SINGLE EVENT EFFECTS
RADIATION TEST REPORT

Part Type : M29F016B and M29F032D

16 and 32 Mb FLASH

Manufacturer : STMicroelectronics

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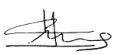
Approved by :	J. F. MOUNES		Date :	December 17th, 2002

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

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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 ", M29F016B and M29F032D 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 M29F016B and M29F032D flash memories, from STMicroelectronics.

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. M29F016B and M29F032D 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 M29F016B

Relevant device identification information is presented here after.

Part type:	M29F016B
Manufacturer:	STMicroelectronics
Package:	40-TSOP
Quality Level:	Commercial
Date Code:	0052
Top Marking:	M29F016B 70N1 588MF 0052 SINGAPORE
Die Size:	7.4 mm x 6.2 mm approximately
Die marking	C 19999 ST M FFFN1
Serial number	SN04-1, SN04-2 (attributed by Hirex)

Die identification is provided in Figure 1.
16 Mbit (2Mb x8, 32 uniform 64 Kbyte memory blocks) 5V Single Supply Flash Memory

4.2 M29F032D

Relevant device identification information is presented here after.

Part type:	M29F032D
Manufacturer:	STMicroelectronics
Package:	40-TSOP
Quality Level:	Commercial
Date Code:	0240
Top Marking:	MF29F032D 70N6 ABSOC 0240 SINGAPORE
Die Size:	8.6 mm x 3.9 mm approximately
Die marking	AFGT1 FFGT 1R2 2000 ST C M
Serial number	SN01-1, SN01-2 (attributed by Hirex)

Die identification is provided in Figure 2.
32 Mbit (4Mb x8, 64 uniform 64 Kbyte memory blocks), 5V Supply Flash Memory

