SINGLE EVENT EFFECTS
RADIATION TEST REPORT

Part Type : CY7C1049B

4 Mb SRAM

Manufacturer : CYPRESS

Report Reference : ESA_QCA0215S_C

Issue : 01

Date : December 17th, 2002

ESA Contract No 13528/99/NL/MV COO-13 dated 11/10/02

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Heavy ion SEE characterization of CY7C1049B SRAM

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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", CY7C1049B SRAM 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 CY7C1049B SRAMs, from CYPRESS.

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. CY7C1049B 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 CY7C1049B

Relevant device identification information is presented here after.

Part type:	CY7C1049B
Manufacturer:	CYPRESS
Package:	36-SOJ
Quality Level:	Commercial
Date Code:	0221
Top Marking:	CY7C1049B- 15VI 0221 C 04 706390
Die Size:	6.7 mm x 6.3 mm approximately
Die marking	C 1999 M CYPRESS 7C1049A 7C1549C
Serial number	SN1, SN2 (attributed by Hirex)

512K x 8 Static RAM, 5V power supply.

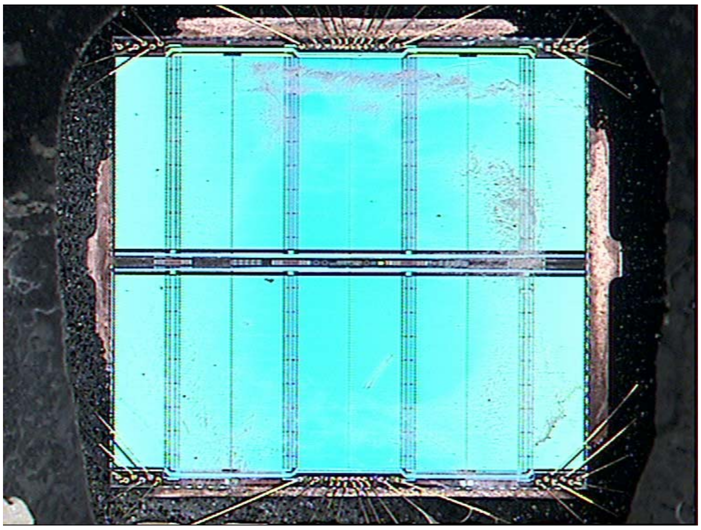

Photo 1

Die, full view

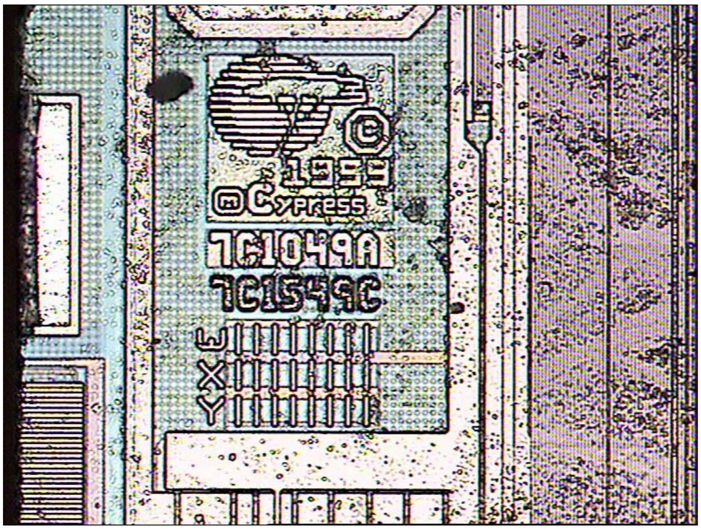

Photo 2

Die marking

Figure 1 - CY7C1049B 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

Two basic configurations were used:

STATIC TEST MODE:
1. Device initialization
2. Write the test pattern in the memory and perform a read to check eventual stuck bits
3. Expose the device to the beam for a given time (typically 10s)
4. Write the memory. At each sequence, an offset is done on the test pattern and the number of errors is cumulated.
5. Read the memory and count the errors
6. Loop with step 2, etc

DYNAMIC 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-write operations. At each sequence, an offset is done on the test pattern and the number of errors is cumulated.
4. 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 SEU 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 dose 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

Functional check after sample opening showed that sample SN2 had 256 words with the last 4 bits stuck to 0 permanently.
The results on this sample presented here below have been corrected accordingly.

The detailed results per run for each device are presented in Table 3 and Table 4. In this table, when the total number of SEUs (words) detected, exceeds the size of the log error file (8192 errors), the distribution of 0 to1 and 1 to 0 bit transitions is extrapolated from the 8192 recorded errors by using the total number of SEU divided by 8192 ratio

The corresponding SEE cross-section per bit vs. Effective LET curve is plotted in Figure 2.

