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RADIATION TESTING OF UV-EPROMs, FLASH-EPROMs AND EEPROMs FOR SPACE APPLICATIONS.

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ABSTRACT

This ESTEC Working Paper present the results of a Cf-252, heavy ion, proton and Co-60 radiation pre-evaluation programme carried out on a large number of commercially available Programmable Read Only Memories (PROMs). Testing issues, results obtained and recommendations are given for 16 UV-EPROM types, 8 FLASH-EPROM types and 17 EEPROM types.

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1. INTRODUCTION

As part of ESA/ESTEC's radiation pre-screening programme on Dynamic and Static Random Access Memories (DRAMs & SRAMs), a large number of different Nonvolatile memories were also radiation evaluated. These radiation assessed Nonvolatile memory types covered devices from three main groups namely; UltraViolet erasable Electrically Programmable Read Only Memories (UV-EPROMs), FLASH-Erasable and Programmable Read Only Memories (FLASH-EPROMs) and Electrically Erasable and Programmable Read Only Memories (EEPROMs). Today's performance and low cost, together with their high density and low power make several of these types candidate devices for future space flight if acceptable radiation and reliability performance can be demonstrated.

In this paper we try to cover the above mentioned radiation performance and report on testing issues and in details on results obtained. Tested types primarily cover commercially available PROMs but a few MIL and space procured types have also been included. Testing results are presented for heavy ion and proton Single Event Effects (SEE) and Co-60 Total Ionising Dose (TID). With the assessment of 16 different UV-PROM types, 8 different FLASH-EPROM types and 17 EEPROM types, the presented data are far from complete but give a first indication of family and/or type to be considered for further space flight evaluations.

2. PROM TYPES TESTED

The number of PROM types available for this radiation evaluation programme can be found in Table 1A for UV-EPROMs, in Table 1B for FLASH-EPROMs and in Table 1C for EEPROMs. General device information and number of devices exposed to the various radiation tests can also be found in these tables. The only selection criteria for testing these

ID	MANUFACTURER	CAPACITY	PACKAGE MARKING	DATE CODE	DIE - MARKING	SIZE mm²	PACKAGE TYPE	Co-60	CASE	H.ION	PROT.
U V - E P R O M s											
U01	CYPRESS	8Kx8	CY7C263-25PC 91411	9224	7C263A CYPRESS 1990	12.5	PDIP 24	2	-	1	2
U02	HITACHI	32Kx8	HN27C256HG-70 PGM 12.5V	9212	27C256H HITACHI	13.9	CDIP28W	4	1	1	-
U03	MITSUBISHI	32Kx8	M5M27C256K-12 75210P		M5M27C256K	26.9	CDIP28W	4	1	1	-
U04	SGS-THOMSON	32Kx8	M27C256B-15XFI B88AH	9222	27C256 ST 1988	16.9	CDIP28W	4	-	1	1
U05	TOSHIBA	32Kx8	TC57256AD-12 VPP 12.5V	9202EBI	G495 TOSHIBA 1985	20.6	CDIP28W	4	1	1	-
U06	SGS-THOMSON	64Kx8	M27C512-15FI B88AF	9214	M302 ST 1988	27.5	CDIP28W	4	-	1	1
U07	TEXAS INST.	64Kx8	SMJ27C512-20JM 5962-8764	9224A	27C512D TI 1988	24.7	CDIP28W	-	-	1	-
U08	HITACHI	128Kx8	HN27C101AG-15 PGM 12.5V	9202	HN27C101A HITACHI	30.9	CDIP32W	4	1	1	-
U09	MITSUBISHI	128Kx8	M5M27C101K-15 127101		M5M27C101 MITSUBISHI	41.6	CDIP32W	4	1	1	-
U10	TEXAS INST.	128Kx8	TMS27C010A-15 EUE9222000	9222	27C010GU 1989TI	14.6	CDIP32W	4	1	1	1
U11	INTEL	128Kx8	D27C010-150V10 U2201847	1986	27C010 INTEL 1988	23.8	CDIP32W	4	1	1	1
U12	SGS-THOMSON	128Kx8	M27C1001-15FI B88GA	9227E5S	M528 ST 134x316	25.7	CDIP32W	4	-	1	-
U13	NEC	256Kx8	D27C2001D-15 9150FD111	9150	D27C2001A NEC 1988	45.9	CDIP32W	4	-	1	1
U14	SGS-THOMSON	512Kx8	M27C4001-12FI V88JB	9240B	M588 1991 ST 316x317	62.1	CDIP32W	4	-	1	-
U15	TOSHIBA	512Kx8	TC574000D-150 VPP12.5V	9042EAK	TC574000 1988 D707C	83.4	CDIP32W	4	1	2	-
U16	TEXAS INST.	512Kx8	SMJ27C040-12JM	IDL9226AI	T27C040 1990 TI	54.4	CDIP32W	4	1	1	-

