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EUROPEAN SPACE AGENCY
CONTRACT REPORT

ESA/ESTEC Contract No. 11755/95/NL/NB-WO1/CO1

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Title

AM29(LV/F)800B-120, 8 MBIT FLASH (AMD)

HEAVY ION & PROTON SEE CHARACTERIZATION TEST REPORT

Summary :

Low Voltage memories were tested under heavy ion and proton irradiation, in order to study the effect of supply voltage on the SEE sensitivity. This report presents the results obtained on AMD 8 Mbit Flash memories.

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Document type	Nb WBS	Keywords :

SUMMARY

Test sample characteristics :

Part Names :	1/ AM29F800B-120 2/ AM29LV800B-120	Function :	8 Mbit Flash memory
Technology :	CMOS	Package :	44 Pin SO
Manufacturer :	AMD	Location :	USA
Sample size :	1/ 2 parts (5V) 2/ 5 parts (3.3V)	Date Code :	1/ 9620 (5V) 2/ 9625 (3.3V)

Heavy ion results

The following tables summarize the Heavy ion SEU test results:

SINGLE EVENT PERMANENT UPSET RESULTS SYNTHESIS		
	LET Threshold ($MeV.cm^2/mg$)	Cross-section (cm^2/bit) at LET=34 $MeV.cm^2/mg$
AM29LV800B-120	>34	no event
AM29F800B-120	>34	no event

SINGLE EVENT SINGLE TRANSIENT ERROR RESULTS SYNTHESIS		
	LET Threshold ($MeV.cm^2/mg$)	Cross-section (cm^2/bit) at LET=34 $MeV.cm^2/mg$
AM29LV800B-120	≤5.85	<3e-12 (estimated)
AM29F800B-120	>34	<3e-12 (no error)

SINGLE EVENT MULTIPLE TRANSIENT ERROR RESULTS SYNTHESIS		
	LET Threshold ($MeV.cm^2/mg$)	Cross-section (cm^2/dev) at LET=34 $MeV.cm^2/mg$
AM29LV800B-120	10<LETth<14.1	<2e-05
AM29F800B-120	not evaluated	<2.5e-06

Heavy ion test conclusion :

The results of these experiments demonstrate that 8 Mbit FLASH AM29(LV)800B-120 from AMD (Low Voltage devices) are not sensitive to heavy ion induced SEU (permanent loss of content). Transient single or multiple errors are observed. The threshold LET is ≤ 5.85 MeV.cm²/mg for single transients, and between 10 and 14.1 MeV.cm²/mg for multiple transients. The sensitivity of 5V, 8 Mbit FLASH AM29(F)800B-120 from AMD is lower : only multiple transient errors were observed, with lower cross sections. Due to low statistic and limited number of tests, we cannot conclude on the single transient sensitivity above 5.85 MeV.cm²/mg.

Additional heavy ion results :

Both devices exhibited no heavy ion induced Latch-up sensitivity, up to a LET of 34 MeV.cm²/mg.

Proton results

The following table summarizes the proton SEE test results:

	Ep Threshold (MeV)	**Saturated Cross-section (cm²/bit)**
AM29LV800B-120	>60	<3e-17 (no error)
AM29F800B-120	not evaluated	not evaluated

Proton conclusion :

The results of these experiments demonstrate that 8 Mbit FLASH AM29(LV)800B-120 from AMD are not sensitive to proton induced SEU or transients, up to a proton energy of 60 MeV. Consequently, no tests were performed on 8 Mbit FLASH AM29(F)800B-120, which sensitivity is expected to be lower.

Additional proton results:

These devices also exhibited no Latch-up sensitivity, up to a proton energy of 60 MeV.

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1. INTRODUCTION

The aim of this work is to investigate radiation effects in low and standard voltage technologies. The study is focused on memory devices, which require lower voltage to achieve higher integration. Parts selected concern SRAM (1 Mbit, 2 types), DRAM (16 Mbit, 2 types), and FLASH memories (8 Mbit, 1 type).

The object of this document is to describe the irradiations performed on the AMD 8 Mbit Flash AM29(LV/F)800B-120 (low voltage device), in order to measure their sensitivity to heavy ion and proton induced SEU. Results are compared with the 5V version (AM29(F)800B-120).

Irradiation was performed in November/December 1996 (30th-1st) according to the procedures referenced in the following paragraph.

This work was performed in the frame of the WO1/CO1 for ESTEC Contract n°11755/95/NL/NB.

2. REFERENCE DOCUMENTS

[1] ESA/SCC Basic Specification 25100

[2] AMD Manufacturer Data Sheet

[3] "Radiation Pre-screening Programme On Low Voltage Memories For ESA/ESTEC Contract N°11755/95/NL/NB" MMS Contract WP1 Report Ref. DOF/DEC/TP6.577.

[4] ESA-ESTEC report No. 1859

[5] "The Heavy Ion Irradiation Facility at CYCLONE-a dedicated SEE beam line", G. Berger. G. Ryckewaert, R. Harboe-Sorensen, L. Adams, 1996 IEEE Radiation Effects Data Workshop

[6] "Testeur de mémoire haute densité", D. Winkel, TSEU-MAV-PE-000 (MMS report)

[7]Radiation data trends on high integrated memories for ESTEC Contract N°11755/95/NL/NB, Bruno Doucin (MMS report, ref DOF/GER/NT6.612)

[8] Statement of work- QCA/RHS-CDS1.WP-MAR.'95, Issue 1, "Call-Off Order 1, Study and radiation testing of Low voltage Technologies".

