SINGLE EVENT EFFECTS
RADIATION TEST REPORT

Part Type : AM29F016D and AM29F032B

16 and 32 Mb FLASH

Manufacturer : AMD

Report Reference : ESA_QCA0211S_C

Issue : 01

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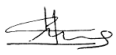
Approved by :	J. F. MOUNES		Date :	December 17th, 2002

Heavy ion SEE characterization of 16 and 32 Mb flash from AMD

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1 Abstract

Under ESA Contract No 13528/99/NL/MV COO-13 dated 11/10/02 covering "Radiation Evaluation of COTS Semiconductor Components: “Radiation evaluation of parts for new VME design ", AM29F016D and AM29F032B flash memories were radiation assessed.

Results from these assessments, primarily focusing on the sensitivity of these devices to Single Event Effects (SEE), are reported in this report.

2 INTRODUCTION

This report presents the results of a Single Event Effects (SEE) test program carried out on AM29F016D and AM29F032B flash memories, from AMD.

Test was conducted on commercial samples delivered by ESA.
These devices were used for heavy ion test at the European Heavy Ion Irradiation Facility (HIF) at Cyclone, Université Catholique de Louvain, Belgium.
This work was performed for ESA/ESTEC under ESA Contract No 13528/99/NL/MV COO-13 dated 11/10/02.

3 REFERENCE DOCUMENTS

RD1. AM29F016D and AM29F032B data sheet
RD2. Single Event Effects Test method and Guidelines ESA/SCC basic specification No 25100
RD3. The Heavy Ion Irradiation Facility at CYCLONE, UCL document, Centre de Recherches du Cyclotron (IEEE NSREC'96, Workshop Record, Indian Wells, California, 1996)

4 DEVICE INFORMATION

4.1 AM29F016D

Relevant device identification information is presented here after.

Part type:	AM29F016D
Manufacturer:	AMD
Package:	40-TSOP
Quality Level:	Commercial
Date Code:	1999
Top Marking:	AM29F016D -70E4C 0121FPA H 1999 AMD
Die Size:	5.2 mm x 4.8 mm approximately
Die marking	FUJITSU M AMD 98J32A 1999
Serial number	SN03-1, SN03-2 (attributed by Hirex)

Die identification is provided in Figure 1.
16 Megabit (2 M x 8-Bit), CMOS 5.0 Volt-only, Uniform Sector Flash Memory (32 uniform sectors of 64 Kbytes each), 0.23 µm process technology.

4.2 AM29F032B

Relevant device identification information is presented here after.

Part type:	AM29F032B
Manufacturer:	AMD
Package:	40-TSOP
Quality Level:	Commercial
Date Code:	1998
Top Marking:	AM29F032B -90E| 0228MBM H 1998 AMD
Die Size:	10.7 mm x 6.4 mm approximately
Die marking	AMD FUJITSU 98325A
Serial number	SN02-1, SN02-2 (attributed by Hirex)

Die identification is provided in Figure 2.
32 Megabit (4 M x 8-Bit), CMOS 5.0 Volt-only, Uniform Sector Flash Memory (64 uniform sectors of 64 Kbytes each), 0.32 µm process technology.

4.3 Sample preparation

2 samples per type were chemically opened using a jet etch machine.