No SEL were observed.

The device was found to be quite sensitive to SEU. Indeed, SEU were observed with an LET as low as 1.7 MeV.cm²/mg.

At low LET, All upsets were mostly randomly distributed in the whole memory as shows Figure 3.
It was observed that with the increase of the LET value, an ion hit could induce clusters of word errors Run120 as shown in Figure 4 is a typical example of such cluster errors. For this run, 13436 words errors were detected for a total of 186 ions which hit the die (fluence of 436 ions/cm², die surface of 0.43 cm²). This means that many multiple errors occurred.

Asymptotic cross-section per bit appears to be around 1 E-5 cm².

Lastly, two very large functional errors were observed on sample SN2 (at the end of Runs 34 and 35): every bit of the memory was reset to 0. No functional error was detected with sample SN1. There is no explanation available about the possible origin of these functional errors.

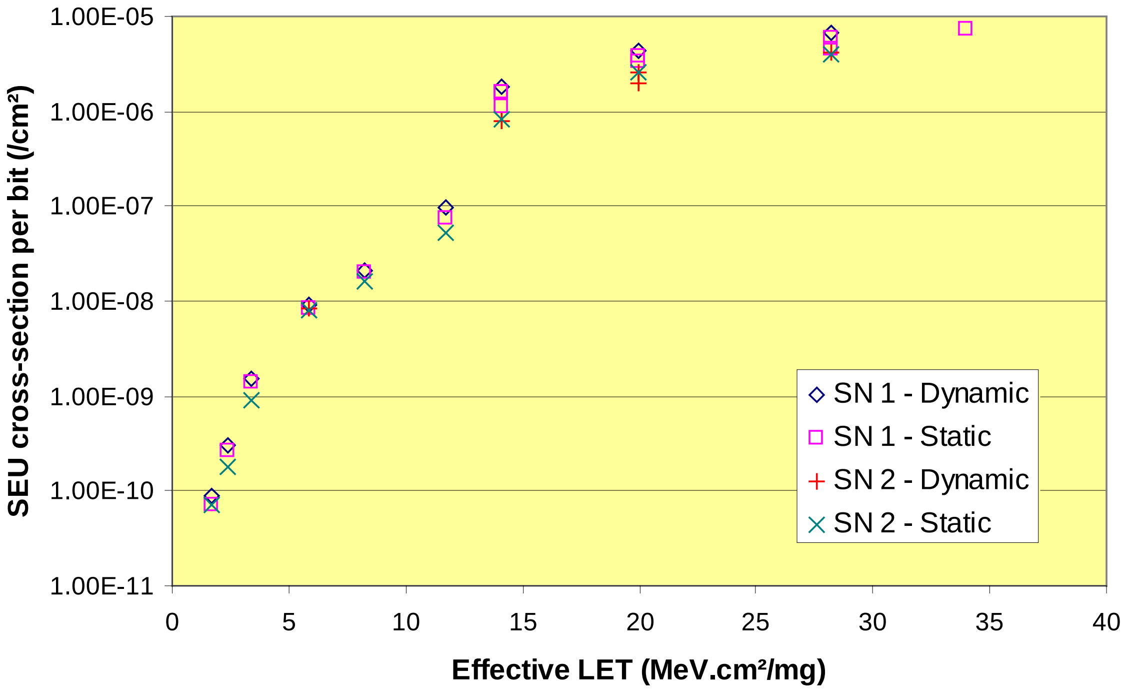

Figure 2 - SEU cross-section per bit vs. Effective LET for CY7C1049B SRAMs

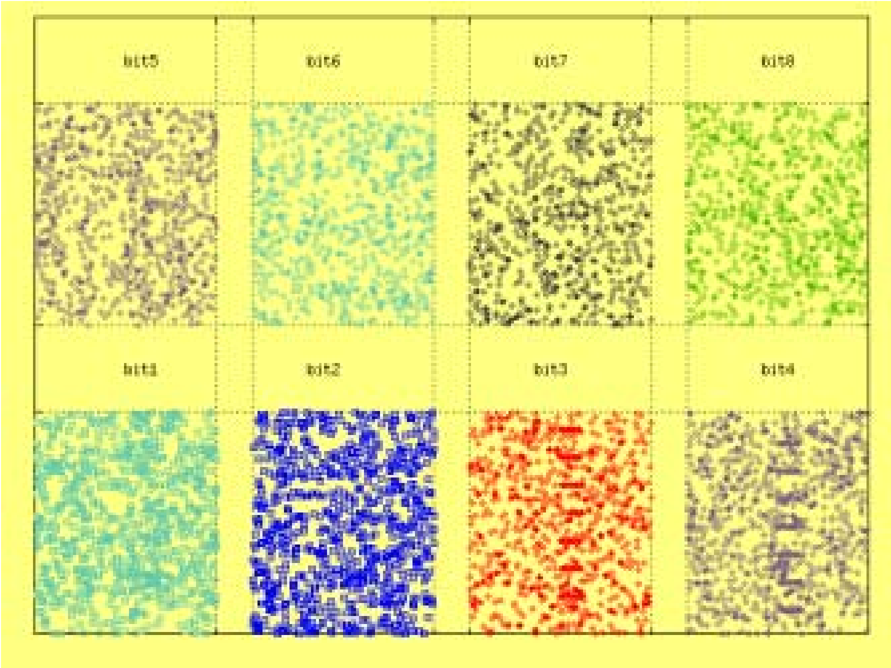

Figure 3 - Distributions of errors in (row, column) coordinates for each bit. In that case (run 99) all errors (each represented by a single symbol) are randomly distributed.

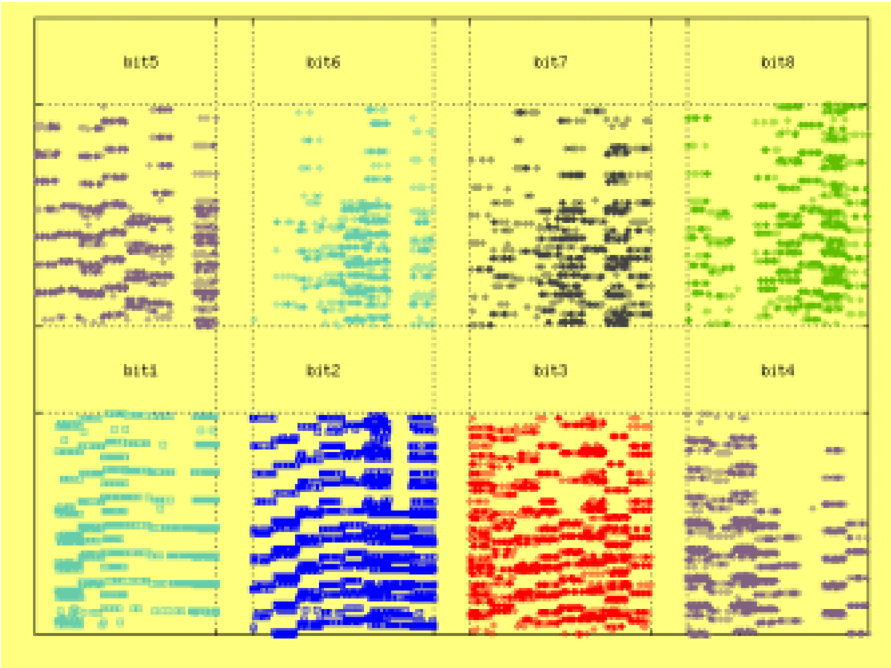

Figure 4 - Distributions of errors in (row, column) coordinates for each bit. In that case (run 120) errors clusters (each represented by a single symbol) can be observed.