3. PART DETAILS

3.1. DEVICE IDENTIFICATION

3.1.1. References

Type : AM29(LV/F)800B-120
Manufacturer : AMD
Place : USA
Packaging : 44 pin SO

3.1.2. Function

1M x 8 bit Flash memory

3.1.3. Technology

CMOS, 0.5 µm (See next page for further details)

3.1.4. Part Procurement

Origin	:	procurement performed by VTT Automation, Finland
Level	:	Standard Level
Temperature range	:	0°C, +70°C (Commercial)
Date code	:	9625 (LV), 9620 (F)
Screening	:	/.
Sample size	:	5(LV), 2 (F)
Manufacturer Marking	:	AM29LV800B-120SC, 9620FGA, 1996 AMD (Low Voltage)
		AM29F800B-120SC 9625CGA L, 1996 AMD (5 V)
Detailed specifications	:	Manufacturer Data sheet,

3.1.5. Previous SEE details/history

No specific radiation data on these devices.

AMD 128K x 8 Flash EPROM (AM29F010-120JC 341JYJT, 1991) was tested to heavy ion (ESA-ESTEC report No. 1859, [4]), and lost its content at LET of 37.5 and 11.7 MeV.cm²/mg. The flash worked well at 6.9 MeV.cm²/mg. The device is not sensitive to single transient errors up to at least 37.5 MeV.cm²/mg.

During this campaign, proton tests were performed prior to heavy ion tests, samples irradiated with heavy ions are different from samples irradiated with protons.

3.2. TECHNICAL INFORMATION

General information

Name	AMD AM29(F/LV)800B-120
Die/package Mark	AM29F800B-120SC, 9620FGA, 1996 AMD AM29LV800B-120SC, 9625CGA L, 1996 AMD
Access time/ns at 5V	120
Temperature range/°C	0, +70
Organisation	1M x 8 Bit
Supply Voltage/V	4.5-5.5/2.7-3.6

Technology

Name	AMD AM29(F/LV)800B-120
CMOS	yes
Epitaxial layer	*
Architecture	*
Design rules	CS29AF (0.5 µm)
Die size	5 mm x 10 mm (LV) 4.95 x 10.5mm (F)
Cell size	*

* The missing information was unsuccessfully required to the manufacturer.

A photography of the die is given in the annex.

4. TEST DESCRIPTION

4.1. IRRADIATION FACILITY

Name : Louvain-La-Neuve Cyclotron

Location : Université Catholique de Louvain
Centre de Recherches du Cyclotron
Chemin du Cyclotron, 2, 1348,
Louvain-La-Neuve, Belgium

4.1.1. Beams currently available

A cocktail of heavy ions can be provided, allowing quick (in a few minutes) changes of ion species. The characteristics of the associated LET are reported in table 1 (**X** in the last column refers to the type of ions used during this campaign) :

Ion	Energy (MeV)	Range [µm Si]	LET (MeV.cm²/mg)	Beam used
^{84}Kr	316	43	34	X
^{40}Ar	150	42	14.1	X
^{20}Ne	78	45	5.85	X
^{15}N	62	64	2.97	
^{10}B	41	80	1.7	X
^{132}Xe	459	43	55.9	

Table 1 Cocktail 1 that can be provided by LLN cyclotron.

- By varying the ion species and angle of incidence, the error Cross-section (σ) can be determined as a function of LET. A controlled flux between 10 and 10^5 (part./cm²)/s is used for heavy ions tests. A complete presentation of the Cyclone Facility SEE beam line is presented in ref [5].

4.1.2. Proton energies available

- Proton energies available at the LLN cyclotron are ranging from 10 to 60 MeV. Low energies are obtained by degrading the 60 MeV beam. For these tests, 2e+07 to 1e+08 (part./cm²)/s proton fluxes were used.

4.2. TEST SET UP DESCRIPTION

4.2.1. Heavy ion test set-up

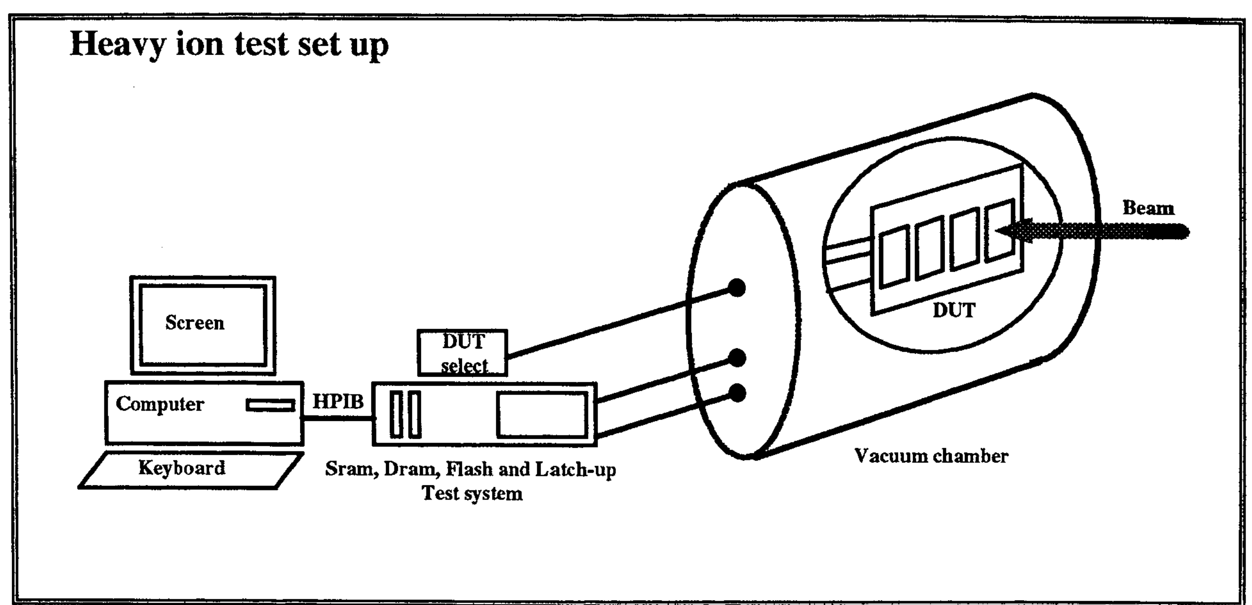


Fig. 1 Description of the heavy ion test set-up.