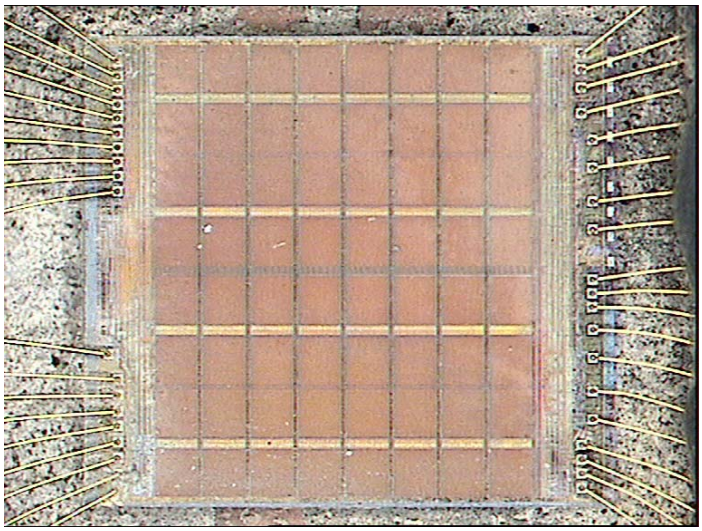

Photo 1

Die, full view

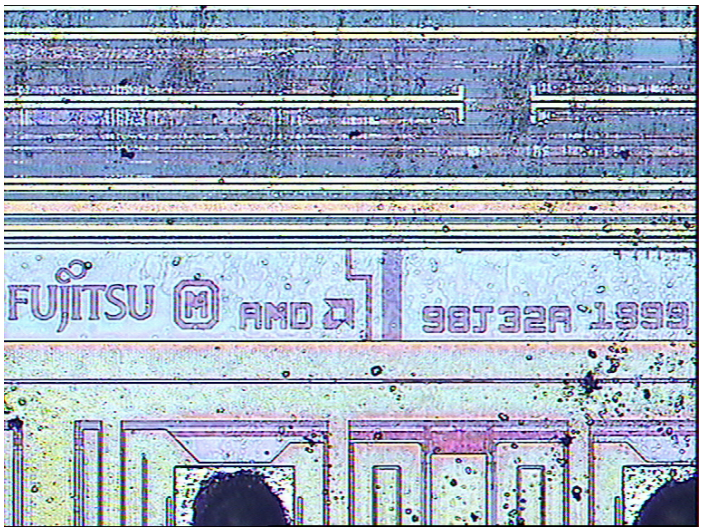

Photo 2

Die marking

Figure 1 - AM29F016D die identification

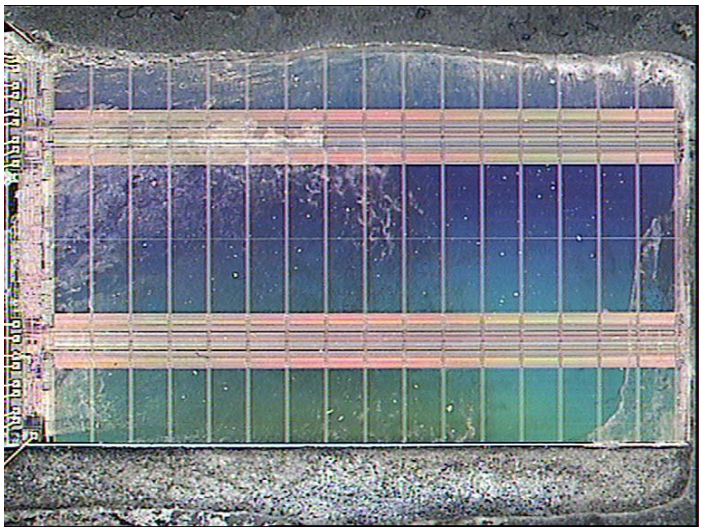

Photo 3

Die, full view

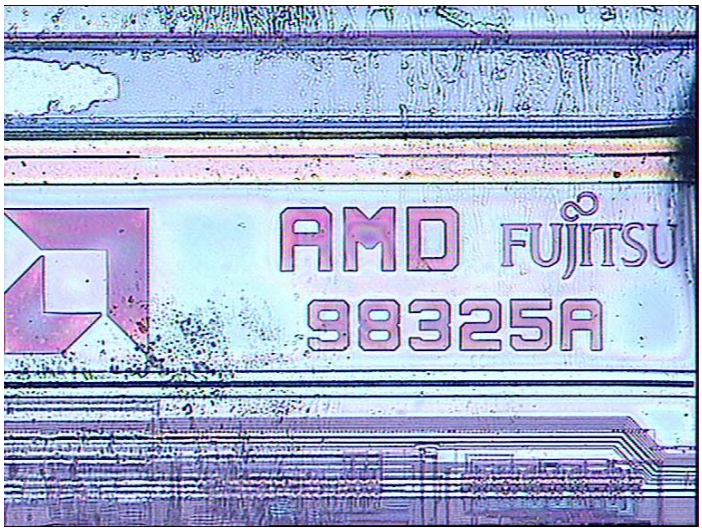

Photo 4

Die marking

Figure 2 - AM29F032B die identification

5 Test Definition

5.1 Test Set-up

Hirex test equipment is composed of a modular rack coupled with a generic memory test board:

This modular rack is derived from iTest BILT modular instrumentation system and presents 8 slots for modular instruments.
In addition to the existing power supply modules which cover the SEE test needs for precision measurements, remote control, LU detection, data storage, scope observation, etc, a specific modular board has been designed to provide:

- A high speed communication link with the test board under vacuum (up to 500 ko/s)
- Particle and test time counting

Dedicated to the test of memories, the generic test board is based on a 12 MIPs on-board processor which controls the test sequence and the communication with the rack.
The board includes programmable logic circuits with a total capacity of 30000cells and 960 macrocells. This logic circuitry can work at high speed (up to 100 MHz) while being compatible with thermal requirements imposed by vacuum environment.
Today, the board has a capacity of 80 pin-drivers, using transceivers able to interface memory devices with voltage supply requirements between 1 and 7 volts. The DUT can have two different power supplies.

5.2 Test Configuration

Two basic configurations were used:

FULL STATIC ON (FSO) TEST MODE:

1. Device initialization.
2. Write the test pattern in the memory and perform a read to check eventual stuck bits, off beam.
3. Expose the device to the beam for a given time.
4. Read the memory off beam and count the errors. (manual command)