Run #	S/N	Test mode	Ion	LET (MeV.cm²/mg)	Angle (°)	Eff LET (MeV.cm²/mg)	Time (s)	Fluence (/cm²)	Flux (/cm²/s)	SEFI	SEU (Words)	Bits up (0 to 1)	Bits down (1 to 0)	Total bits (Up+Down)	SEU cross-section per bit (/cm²)	Comments
95	1	D	B	1.70	0	1.70	156	1.00E+06	6410	0	371	176	195	371	8.85E-11	
97	1	D	B	1.70	45	2.40	231	1.00E+06	4329	0	1274	-	-	-	3.04E-10	Log error file not recorded
99	1	D	B	1.70	60	3.40	315	1.00E+06	3175	0	6265	3142	3123	6265	1.49E-09	
84	1	D	Ne	5.85	0	5.85	176	2.08E+05	1180	0	8048	4022	4029	8051	9.24E-09	
81	1	D	Ne	5.85	45	8.27	111	8.65E+04	780	0	7615	3861	3894	7755	2.10E-08	
83	1	D	Ne	5.85	60	11.70	37	2.09E+04	564	0	8450	4260	4427	8687	9.66E-08	
6	1	D	Ar	14.10	0	14.10	84	1.39E+04	166	0	107591	56317	60218	116535	1.84E-06	
10	1	D	Ar	14.10	45	19.94	74	1.00E+04	135	0	185438	100596	103607	204204	4.42E-06	
11	1	D	Ar	14.10	60	28.20	91	1.00E+04	110	0	280640	152413	155428	307841	6.69E-06	
94	1	S	B	1.70	0	1.70	165	1.00E+06	6061	0	302	143	159	302	7.20E-11	
96	1	S	B	1.70	45	2.40	216	1.00E+06	4630	0	1135	575	560	1135	2.71E-10	
98	1	S	B	1.70	60	3.40	303	1.00E+06	3300	0	5798	2882	2919	5801	1.38E-09	
79	1	S	Ne	5.85	0	5.85	185	2.18E+05	1180	0	7670	3831	3840	7671	8.38E-09	
80	1	S	Ne	5.85	45	8.27	117	9.32E+04	797	0	7883	3955	3959	7914	2.02E-08	
82	1	S	Ne	5.85	60	11.70	67	3.74E+04	559	0	11803	5909	6126	12035	7.52E-08	
4	1	S	Ar	14.10	0	14.10	22	2.20E+04	1000	0	104136	42788	71136	113924	1.13E-06	
5	1	S	Ar	14.10	0	14.10	87	1.83E+04	210	0	123653	56679	77585	134264	1.61E-06	
9	1	S	Ar	14.10	0	14.10	54	1.00E+04	185	0	68045	24836	49530	74366	1.62E-06	
14	1	S	Ar	14.10	0	14.10	60	1.26E+03	21	0	8539	4400	4758	9158	1.62E-06	
7	1	S	Ar	14.10	45	19.94	79	8.13E+03	103	0	132096	56454	85382	141836	3.87E-06	
13	1	S	Ar	14.10	45	19.94	99	1.00E+04	101	0	139274	46294	114877	161172	3.32E-06	
8	1	S	Ar	14.10	60	28.20	123	1.06E+04	87	0	263174	112087	176627	288714	5.90E-06	
12	1	S	Ar	14.10	60	28.20	147	1.00E+04	68	0	191166	56822	173594	230417	4.56E-06	
120	1	S	Kr	34.00	0	34.00	39	4.36E+02	11	0	13410	6623	7784	14407	7.33E-06	

(*) S stands for STATIC TEST MODE; D for DYNAMIC TEST MODE

Table 3 - Heavy ion detailed results per run (sample 1)

Run #	S/N	Test mode	Ion	LET (MeV.cm²/mg)	Angle (°)	Eff LET (MeV.cm²/mg)	Time (s)	Fluence (/cm²)	Flux (/cm²/s)	SEFI	SEU	Up	Down	Up+Down	SEU cross-section per bit (/cm²)	Comments
86	2	D	Ne	5.85	0	5.85	57	6.95E+04	1220	0	2413	1223	1191	2413	8.27E-09	
32	2	D	Ar	14.10	0	14.10	59	1.33E+03	22	0	4324	2157	2446	4603	7.77E-07	
34	2	D	Ar	14.10	45	19.94	96	1.22E+03	13	1	10014	5624	6316	11940	1.95E-06	
35	2	D	Ar	14.10	45	19.94	132	1.50E+03	11	1	16217	8688	8832	17521	2.57E-06	
37	2	D	Ar	14.10	60	28.20	199	1.47E+03	7	0	25179	14089	14049	28139	4.09E-06	
100	2	S	B	1.70	0	1.70	143	1.00E+06	6993	0	294	155	139	294	7.01E-11	
101	2	S	B	1.70	45	2.40	202	1.00E+06	4950	0	752	342	410	752	1.79E-10	
102	2	S	B	1.70	60	3.40	309	1.00E+06	3236	0	3752	1884	1866	3750	8.95E-10	
85	2	S	Ne	5.85	0	5.85	146	1.72E+05	1179	0	5813	2952	2892	5844	8.05E-09	
87	2	S	Ne	5.85	45	8.27	110	1.07E+05	970	0	7091	3453	3649	7101	1.59E-08	
88	2	S	Ne	5.85	60	11.70	87	5.53E+04	636	0	12246	6154	6493	12647	5.28E-08	
31	2	S	Ar	14.10	0	14.10	105	2.16E+03	21	0	7608	3922	4145	8066	8.41E-07	
33	2	S	Ar	14.10	45	19.94	66	9.28E+02	14	0	10189	5349	5603	10952	2.62E-06	
36	2	S	Ar	14.10	60	28.20	129	1.02E+03	8	0	16712	8877	9100	17977	3.91E-06	

(*) S stands for STATIC TEST MODE; D for DYNAMIC TEST MODE

Table 4 - Heavy ion detailed results per run (sample 2)

8 CONCLUSION

Heavy ion tests were conducted on commercial samples of CY7C1049B memories from CYPRESS, using the heavy ions available at the European Heavy Ion Irradiation Facility (HIF) at Cyclone, Université Catholique de Louvain, Belgium.

The device turned out to be sensitive to SEU. Clusters of words errors can be observed with the high LET values.

No SEL were observed.

Two functional errors were observed on one out of two samples. No explanation is available on the origin of these two errors.