Comments :

The DUT are mounted on 4 zero-insertion-force sockets. Due to the low heavy ion penetration, parts were delidded for the heavy ion tests.

The tested device is selected by a switching commuter, located outside of the vacuum chamber.

The supply voltage is provided by the memory tester. The memory tester is also located outside of the vacuum chamber. The maximum frequency (Fmax) for tests is 0.83 MHz for EEPROMs. This frequency can be divided by 2, 4, or 8. The maximum SEU rate is 415000 SEU/s (errors are systematically counted and recorded with the corresponding address).

The tester also includes a delatcher. The Latch-up detection threshold is programmable (≈20 mA). The cut-off time is of 10 ms.

A complete description of the memory tester is given in [6].

4.2.2. Proton test set-up

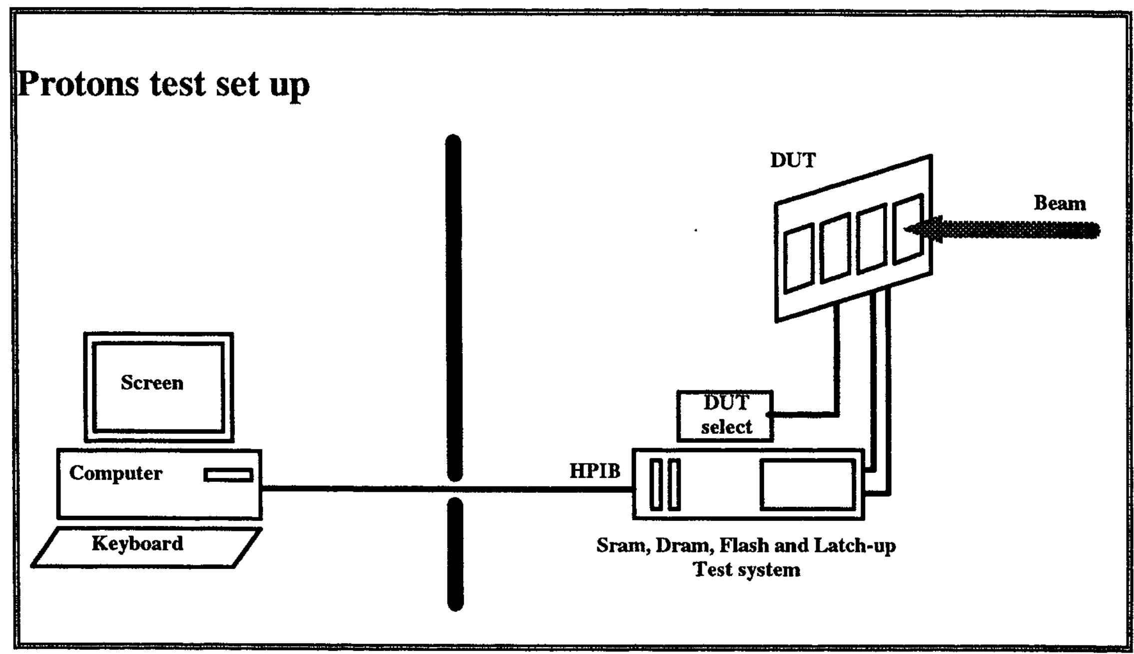
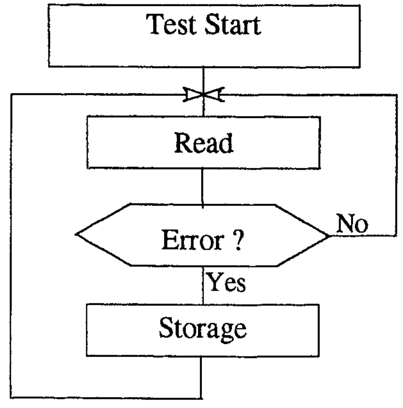


Fig. 2 Description of the proton test set-up

The proton test set-up is the same as the heavy ion test set-up (see previous page for details). The main difference is that no vacuum chamber is needed for proton tests.

4.2.3. Test sequence

Parts were programmed with a pattern before irradiation. During irradiation, they were only tested in Read Mode.



Test sequence flow chart

5. HEAVY ION EXPERIMENTAL RESULTS

5.1. HEAVY ION IRRADIATION TEST SEQUENCE

The heavy ion irradiation test sequence is reported in the following tables. Fluences given in column 9 are corrected fluences. They have been corrected according to the tilt (corrected fluences = real fluences x cosθ). The run number refers to the total irradiation test sequence, including all the memories tested during this campaign.

ICC+ is the consumption current for 4 memories biased together.