CONTINUOUS READ (C/R) TEST MODE:

1. Device initialization
2. Write the test pattern in the memory and make a read to detect eventual stuck bits.
3. Expose the device to the beam for a given time and perform continuous-read sequences. At each sequence, an offset is done on the test pattern and the number of errors is cumulated.
4. Perform an hardware reset
5. Loop with step 2, etc…

The table here below provides, for each group of 4 bits, the 14 words repetitive pattern.

	It k	It k+1	It k+2	It k+3	It k+4	It k+5	It k+6	It k+7	It k+8	It k+9	It k+10	It k+11	It k+12	It k+13	It k+14
address n	0000	1111	0101	0101	0110	1010	1001	0000	1111	1010	0101	0110	1010	1001	0000
address n+1	1010	1001	0000	1111	1010	0101	0110	1010	1001	0000	1111	0101	0101	0110	1010
address n+2	0101	0110	1010	1001	0000	1111	0101	0101	0110	1010	1001	0000	1111	1010	0101
address n+3	1111	0101	0101	0110	1010	1001	0000	1111	1010	0101	0110	1010	1001	0000	1111
address n+4	1001	0000	1111	1010	0101	0110	1010	1001	0000	1111	0101	0101	0110	1010	1001
address n+5	0110	1010	1001	0000	1111	0101	0101	0110	1010	1001	0000	1111	1010	0101	0110
address n+6	0101	0101	0110	1010	1001	0000	1111	1010	0101	0110	1010	1001	0000	1111	0101
address n+7	0000	1111	1010	0101	0110	1010	1001	0000	1111	0101	0101	0110	1010	1001	0000
address n+8	1010	1001	0000	1111	0101	0101	0110	1010	1001	0000	1111	1010	0101	0110	1010
address n+9	0101	0110	1010	1001	0000	1111	1010	0101	0110	1010	1001	0000	1111	0101	0101
address n+10	1111	1010	0101	0110	1010	1001	0000	1111	0101	0101	0110	1010	1001	0000	1111
address n+11	1001	0000	1111	0101	0101	0110	1010	1001	0000	1111	1010	0101	0110	1010	1001
address n+12	0110	1010	1001	0000	1111	1010	0101	0110	1010	1001	0000	1111	0101	0101	0110
address n+13	1010	0101	0110	1010	1001	0000	1111	0101	0101	0110	1010	1001	0000	1111	1010
address n+14	0000	1111	0101	0101	0110	1010	1001	0000	1111	1010	0101	0110	1010	1001	0000