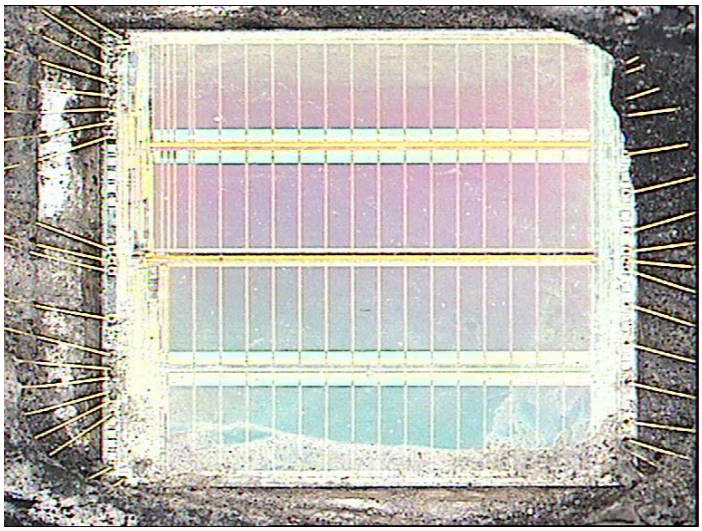

Photo 1

Die, full view

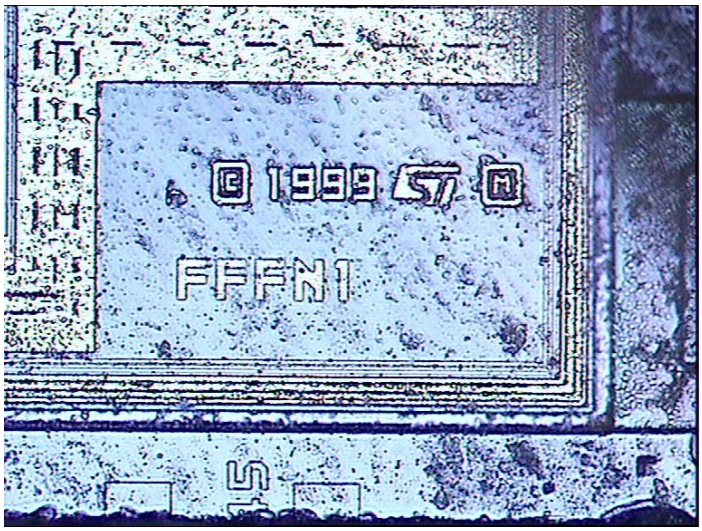

Photo 2

Die marking

Figure 1 - M29F016B die identification

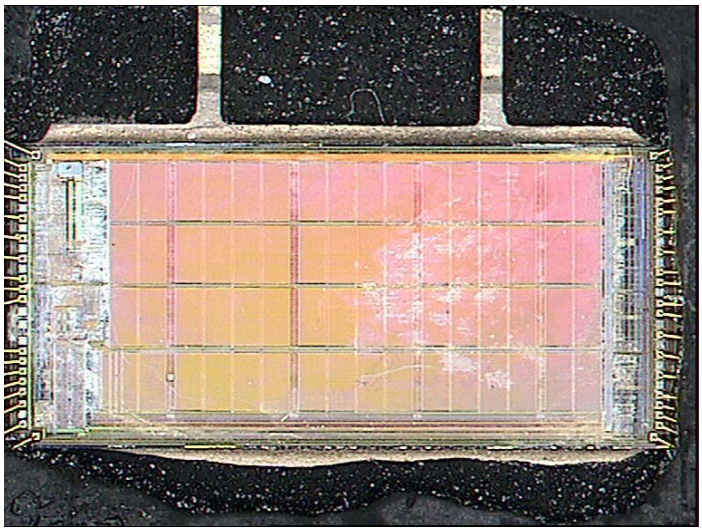

Photo 3

Die, full view

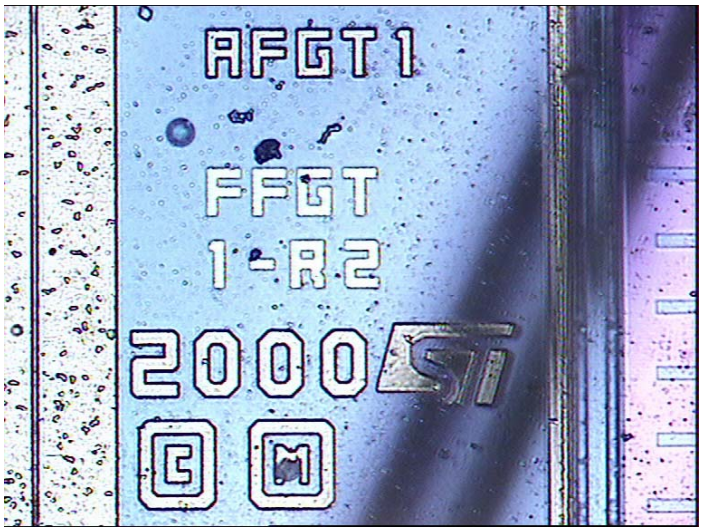

Photo 4

Die marking

Figure 2 - M29F032D 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 30000 cells 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

Four 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)

STATIC READ ONLY (S-R/O) 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 (typically 45 s), and regularly perform read operations followed by a hardware reset.
4. Loop with step 2, etc…

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…

READ WRITE (R/W) 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-erase/write/read sequences on 2 blocks. At each sequence, an offset is done on the test pattern and the number of errors is cumulated.
4. Loop with step 2, etc …

In this last configuration when a word error is read, a second read is performed to check if it is a read SEU or a Write SEU.

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

	lt k	lt k+1	lt k+2	lt k+3	lt k+4	lt k+5	lt k+6	lt k+7	lt k+8	lt k+9	lt k+10	lt k+11	lt k+12	lt k+13	lt 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 SEU errors induced during latch-up events.

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 M29F016B and in Table 4 for M29F032D. Each run is commented in detail in the two tables.

M29F016B:

Almost no SEU was observed for the corresponding set of runs.
No stuck bit was observed either.
High increase of DUT power consumption under full static condition (runs 5, 7, 9, 11) have been observed up to 25mA compared to normal consumption of 360µA.
However samples have been affected by few SEFIs (Single Event Functional Interrupt). First SEFI was observed at a LET of 14. Some severe and persistent SEFI occurred. In some cases, the DUT goes into programming mode, and sometimes needs power OFF/ON to recover. In one particular case, a severe SEFI made the DUT go into programming mode, but even after power OFF/ON was performed, the device couldn't recover and remained permanently damaged.