Run	Device	Vcc/f	LET (Si) [MeV.cm²/mg]	Tilt [°]	Eff. LET (Si) [MeV.cm²/mg]	Flux [p/cm²/s]	Time (s)	Fluence [p/cm²]	ICC+ [mA]
28	SN3	3.3V/fmax	34	0	34	150	165	356129	+5.37
29	SN4	3.3V/fmax	34	0	34	150	37	106615	+5.86
40	SN5	3.3V/fmax	14.1	0	14.1	2000	598	907287	+33.7
41	SN6	3.3V/fmax	14.1	0	14.1	2000	340	396929	+33.7
58	SN10	3.3V/fmax	5.85	0	5.85	4000	123	1000000	+35.7
59	SN10	3.3V/fmax	5.85	54	10	4000	276	1000000	+35.7
85	SN7	5V/fmax	5.85	0	5.85	4000	/	1500000	/
86	SN8	5V/fmax	34	0	34	500	/	1000000	+52.3
87	SN7	5V/fmax	34	0	34	500	/	221000	+52.3

Table 2 : Heavy Ion Irradiation Test Sequence

5.2. ANALYSIS OF HEAVY ION RESULTS: METHOD

5.2.1. Calculation of SEE cross-sections

The cross-sections were calculated as follows :

$$\sigma(\text{LET}) = N/F$$

where :

σ is the SEE Cross-section (cm²/device), expressed as a function of the Heavy Ion LET

LET is the Linear Energy Transfer $\left(\frac{1}{\rho}\frac{dE}{dx}\right)$, in MeV.cm²/mg

N is the total Number of SEE

F = Fluence (part./cm²) (corrected according to the incident angle).

The minimum of fluence required is 1e+6 p/cm², if no event detected. By default, a value of 1 for N is used to calculate the cross-section when no event is observed (Cf. statistical treatment).

The LET threshold is defined as the maximum LET value at which no event occurs at a fluence of 10^6 particle/cm².

5.2.2. Statistical treatment

The confidence limits shown in the following tables represent the values of the cross section between which the true value of cross section lies within a 90% probability.

The calculation of the confidence limits is made on the basis of a Poisson distribution for the events. Note that when large numbers of errors are observed, the statistical errors become insignificant. The assumptions made therefore are :

- only one event possible per incident ion

- small probability of event

For an error rate > 600, no confidence limit is calculated

5.3. HEAVY ION CROSS SECTION MEASUREMENTS

The following tables exhibit the heavy ion results performed on AM29(LV)800B-120 and AM29(LV)800B-120 Flash EEPROM memories.

Devices were either programmed with $00 (All bits to 0) pattern or $FF (All bits to 1) pattern. Due to incorrect Cb pattern programmation, no Cb (Checker board) pattern was tested (see §5.3.6. for explanation).

All the tests were performed in Read Mode. No test in Write Mode was performed.

When an error occurs the bit content cannot be modified by the tester. So, if the error is permanent, it must be detected at each new memory exploration when the address in error is met. Therefore, permanent errors can be easily separated from transient errors by analysis of error file contents.

Cross sections were calculated according to the number of tested bits, as reported in the following table. This number is not equal to the total number of bits of the memories (see § 5.3.6 for explanation).

Sample (content)	Test n°	Number of tested bits
SN3 ($00)	28	4 MBit
SN4 ($00)	29	4 MBit
SN5 ($FF)	40	3/8 x 4 MBit
SN6 ($FF)	41	3/8 x 4 MBit

Sample (content)	Test n°	Number of tested bits
SN10 ($FF)	59	3/8 x4 MBit
SN10 ($FF)	58	3/8 x4 MBit
SN8 ($FF)	86	7/8 x 4 MBit
SN7 ($FF)	85, 87	7/8 x 4 MBit

Table 3 Number of tested bits for each run

All the results are reported in the following pages.

5.3.1. Permanent loss of contents

No permanent loss of contents was identified during the tests. Single or multiple errors are only detected and recorded one time in the error data file : during the following memory exploration the error is no longer present. Since we are in Read mode only (erroneous data is never corrected), this means that such kind of error is a transient error.

These results are different from previous test results on AMD flash memories : AMD 128K x 8 Flash EPROM (AM29F010-120JC 341JYJT, 1991) were tested with heavy ion (ESA-ESTEC report No. 1859, [4]), and exhibited a permanent loss of contents down to a LET of 11.7 MeV.cm²/mg.

5.3.2. Tables of heavy ion induced multiple transient error results

In the following analysis, a multiple error is counted when several consecutive addresses are in error. For such an error group only one multiple error is counted and noted 1M. The cross section is expressed in cm²/device. Details on such error types are given in the annex (§8.2).

Test Sample	Test n°	SEU	Fluence (part/cm²)	Effective LET [MeV.cm²/mg]	X-Section [cm²/dev]	90% Conf. Limits [cm²]
SN4 ($00)	29	1M	1.1 e+05	**34**	**1,82E-05**	8.62e-5/9.32e-7
SN5 ($FF)	40	1M	9.1 e+05	**14.1**	**5,86E-06**	2.78e-5/3.00e-7
SN6 ($FF)	41	1M	3.9 e+05	**14.1**	**1,37E-05**	6.48e-5/3.07e-7
SN10 ($FF)	59	0	1.0 e+06	**10**	**<5,30E-06**	1.22e-5/5.33e-10
SN10 ($FF)	58	0	1.0 e+06	**5.85**	**<5,30E-06**	1.22e-5/5.33e-10

Table 4 : Cross section measurements for AM29(LV)800B

Test Sample	Test n°	SEU	Fluence (part/cm²)	Effective LET [MeV.cm²/mg]	X-Section [cm²/dev]	90% Conf. Limits [cm²]
SN7 ($FF)	87	0	2.2 e+05	**34**	**<1,04E-05**	2.39e-5/2.28e-10
SN8 ($FF)	86	1M	1.0 e+06	**34**	**2,29E-06**	1.08e-5/1.17e-7
SN7 ($FF)	85	0	1.5 e+06	**5.85**	**<1,52E-06**	3.5e-6/2.28e-10

Table 5 : Cross section measurements for AM29(F)800B

For the (F) version, no LET between 5.85 and 34 MeV.cm²/mg was investigated, the aim of this study being to highlight the lower sensitivity of the (F) version, and not perform a full characterization of both devices.