Table 1 – Test pattern

Errors which can be detected and counted are the following:

- Any single error in the memory block with identification of the transition (1->0 or 0->1)
- Any word with at least one bit flip with the identification of the word address

DUT power supply module is monitored and each time the current consumption exceeds a programmable threshold, a power reset cycle is done and latch-up error counter is incremented.

In addition the use of fast latch-up detection with a high speed comparator avoids the counting of errors which could be induced by the latch-up condition.

DUT power supply is 5V.

6 TEST FACILITIES

Test at the cyclotron accelerator was performed at Université de Louvain (UCL) in Louvain-La-Neuve (Belgium) under HIREX Engineering responsibility.

6.1 Beam Source

In collaboration with the European Space Agency (ESA), the needed equipment for single events studies using heavy ions was built and installed on the HIF beam line in the experimental hall of Louvain-La-Neuve cyclotron.
CYCLONE is a multi particle, variable energy, cyclotron capable of accelerating protons (up to 75 MeV), alpha particles and heavy ions. For the heavy ions, the covered energy range is between 0.6 MeV/AMU and 27.5 MeV/AMU. For these ions, the maximal energy can be determined by the formula:

$$110\ Q^2/M,$$

where Q is the ion charge state, and M is the mass in Atomic Mass Units.

The heavy ions are produced in a double stage Electron Cyclotron Resonance (ECR) source. Such a source allows producing highly charged ions and ion "cocktails". These are composed of ions with the same or very close M/Q ratios. The cocktail ions are injected in the cyclotron, accelerated at the same time and extracted separately by a fine tuning of the magnetic field or a slight changing of the RF frequency. This method is very convenient for a quick change of ion (in a few minutes) which is equivalent to a LET variation.

6.2 Beam Set-up

6.2.1 Ion Beam Selection

The LET range was obtained by changing the ion species and incident energy and changing the angle of incidence between the beam and the chip.
For each run, information is provided on the beam characteristics in the detailed results table in paragraph 7.

6.2.2 Flux Range

For each run, the averaged flux value is provided in the detailed results table of paragraph 7.

6.2.3 Particle Fluence Levels

Maximum fluence level was set to 1 E6 ions/cm²

6.2.4 Dosimetry

The current UCL Cyclotron dosimetry system and procedures were used.

6.2.5 Accumulated Total Dose

For each run, the equivalent cumulated doses received by the DUT sample is computed.

6.2.6 Test Temperature

Tests have been performed at 22 deg. C.

6.3 Available ions

The most commonly used ions at the UCL HIF facility are listed along with some of their features in the table here below:

Ion Specie	Energy	LET	Range
	(MeV)	(MeV.cm²/mg)	µm
10-B	41	1.7	80
20-Ne	78	5.85	45
40-Ar	150	14.1	42
84-Kr	316	34	43

Table 2 – HIF ions

The use of a tilt angle allows intermediate effective LETs.

7 RESULTS

The detailed results per run are presented in Table 3 for AM29F016D and in Table 4 for AM29F032B.
Each run is commented in detail in the two tables

Very few Read SEUs (i;e. observed only at one read cycle), have been observed for both devices
The first SEU was observed at a LET of 11.7 for AM29F016D and at a LET of 14 for AM29F032B.

Both devices have been found to exhibit stuck bits, more with the 32M-bit than with the 16M-bit. These stuck bits are not cured by a reset or by an off/on cycle. The device needs to be reprogrammed to get the stuck bits cured.
First stuck bit for AM29F016D was observed at a LET of 19.8 and at a LET of 11.7 for AM29F032B.

