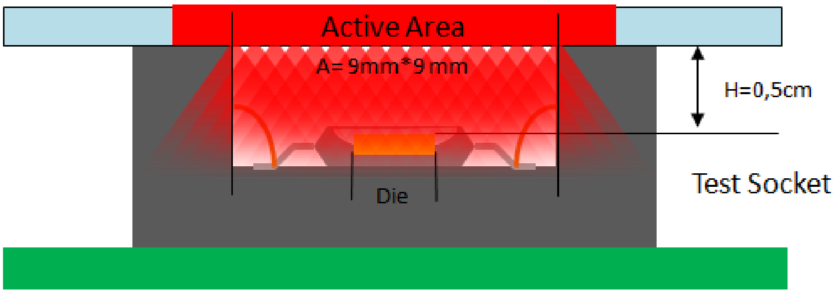
$$\mathrm{SER}_{(natural)} = \mathrm{SER}_{(accellerated)} * \frac{\mathrm{N}_{flux(natural)}}{\mathrm{N}_{flux(accellerated)}}$$

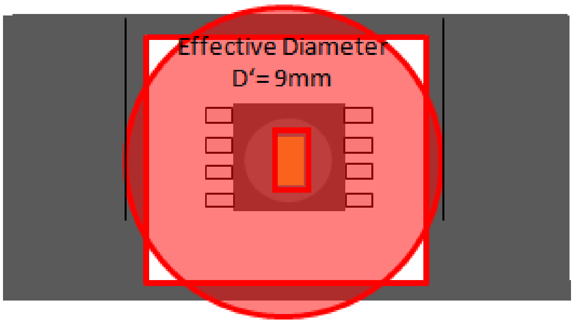
Experiment Set Up

For the measurement a device package has been opened. The distance between active area and die is about 5mm and the active area >> die area so that all corners of incidence are enabled. In this experiment a calibrated Alpha Source with 3720Bq was used. During the entire duration of the experiment the memory was continously monitored to find individual errors quickly.



Accellerated Flux





Not all alpha particles emitted from a specific point of the area (AA) will hit the die. The probability to hit the die decreases with the distance between active area and the inverse of the effective diameter of the active area. According to [13] a raw estimation for the compensation factor can be calculated by:

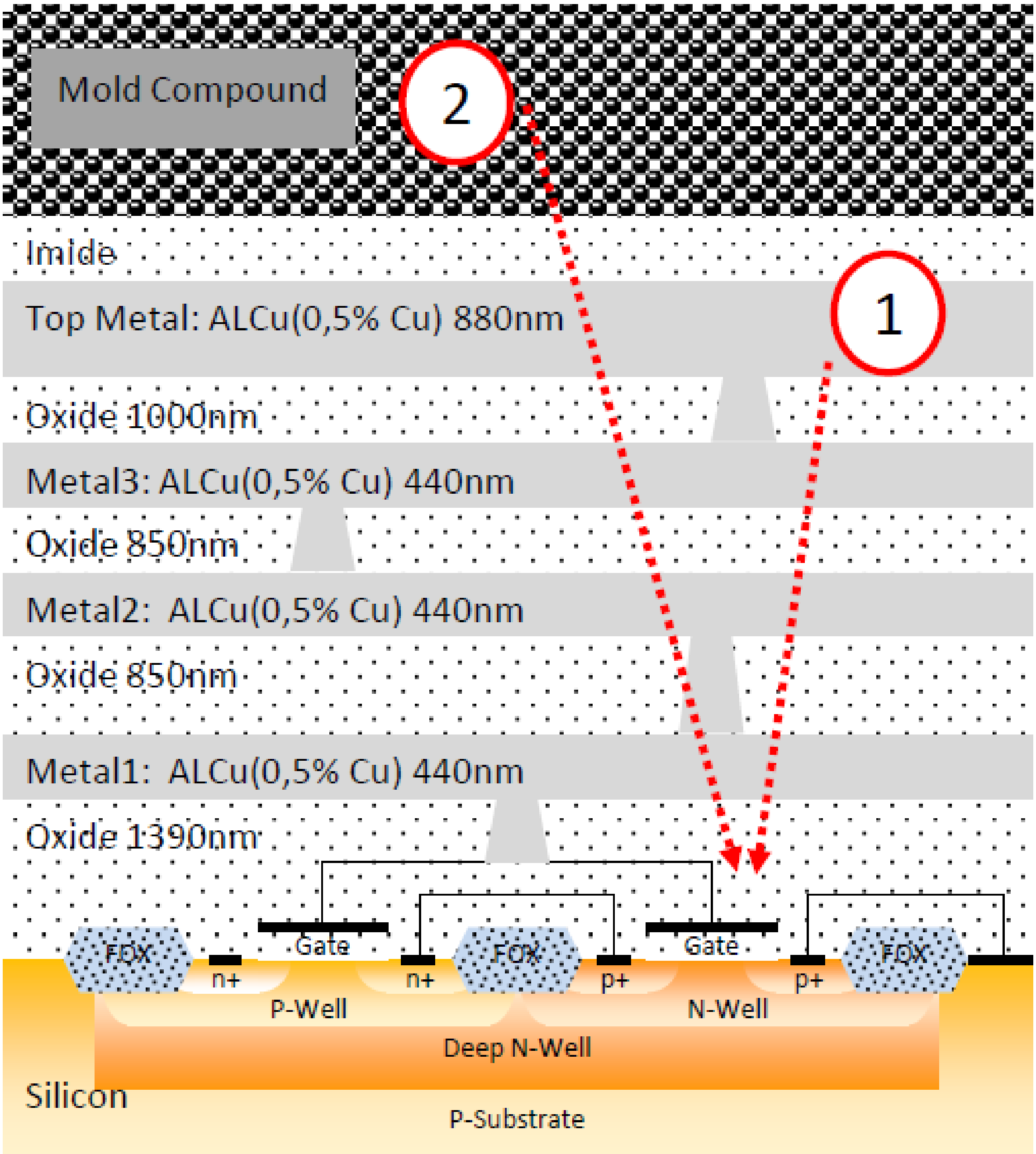
$$Comp = \frac{\mathrm{H}}{\sqrt{\mathrm{H}^2 + (0{,}5 * \mathrm{D}')^2}}$$