Table 1A. Identification of UV-PROMs by ID number, manufacturer, organization, marking, die marking and size, package and number of devices exposed to each test.

ID	MANUFACTURER	CAPACITY	PACKAGE MARKING	DATE CODE	DIE - MARKING	SIZE mm²	PACKAGE TYPE	Co-60	CASE	H.ION	PROT.
F L A S H - E P R O M s											
F01	SGS-THOMSON	32Kx8	M28F256-15BI VP8AB	9309	28F256 1989	23.2	PDIP 32	2	-	-	1
F02	INTEL	64Kx8	P28F512-120 FLASH U10938P2		28F512 INTEL 1990	24.2	PDIP 32	4	-	1	1
F03	TEXAS INST.	64Kx8	TMS28F512-120C3NL	LUE933100	T28F512 1992TI	16.7	PDIP 32	4	-	2	1
F04	AMD	128Kx8	AM29F010-120JC 341JYJT	1991	AMD 1991 98103D	22.8	PLCC 32	-	-	1	-
F05	CATALYST	128Kx8	CAT28F010P-15 OES9213	9213	28F010B 1990 CSI OKI	45.4	PDIP 32	2	-	1	1
F06	INTEL	128Kx8	P28F010-120 FLASH U13602P1		28F010 INTEL 1989	35.3	PDIP 32	4	-	1	1
F07	MITSUBISHI	128Kx8	M5M28F101P-12 312107		M5M28F010 MITSUBISHI	36.5	PDIP 32	3	-	2+1	1
F08	SGS-THOMSON	128Kx8	M28F101-150PI VP8AA	9344	28F101B 1991	32.1	PDIP 32	2	-	2	1

Table 1B. Identification of FLASH-EPROMs by ID number, manufacturer, organization, marking, die marking and size, package and number of devices exposed to each test.

ID	MANUFACTURER	CAPACITY	PACKAGE MARKING	DATE CODE	DIE - MARKING & SIZE	mm²	PACKAGE TYPE	Co-60	H.ION CASE		PROT.
					EEPROMs						
E01	HITACHI	8Kx8	HN58C65P-25 R0432SS0	9216	58C65R HITACHI	24.0	PDIP 28	4	1	-	-
E02	HITACHI	8Kx8	HN58C66P-25 S0432310	9050	58C66S HITACHI	24.0	PDIP 28	4	-	1	1
E03	SAMSUNG	8Kx8	KM28C64-20 104 KOREA		KM28C64Z SAMSUNG 1986	24.5	PDIP 28	4	1	-	1
E04	SEEQ	8Kx8	JANM38510/26003BYA 61394IB9204		52C33 1026 SEEQ 1986	23.1	MLCC 32	3	-	-	-
E05	SGS-THOMSON	8Kx8	M28C64C-20P1 G993A9248	9248	28C64CC 1992 ST	20.3	PDIP 28	3	-	1	1
E06	HITACHI	32Kx8	NH58C256P20	9222	58C256R HITACHI	33.1	PDIP 28	4	-	-	-
E07	HITACHI	32Kx8	HN58C256P-20 R3102340	9232	58C256R HITACHI	33.1	PDIP 28	8	2	1	1
E08	HYBRID M.P.	32Kx8	MEM832VMB-20 6675	9246	15105 ATMEL 1989	44.7	CZIP 28	3	1	-	1
E09	SAMSUNG	32Kx8	KM28C256-20 142 KOREA		KM28C256Y SAMSUNG 1988	45.6	PDIP 28	4	-	-	2
E10	SEEQ	32Kx8	5962-8852506XA C	9223B	57C53B-5001 SEEQ 1989	38.4	CDIP 28	6	2	2	1
E11	SEEQ	32Kx8	DQ28C256-250	9234	52C53 1021 SEEQ 1986	47.9	CDIP 28	6	-	-	-
E12	SEEQ	32Kx8	FM28C256-200	9331	52C53 1021 SEEQ 1986	47.9	MFP 28	-	-	2	1
E13	NEC	32Kx8						4	-	-	-
E14	XICOR	64Kx8	X28C512D-15 V9144ES	9144	X28C512A XICOR 1989	48.5	CDIP 32	4	-	1	1
E15	ATMEL	64Kx16	AT28C1024 15BM/883C 1F 1B9131A		17107 ATMEL	89.2	MDIP 40	2	1	1	-
E16	XICOR	128Kx8	X28C010D-20 V9236ES	9236	X28C010A XICOR 1988	79.4	CDIP 32	4	1	1	1
E17	HYBRID M.P.	128Kx8	MEM8129W-20 7603	9318	58C1000 HITACHI	48.7	MLCC 32	2	-	2	-