M29F032D:

SEUs were observed. In fact the error signature consists in sequences of 10 to 100 words in errors (in most cases 1bit in error per word).
Sample 1-1 may have been affected by a shadowing problem when tilting the device, caused by the DUT opening window dimensions
No stuck bit was detected
High increase of DUT power consumption under full static condition (run 16) have bee observed up to 10.5mA compared to normal consumption of 360µA.
SEFI were observed, the first one occurring at a LET of 11.7 MeV.cm²/mg. Some severe and persistent SEFI occurred on both types. In some cases, the DUT goes into programming mode, and sometimes needs power OFF/ON to recover.

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
60	ST-16	04_1	FSO	Ne	78	5,85	60	11,70	3846,17	260	1,00E+06	0	0	No event
61	ST-16	04_1	C/R	Ne	78	5,85	60	11,70	4000,02	250	1,00E+06	0	0	No event
1	ST-16	04_1	S-R/O	Ar	150	14,1	0	14,1	4807,69	208	1,00E+06	0	0	No event, 5 iterations of 45 seconds
7	ST-16	04_1	FSO	Ar	150	14,1	0	14,1	9090,91	110	1,00E+06	0	1	DUT current supply consumption increase during exposure to 13.7mA (normal consumption is 360µA), 1 SEFI (2 millions upsets, almost the whole memory), large read event, after reset DUT OK, no data lost
8	ST-16	04_1	C/R	Ar	150	14,1	0	14,1	6666,67	150	1,00E+06	0	0	No event
5	ST-16	04_1	FSO	Ar	150	14,1	45	19,9	6756,76	148	1,00E+06	0	0	No upset .. but DUT current supply consumption increase to 13.7mA,.. after reset : current consumption back to normal (360µA),
6	ST-16	04_1	C/R	Ar	150	14,1	45	19,9	6250,00	160	1,00E+06	1	0	1 SEU, no SEFI
2	ST-16	04_1	S-R/O	Ar	150	14,1	60	28,2	2227,17	449	1,00E+06	0	1	10 iterations of 45 seconds, 1 SEFI (read error) at iteration no5 (all memory), reset ok
3	ST-16	04_1	C/R	Ar	150	14,1	60	28,2	2686,27	255	685000	0	5	4 SEFI (read events) + a last SEFI with 8 DUT memory blocks (64 kbytes) entirely to 0 : after reset and power/off: these blocks are still at 0, after re-write: DUT OK
4	ST-16	04_1	FSO	Ar	150	14,1	60	28,2	2710,03	369	1,00E+06	0	1	1 Functional event: 2 blocs erased (FF). Impossible to reprogram (status bit error): needs power off/on to rewrite. after power off DUT OK
9	ST-16	04_2	FSO	Ar	150	14,1	0	14,1	7518,80	133	1,00E+06	0	0	No error, no event, but DUT current supply consumption increase to 25 mA at the end of the run
10	ST-16	04_2	S-R/O	Ar	150	14,1	0	14,1	8771,93	114	1,00E+06	0	1	SEFI -> the part goes into program mode .. after "prog release" command -> DUT OK, no data lost ..
11	ST-16	04_2	FSO	Ar	150	14,1	45	19,9	5617,98	178	1,00E+06		1	High DUT current supply consumption increase to 16mA during exposure, very big SEFI going into prog mode again: but this time the "release" command doesn't work, after reset, DUT OK .. Some data lost: 219 SEU (permanent errors) - in the whole 1st block, each word which have the to 2 last add. bits at 0 have data = to 00 or 80 - rewrite w/o power off : not possible - after power off : still the same errors - after power off : reprog still not possible - device **destroyed**