5.3.3. Heavy ion induced multiple transient error analysis

The figure 4 exhibits the heavy ion induced multiple error cross sections for 8 Mbit AMD (LV/F) Flash memory.

Tests on 8 Mbit LV Flash were performed at LET values : 5.85, 10, 14.1, and 34 MeV.cm²/mg. Tests on F (5V) devices were performed at LET=5.85 and 34 MeV.cm²/mg.

Only multiple errors were considered in this graph.

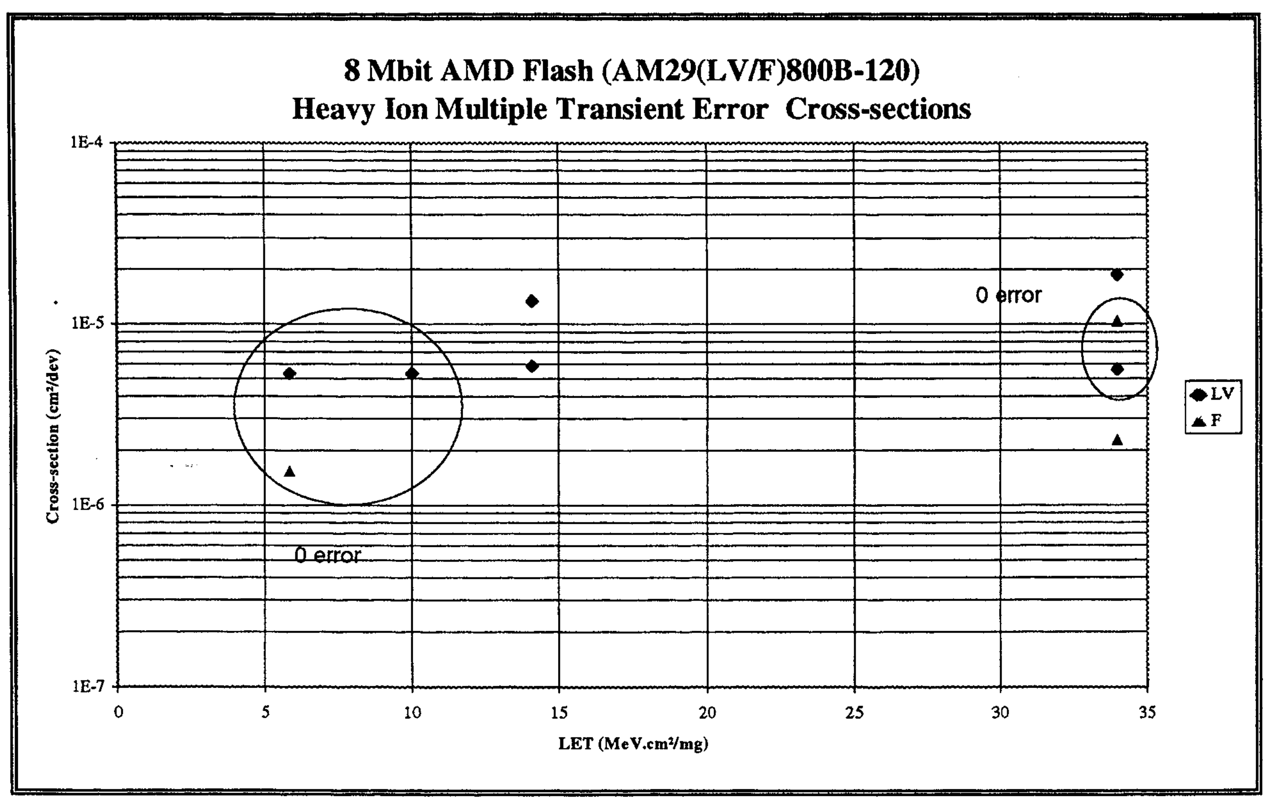


Fig. 4 Heavy ion MultipleError Cross section measurements on 8 Mbit Flash memory

This figure evidences the following results :

AMD (LV) Flash memories is sensitive to heavy ion induced multiple transient errors. Cross section at 34 MeV.cm²/mg is <2e-5 cm²/device, and threshold LET is estimated between 10 and 14.1 MeV.cm²/mg. The AMD (F) Flash memories exhibits a lower sensitivity : cross sections are lower.

No effect of the memory content has been evidenced.

5.3.4. Tables of heavy ion induced single transient errors

The following tables exhibit the AMD(LV/F) Flash memory sensitivity to heavy ion induced single transients. A single transient is identified when a bit error occurs in a given address, and disappears after the following Read cycle. These tests were performed simultaneously with multiple transient error tests (shown in the previous paragraphs).

Test Sample	Test n°	Trans. SEU	Fluence (part/cm²)	**Effective LET [MeV.cm²/mg]**	**X-Section [cm²/Bit]**	90% Conf. Limits [cm²]
SN4	29	0	1.0 e+05	**34**	**<2.24e-12**	1.06e-11/1.14e-13
SN5	40	3	9.1 e+05	**14.1**	**2.10e-12**	5.41e-12/5.71e-13
SN6	41	1	3.9 e+05	**14.1**	**1.60e-12**	7.59e-12/8.21e-14
SN10	59	1	1.0 e+06	**10**	**6.36e-13**	3.01e-12/3.26e-14
SN10	58	1	1.0 e+06	**5.85**	**6.36e-13**	3.01e-12/3.26e-14

Table 6 : Cross section measurements for AM29(LV)800B

*Since no error data file was recorded for this run, it will not be considered in the result analysis.