Sample 02-1 may have been affected by a shadowing problem on the DUT control logic area when tilting the device, caused by the DUT opening window dimensions

Lastly, both devices experienced SEFIs (Single Event Functional Interrupt), first SEFI for AM29F016D at a LET of 19.8 and at a LET of 11.7 for AM29F032B.
These SEFIs could be quite severe (more than 20 sectors in error). For both devices, one SEFI put the device in programming mode. The error was cured only by reprogramming the DUT (after a reset and an off/on cycle, the samples were still in error).

Run #	Part type	S/N	Test mode	Ion	Energy (MeV)	LET (MeV.cm²/mg)	Angle (°)	Eff. LET (MeV.cm²/mg)	Flux (/s/cm²)	Time (s)	Fluence (/cm²)	SEU	SEFI	Comments
48	AMD-16	03_1	FSO	Ne	78	5,85	0	5,85	8849,56	113	1,00E+06	0	0	No event
49	AMD-16	03_1	C/R	Ne	78	5,85	0	5,85	9009,01	111	1,00E+06	0	0	No event
50	AMD-16	03_1	FSO	Ne	78	5,85	60	11,70	4115,23	243	1,00E+06	0	0	No event
51	AMD-16	03_1	C/R	Ne	78	5,85	60	11,70	3921,57	255	1,00E+06	1	0	Read upset
36	AMD-16	03_1	FSO	Ar	150	14	0	14,00	5813,95	172	1,00E+06	1	0	1 stuck bit - (last word) - after rewrite DUT OK
37	AMD-16	03_1	C/R	Ar	150	14	0	14,00	7092,21	141	1,00E+06	2	0	2 Read SEU
38	AMD-16	03_1	FSO	Ar	150	14	45	19,80	4975,12	201	1,00E+06	0	0	No event
39	AMD-16	03_1	C/R	Ar	150	14	45	19,80	4950,50	202	1,00E+06	2	0	2 read SEU
40	AMD-16	03_1	FSO	Ar	150	14	60	28,00	3424,66	292	1,00E+06	0	0	No event
41	AMD-16	03_1	C/R	Ar	150	14	60	28,00	3152,44	164	5,17E+05	0	1	1read SEU + 1 SEFI - after reset still not OK - after w/r recovered
52	AMD-16	03_2	FSO	Ne	78	5,85	60	11,70	3984,07	251	1,00E+06	0	0	No event
53	AMD-16	03_2	C/R	Ne	78	5,85	60	11,70	4065,05	246	1,00E+06	0	0	No event
42	AMD-16	03_2	FSO	Ar	150	14	0	14,00	7092,20	141	1,00E+06	0	0	No event
43	AMD-16	03_2	C/R	Ar	150	14	0	14,00	6666,67	150	1,00E+06	3	0	3 Read SEU
44	AMD-16	03_2	FSO	Ar	150	14	45	19,80	3952,58	253	1,00E+06	0	1	Functional event - 28 blocks to 00. permanent - reset, off/on, still not OK - after rewrite: DUT OK
45	AMD-16	03_2	C/R	Ar	150	14	45	19,80	3508,78	285	1,00E+06	5	0	5 real read SEU
46	AMD-16	03_2	FSO	Ar	150	14	60	28,00	2336,45	428	1,00E+06	0	1	1 BIG SEFI
47	AMD-16	03_2	C/R	Ar	150	14	60	28,00	3649,64	274	1,00E+06	3	3	3 Read SEU