Table 3 - Heavy ion detailed results per run for M29F016B

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
62	ST-32	01_1	FSO	Ne	78	5,85	0	5,85	8130,11	123	1,00E+06	0	0	No event
63	ST-32	01_1	C/R	Ne	78	5,85	0	5,85	8928,61	112	1,00E+06	0	0	No event
18	ST-32	01_1	FSO	Ar	150	14,1	0	14,1	7518,80	133	1,00E+06	0	1	1 large SEFI ,after reset : DUT OK
19	ST-32	01_1	C/R	Ar	150	14,1	0	14,1	8695,65	115	1,00E+06	0	1	1 large SEFI ,after reset : DUT OK
20	ST-32	01_1	FSO	Ar	150	14,1	45	19,9	5102,04	196	1,00E+06	0	0	No event
21	ST-32	01_1	C/R	Ar	150	14,1	45	19,9	4739,34	211	1,00E+06	2	0	2 SEUs
22	ST-32	01_1	FSO	Ar	150	14,1	60	28,2	3773,58	265	1,00E+06	0	0	No event, possible beam shadowing problem when tilting to 60 deg.
23	ST-32	01_1	C/R	Ar	150	14,1	60	28,2	3984,06	251	1,00E+06	0	0	No event, possible beam shadowing problem when tilting to 60 deg.
64	ST-32	01_2	FSO	Ne	78	5,85	0	5,85	8474,60	118	1,00E+06	0	0	No event
65	ST-32	01_2	C/R	Ne	78	5,85	0	5,85	8403,39	119	1,00E+06	0	0	No event
66	ST-32	01_2	FSO	Ne	78	5,85	60	11,70	4032,28	248	1,00E+06	0	1	1 BIG SEFI - after reset - DUT OK
67	ST-32	01_2	C/R	Ne	78	5,85	60	11,70	4149,40	241	1,00E+06	982	0	982 SEUs
68	ST-32	01_2	R/W	Ne	78	5,85	60	11,70	4310,38	232	1,00E+06	42	1	Continuous erase/write/read on blocks 10 and 11 : 3 read SEUs, 38 write SEUs, 1 SEFI = write error in status register during write
12	ST-32	01_2	FSO	Ar	150	14,1	0	14,1	8547,01	117	1,00E+06	0	0	No event - but after "write mem" command : max time error (gone into prog mode again ?)
13	ST-32	01_2	C/R	Ar	150	14,1	0	14,1	4422,41	116	5,13E+05	554	1	SEUs : sort of row errors on 1 bit - afterwards SEFI : all mem to 0 - after reset : DUT OK, no data lost
14	ST-32	01_2	FSO	Ar	150	14,1	45	19,9	6493,51	154	1,00E+06	0	0	No event
15	ST-32	01_2	C/R	Ar	150	14,1	45	19,9	8695,92	24	208702	250	1	250 SEUs (sort of row errors of 1 bit), afterwards 1 SEFI (small read error, 2470 errors), after reset DUT OK, not data lost
16	ST-32	01_2	FSO	Ar	150	14,1	60	28,2	4115,23	243	1,00E+06	0	0	No event - DUT current supply consumption increase during exposure to 10.5mA - after reset everything's OK (normal consumption is 360µA)
17	ST-32	01_2	C/R	Ar	150	14,1	60	28,2	4105,50	178	7,31E+05	2504	2	2504 SEUs (same as previous runs), 2 SEFI : 1 normal (read error, 6333 words error), reset -> run continues, 2nd: persistent func error, -> component went into prog mode, "release" command didn't work, reset neither, after power off/on DUT OK

Table 4 - Heavy ion detailed results per run for M29F032D

8 CONCLUSION

Heavy ion tests were conducted on commercial samples of M29F016B and M29F032D flash memories from STMicroelectronics, 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.)

No stuck bits were observed during these tests.

The 32Mb device was found sensitive to read SEUs which occurred in sequences of 10 to 100 words in error, but almost no SEU was observed with the 16Mb.

Current consumption increases under exposure have been observed up to 25mA to be compared to the normal value of 360µA in full static conditions. (M29F032D: run16, M29F016B: runs 5, 7, 9, 11)

SEFI were observed on both types during the test. In some cases, the SEFI put the device into programming mode, and it needs power OFF/ON to recover. In the case of one particularly severe SEFI on the 16 Mb device, the functional error induced permanent damage of the device.