Test Sample	Test n°	Trans SEU	Fluence (part/cm²)	**Effective LET [MeV.cm²/mg]**	**X-Section [cm²/Bit]**	90% Conf. Limits [cm²]
SN7 ($FF)	87	0	2.2 e+05	**34**	**<1.23e-12**	2.84e-12/2.72e-17
SN8 ($FF)	86	0	1.0 e+06	**34**	**<2.72e-13**	6.27e-13/2.72e-17
SN7 ($FF)	85	0	1.5 e+06	**5.85**	**<1.82e-13**	4.18e-13/2.72e-17

Table 7 : Cross section measurements for AM29(F)800B

For the (F) version, no LET between 5.85 and 34 MeV.cm²/mg was investigated, the aim of this study being to highlight the lower sensitivity of the (F) version, and not perform a full characterization of both devices.

5.3.5. Heavy ion induced single transient analysis

The figure 5 exhibits the heavy ion induced single transient error cross sections for 8 Mbit AMD (LV) Flash memory. Tests on 8 Mbit (F) AMD were also performed, but, since no single transient sensitivity was found, the results are not plotted in this graph.

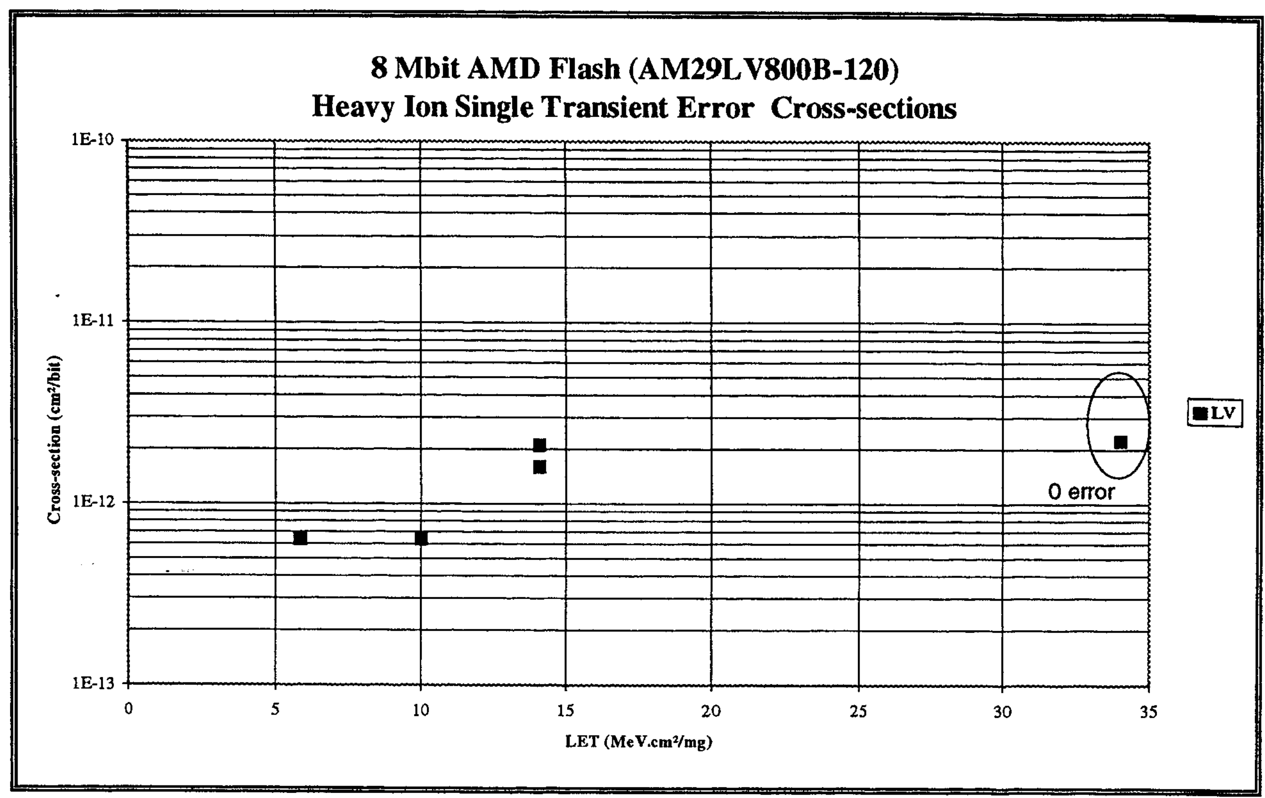


Fig. 5 Heavy Ion induced single transients on AMD(LV) Flash memory

This figure evidences the following results :

AMD (LV) Flash memories exhibit a sensitivity to heavy ion induced single transient error. This sensitivity is very low, with a cross-section of 3e-12 cm²/bit at LET=34 MeV.cm²/mg. The threshold LET is ≤ 5.85 MeV.cm²/mg. AMD (F) flash memories did not exhibit any heavy ion single event error.

5.3.6. Problems encountered/Discussion

Device programmation :

In the initial experimental test plan, some memories were expected to be programmed with the following patterns :

1/ SN5, SN6, SN10 : checkerboard

2/ SN3, SN4 : $00

3/ SN7, SN8 : $FF

Checkerboard programmation :

Programming of checkerboard was not correctly performed, so :

- only half a 8 bit word could be tested.

- pattern was not correctly initialized

Due to the fact that flash memories were not correctly programmed with the patterns that could be read by the tester ($00, $11 or CB), an adaptation had to be done in order to allow the memory tester to read the Flash memories. Therefore, the total number of tested bits was reduced in some tests according to the type of programmation. This explains why the total number of tested bits is not constant from one run to another (see table 3).