In the given testcase the compensation factor is 0,30.

Activity alpha source:	$3720Bq$
Diameter active area:	$5cm$
Active area total:	$19{,}63cm^2$
Distance compensation:	$0{,}30$
Compensated flux (s^{-1}):	$56{,}82cm^{-2}s^{-1}$
Compensated flux (h^{-1}):	$2{,}05 * 10^5cm^{-2}h^{-1}$
Compensated flux (a^{-1}):	$1{,}79 * 10^8cm^{-2}a^{-1} = Nflux_{accellerated}$

Natural Flux

Alpha radiation in packages is caused by natural contamination of the Aluminium used in the metal layers (1) and the filling material of the mold compound (2).



Natural Flux Aluminium

$$\Phi = t_{Alu} \frac{\ln 2}{2} \left(\frac{n_{Th} d_{Th}}{T_{H_{Th}}} + \frac{n_U d_U}{T_{H_U}} \right)$$ [5]

$$t_{Alu} = \text{ 2,2um (all layers stacked and holohedral)}$$ [11]

$$C_U = \text{ 1ppm contamination 238U}$$ [5]

$$C_{Th} = \text{ 1ppm contamination 232Th}$$ [5]

$$d_{Th} = \text{ 6 (daughter conversion factor Thorium)}$$ [5]

$$d_U = \text{ 8 (daughter conversion factor Uranium)}$$ [5]

$$n_U = 6{,}83 * 10^{15} cm^{-3} \text{ (spatial particle density Uranium)}$$ [5]

$$n_{Th} = 7,01 * 10^{15} cm^{-3} \text{ (spatial particle density Thorium)}$$ [5]

$$T_{H_U} = 4,5 * 10^9 a \text{ (half-life period U238)}$$ [5]

$$T_{H_{Th}} = 1,4 * 10^{10} a \text{ (half-life period Thorium232)}$$ [5]

$$\underline{\underline{\Phi = 1160\ cm^{-2} a^{-1}}}$$

Natural Flux Mold Compound

Alpha particle flux of mold compounds

Material	Alpha particles flux ($\alpha cm^{-2} h^{-1}$)	Alpha particles flux ($\alpha cm^{-2} a^{-1}$)	Reference
Standard Mold Compound (1)	0,008 – 0,030	70 – 263	[14]
Standard Mold Compound (2)	0,002 – 0,024	18 – 210	[10]
Low Alpha (LA) Mold Compound	0,0002	2	[10]

For the following calculation a particle flx of $263\ \alpha cm^{-2} a^{-1}$ is used as worst case assumption.