Table 3 - Heavy ion detailed results per run for AM29F016D

Run #	Part type	S/N	Test mode	Ion	Energy (MeV)	LET (MeV.cm²/mg)	Angle (°)	Eff. LET (MeV.cm²/mg)	Flux (/s/cm²)	Time (s)	Fluence (/cm²)	SEU	SEFI	Comments
54	AMD-32	02_1	FSO	Ne	78	5,85	0	5,85	7246,38	138	1,00E+06	0	0	No event
55	AMD-32	02_1	C/R	Ne	78	5,85	0	5,85	6802,73	147	1,00E+06	0	0	No event
24	AMD-32	02_1	FSO	Ar	150	14	0	14,00	7092,20	141	1,00E+06	1	0	1 permanent SEU error at address 0xFF - 8 bits all 1 -> 0 - after write/read DUT OK
25	AMD-32	02_1	C/R	Ar	150	14	0	14,00	5882,35	170	1,00E+06	30	2	30 upsets =1 stuck word observed at each read cycle + 2 SEFI - no problem to recover after reset - after reset and power off : stuck word still present
26	AMD-32	02_1	FSO	Ar	150	14	45	19,80	3816,79	262	1,00E+06	0	0	No event
27	AMD-32	02_1	C/R	Ar	150	14	45	19,80	4587,16	218	1,00E+06	0	0	No event
28	AMD-32	02_1	FSO	Ar	150	14	60	28,00	3164,56	316	1,00E+06	0	0	No event, possible beam shadowing problem on the DUT control logic area when tilting to 60 deg.
29	AMD-32	02_1	C/R	Ar	150	14	60	28,00	3344,48	299	1,00E+06	1	0	1SEU event, possible beam shadowing problem on the DUT control logic area when tilting to 60 deg.
56	AMD-32	02_2	FSO	Ne	78	5,85	0	5,85	8130,10	123	1,00E+06	0	0	No event
57	AMD-32	02_2	C/R	Ne	78	5,85	0	5,85	9009,04	111	1,00E+06	0	0	No event
58	AMD-32	02_2	FSO	Ne	78	5,85	60	11,70	4032,27	248	1,00E+06	0	1	1 SEFI - and 1 stuck word (at the end of the memory) - after reset : all OK
59	AMD-32	02_2	C/R	Ne	78	5,85	60	11,70	4000,02	250	1,00E+06	0	0	No event
30	AMD-32	02_2	FSO	Ar	150	14	0	14,00	7751,94	129	1,00E+06	0	1	1 SEFI - 1 block is at 44 - reset, then everything OK - 1 stuck bit at address 0xFF - after re-write all OK
31	AMD-32	02_2	C/R	Ar	150	14	0	14,00	6896,55	145	1,00E+06	0	3	2 Read SEU, 3 SEFI - 1 stuck bit
32	AMD-32	02_2	FSO	Ar	150	14	45	19,80	4545,45	220	1,00E+06	0	0	1 SEU
33	AMD-32	02_2	C/R	Ar	150	14	45	19,80	6134,98	163	1,00E+06	26	2	(26 upset = 1 stuck word), 1 SEFI (1 block) - then 1 permanent SEFI - last SEFI -> prog. mode, "release" OK read mode but 18 block to 00 - power off/on still the same - after rewrite, DUT OK
34	AMD-32	02_2	FSO	Ar	150	14	60	28,00	3048,78	328	1,00E+06	0	1	1 big SEFI (24 blocks)- after reset, DUT OK
35	AMD-32	02_2	C/R	Ar	150	14	60	28,00	2645,51	378	1,00E+06	1	2	1 Read SEU + 2 SEFI

Table 4 - Heavy ion detailed results per run for AM29F032B

8 CONCLUSION

Heavy ion tests were conducted on commercial samples of AM29F016D and AM29F032B flash memories from AMD, using the heavy ions available at the European Heavy Ion Irradiation Facility (HIF) at Cyclone, Université Catholique de Louvain, Belgium.

Both device types were tested up to a LET of 28 MeV/mg/cm² (Argon at 60 deg.)

Very few Read SEUs and stuck bits have been observed during these tests.

However, severe and persistent SEFI were observed on the tested devices. A power reset did not cure the SEFI error and the device need to be reprogrammed. The 32 Mb device turned out to be slightly more sensitive than the 16 Mb.