Statistics :

Total fluence for run 87 is very low : during this run the tester always wrote false errors in the error file. Therefore, it was decided to stop the run after a fluence of 2.2e+05 part/cm².

Total fluence for run 29 is also low, because the run was stopped after 475 errors in consecutive addresses (see annex for details). This error was considered as one multiple error.

5.4. HEAVY ION TEST CONCLUSIONS

The results of these experiments demonstrate that 8 Mbit FLASH AM29(LV)800B-120 from AMD (Low Voltage devices) are not sensitive to heavy ion induced SEU (permanent loss of content). Transient single or multiple errors are observed. The threshold LET is ≤ 5.85 MeV.cm²/mg for single transients, and between 10 and 14.1 MeV.cm²/mg for multiple transients. The sensitivity of 5V, 8 Mbit FLASH AM29(F)800B-120 from AMD is lower : only multiple transient errors were observed, with lower cross sections. Due to low statistic and limited number of tests, we cannot conclude on the single transient sensitivity above 5.85 MeV.cm²/mg.

Additional heavy ion results:

These devices also exhibited no Latch-up sensitivity, up to a LET of 34 MeV.cm²/mg. No higher LET was tested.

6. PROTON EXPERIMENTAL RESULTS

6.1. PROTON IRRADIATION TEST SEQUENCE

The proton irradiation test sequence is given in the following tables.

The run number refers to the total irradiation test sequence, including all the memories tested during this campaign. Flux values have been averaged.

Run	Device	Vcc/f	Energy (p) [MeV]	Flux [p/cm²/s]	Fluence [p/cm²]	ICC+ [mA]
66	SN1	5V/fmax	60	1.2e+08	1e+10	/
67	SN2	5V/fmax	60	1.2e+08	1e+10	/

Table 8 : Proton Irradiation Test Sequence

6.2. ANALYSIS OF PROTON RESULTS : METHOD

6.2.1. Calculation of SEE cross-sections

The cross-sections were calculated as follows :

$$\sigma(Ep) = N/F$$

where :

σ is the SEE Cross-section (cm^2/device), expressed as a function of the Proton Energy

N is the total Number of SEE

F = Fluence (part./cm^2).

The fluence is set at 1e+10 p/cm^2 for all the runs. By default, a value of 1 for N is used to calculate the cross-section when no event is observed (Cf. statistical treatment).

6.2.2. Statistical treatment

The confidence limits shown in the following tables represent the values of the cross section between which the true value of cross section lies within a 90% probability.

The calculation of the confidence limits is made on the basis of a Poisson distribution for the events. Note that when large numbers of errors are observed, the statistical errors become insignificant. The assumptions made therefore are :

- only one event possible per incident proton
- small probability of events

For an error rate > 600, no confidence limit is calculated

6.3. PROTON CROSS SECTION MEASUREMENTS

6.3.1. Tables of proton induced SEU results

The following table exhibits the proton results performed on AM29(LV)800B-120 flash EPROM memories. Since these devices exhibited no SEE (either permanent or transient), no tests were performed at lower proton energy. No SEE tests were performed on AM29(F)800B-120 (5V) either.

SN1 was programmed $FF, SN2 was programmed $00. Only 4 Mbit were tested.

Test Sample	Test n°	SEU	Fluence (part/cm²)	**P. Energy [MeV]**	**X-Section [cm²/bit]**	90% Conf. Limits [cm²]
SN1	66	0	1.0 e+10	**60**	**2.4e-17**	1.12e-16/1.22e-18
SN2	67	0	1.0 e+10	**60**	**2.4e-17**	1.12e-16/1.22e-18

Table 9 : AM29(LV)800B-120 SEU cross section measurements

No SEU cross section versus Proton Energy is plotted, because no SEU sensitivity was detected

6.3.2. Problems encountered/Discussion

No specific problem was encountered during irradiation.

6.4. PROTON TEST CONCLUSIONS

The results of these experiments demonstrate that 8 Mbit FLASH AM29(LV)800B-120 from AMD are not sensitive to proton induced SEU or transients, up to a proton energy of 60 MeV. Consequently, no tests were performed on 8 Mbit FLASH AM29(F)800B-120, which sensitivity is expected to be lower.

Additional proton results:

These devices also exhibited no Latch-up sensitivity, up to a proton energy of 60 MeV.

7. CONCLUSION

AM28(LV/F)800B-120 Flash memories were tested under heavy ion and proton irradiation. Results are reported in the following tables :

SINGLE EVENT PERMANENT UPSET RESULTS SYNTHESIS (HEAVY IONS)		
	LET Threshold (MeV.cm²/mg)	Cross-section (cm²/bit) at LET=34 MeV.cm²/mg
AM29LV800B-120	>34	no error
AM29F800B-120	>34	no error

Summary of heavy ion results (permanent SEU)

SINGLE EVENT SINGLE TRANSIENT ERROR RESULTS SYNTHESIS		
	LET Threshold (MeV.cm²/mg)	Cross-section (cm²/bit) at LET=34 MeV.cm²/mg
AM29LV800B-120	≤5.85	<3e-12 (estimated)
AM29F800B-120	>34	<3e-12 (no error)

Summary of heavy ion results (transients)

SINGLE EVENT UPSET RESULTS SYNTHESIS (PROTONS)		
	Ep Threshold (MeV)	Saturated Cross-section (cm²/bit)
AM29LV800B-120	>60	<3e-17
AM29F800B-120	not evaluated	not evaluated