Natural Flux in Package

Alpha particle flux in the whole package contains the flux of the mold compound the flux of the metal layers and also the cosmic rays.

Package (non low alpha mold compound)	$263\ cm^{-2} a^{-1}$
AL Metal 1 – 4	$1160\ cm^{-2} a^{-1}$
Si (cosmic rays induced at sea level)	$1\ cm^{-2} a^{-1}$
B (cosmic rays induced at sea level)	$1\ cm^{-2} a^{-1}$
$\sum = Nflux_{natural}$	$\underline{\underline{1425\ cm^{-2} a^{-1}}}$

Accellerated Measurement Results

In this described test case we used three 256kBit Devices to measure the Soft error Rate.

Device No.	Soft Error	Measurement Time
1	0	2h
2	0	2h
3	0	2h

We found 0 Errors in 6 hours with a accelerated flux of $2{,}05 * 10^5 cm^{-2} h^{-1}$ so that we used the χ^2-methode to get the Soft Error Rate ($\mathrm{SER}_{(natural)}$).

$$SER_{natural} = \frac{10^9 * \chi^2(2\ degrees\ of\ freedom, confidence\ level)}{2 * (total\ device\ hours * acceleration\ factor)}$$

$$total\ device\ hours = 6h$$

$$\chi^2(2\ degrees\ of\ freedom, 95\%) = 5{,}991$$

$$acceleration\ factor = \frac{Nflux_{accellerated}}{Nflux_{natual}} = \frac{1{,}79 * 10^8 cm^{-2} a^{-1}}{1425\ cm^{-2} a^{-1}} = 1{,}26 * 10^6$$

$$SER_{natural} = \frac{396{,}23}{10^9 h} = \frac{3{,}96 * 10^{-7}}{h} = \frac{9{,}50 * 10^{-6}}{d} = \frac{3{,}47 * 10^{-3}}{a}$$

This means there would be 1 Error in ~288 years with an accelerated flux of $1{,}79 * 10^8 cm^{-2} a^{-1}$.

Final Report by JEDEC-Standart JESD89a

DUT Description

1. Sample Size	3
2. Vendor, Part #	Anvo-Systems-Dresden, ANV32C81W
3. Process technology	180nm
4. Circuit	SRAM/SONOS-Flash
5. On-Chip Error correction	None
6. Dimension of the active device area tested	$19{,}63 cm^2$
7. Package	SOP8, etch back of encapsulant

Test Description

8. Test Duration	2h each device, 6h in total
9. Voltage	3,7V
10. Junction and ambient temperature during Test	25°C
11. Static or Dynamic test	Dynamic test, burst read
12. Test Pattern and data pattern, including dead-time calculation	0x55 continuously with, No dead time
13. Test board description	Anvo-Systems Evaluation-Board with engineering Socket

Fail Information

14. Failure count	0, No failure during test

Alpha Source description

15. Source description	AEA Technology/QSA, Inc Model No. AMN-V997, Capsule Type X1
16. Source isotope	AM-241:Be
17. Source activity	$3720Bq\ (1 * 10^{-7}Ci)$
18. Dimension of source active area	$5cm$

Source Setup

19. Source-to-die spacing	$0{,}5cm$
20. Estimate of the alpha flux reaching the active device surface	$56{,}82cm^{-2}s^{-1}$

SER Calculation

21. Soft Error Rate	$\frac{3{,}96 * 10^{-7}}{h}$

References

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[2] *The Programmable Gate Array Data Book. Xilinx Inc. 1991*

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[10] J. Ziegler, Helmut Puchner, “SER – History, Trends and Challenges a Guide for Designing with Memory ICs”, Cypress Semiconductor (2004)

[11] Process Specification XP018, Anvo-Systems Dresden

[12] Measurement and Reporting of Alpha Particle and Terrestrial Cosmic Ray-Induced Soft Errors in Semiconductor Devices JEDEC STANDARD JESD89A

[13] Radiation Results of the SER Test of Actel, Xilinx and Altera FPGA instances - iRoC Technologies, SA 2004

[14] Alpha count for non-alpha compounds, Sumitomo Plastics America, Inc. 2003

Document Revision History

Revision	Date	Summary
1.0	Jan 2014	Initial version
2.0	Aug 2016	New Testcase, larger radiation source, χ^2- calculation

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