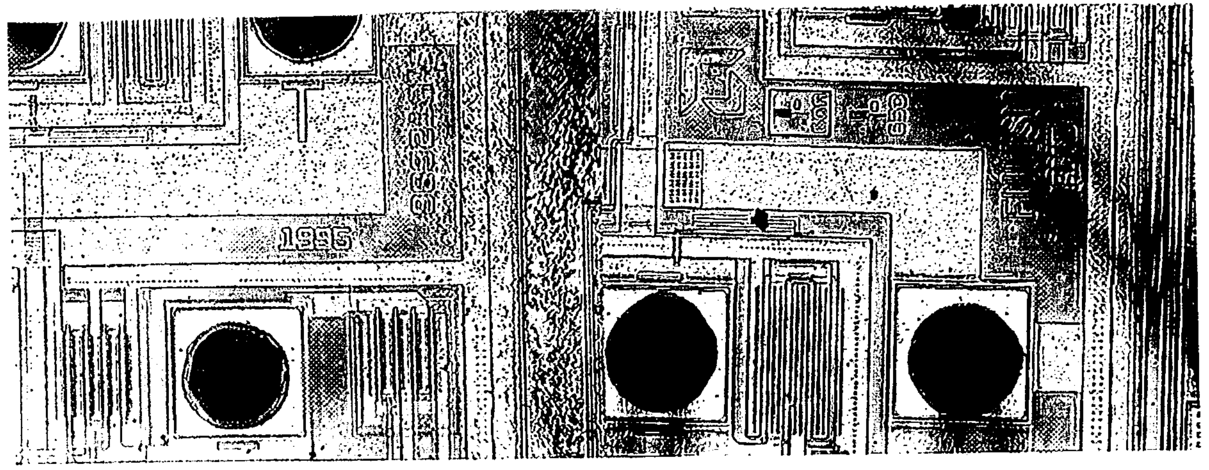
Summary of AM29(LV/F)800B-120 proton induced SEU results

No sensitivity to proton induced SEE was found on these devices at energies <60 MeV.

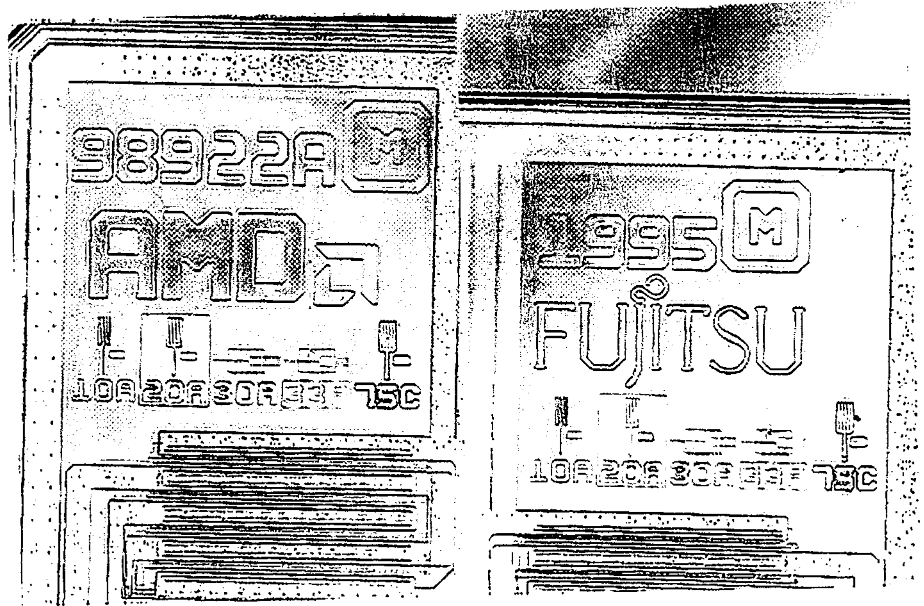
The AMD (LV) memory exhibited a higher sensitivity to heavy ion than the AMD (F) memory : transient and multiple errors were found down to a LET of 14.1 MeV.cm²/mg. These results differ from previous tests performed on AMD flash memories [4].

8. ANNEX

8.1. DIE PHOTOGRAPHY



(LV)



(F)

Photography of the die marking

8.2. DETAILS OF RESULT ANALYSIS

During the experiments, only a few single or multiple transient errors were observed.

The details are given below for heavy ions.

Multiple transient errors

Test Number	SN	Effect. LET	Multiple Errors	Address	Initial content	Content when error
28	3	34	Not considered, due to unrecorded corresponding error data file			
29	4	34	1	from 227c1 to 22a75	**00000000**	**01000000**
40	5	14.1	1	from 0c4cc to 0c741	11111**111**	01000**000**
41	6	14.1	1	from 200a4 to 20271	11111**111**	01000**000**
58	10	5.85	0	/	11111**111**	/
59	10	10	0	/	11111**111**	/
85	7	5.85	0	/	**11111111**	/
86	8	34	1	from 78000 to 781d8	**11111111**	11011101
87	7	34	0	/	**11111111**	/

In the table only bits in bold are tested: 3/8 for tests 40, 41, 58, 59 and 7/8 for tests 85, 86, 87.

Single transient errors

Test Number	SN	Eff. LET	Single transient error	Adress	Initial content	Content when error
28	3	34	Not considered, due to unrecorded corresponding error data file			
29	4	34	0	/	00000000	/
40	5	14.1	3	0000e 0a526 05f32	11111**111**	00001**011** 10011**101** 00001**011**
41	6	14.1	1	0000d	11111**111**	1**011**
58	10	5.85	1	0000b	11111**111**	1**011**
59	10	10	1	0000c	11111**111**	1**011**
85	7	5.85	0	/	1**1111111**	/
86	8	34	0	/	1**1111111**	/
87	7	34	0	/	1**1111111**	/

In the table only bits in bold are tested: 3/8 bits for tests 40, 41, 58, 59 and 7/8 bits for tests 85, 86, 87.