Table 1C. Identification of EEPROMs by ID number, manufacturer, organization, marking, die marking and size, package and number of devices exposed to each test.

types were availability and the devices in hand when testing started. However, in some cases the PROM type could not be tested due lack of programming (manufacturer/type information not in programming library) or the plastic above the die could not be removed nondestructively.

3. TEST SYSTEMs

Two dedicated memory test systems, one for TID testing (old tester) [1] and one for SEE testing (new tester) [2], were used. Testing was carried out using a random generated 2Mbit test pattern, checking for functionality errors and monitoring the current. UV-EPROMs and FLASH-EPROMs were programmed prior to test and only checked in read mode whereas EEPROMs were programmed during test, thus tested in both read and write mode. For SEE testing in read mode, following programming, normal read cycles (checking the memory content) were carried out. In write mode, the following test cycle was used: first a write "1" followed by 3 read cycles then a write "0" followed by 3 read cycles. The three read cycles allow the separation of errors into read errors (one error in one of the three read cycles) and in write errors (the same error in all three cycles). For TID testing, following programming with "1", the test cycle was changed to read for 30 minutes then re-programming (write with "0"), 30 minutes read, then re-programming (write with 1), 30 minutes read, and so on.

4. TEST CONDITIONS AND TEST FACILITIES

All results presented here were obtained with VDD = 5.0 V (if biased), using the 2Mbit test pattern and monitoring the ICC current. Initially all PROM types were heavy ion tested in an unbiased condition and in read mode whereas EEPROMs were additionally tested in write mode. Proton and Co-60 TID testing of UV-EPROMs and FLASH-EPROMs were only carried out in read mode and EEPROMs only in write mode. Other tests conditions or different test modes could be considered but for this pre-screening exercise we tried to limit these variables in order to get a first set of radiation data which could be directly compared.

The following test facilities were used during this pre-screening programme -

4.1 "CASE"

ESTEC source IV and V, respectively 1.38 and 1.37 microcuries of Cf-252, were used during these initial "Californium-252 Assessment of Single-event Effects" (CASE) tests [1]. The average Linear Energy Transfer (LET) of Cf-252 is 43.0 MeV/(mg/cm²), a value which has been used for data presentation in this paper. Testing was carried out in vacuum with fission fragment fluxes ranging from 240 to 1600 ions/cm²/min.

4.2 HEAVY ION

SEE heavy ion testing was carried out at the twin Tandem Van de Graaff accelerator at Brookhaven National Laboratory, Long Island, USA. The dedicated Single Event Upset (SEU) test facility at beam line 55° East in target room 4, was used [3][4]. Testing was carried out with ^{197}Au ions at 341 MeV, ^{127}I ions at 320 MeV, ^{79}Br ions at 270 MeV, ^{58}Ni ions at 265 MeV, ^{25}Cl ions at 202 MeV and ^{12}C ions at 98 MeV covering a LET range of 81.8 to 1.45 MeV/(mg/cm²). Testing was carried out in February 1993 (BNL9302), in November 1993 (BNL9311) and in August 1994 (BNL9408).

4.3 PROTON

Proton testing was performed at the Paul Scherrer Institute (PSI), Villigen, Switzerland. Testing was carried out at the Proton Irradiation Facility (PIF) with calibrated beams of 300, 200, 100, 51 and 29 MeV [4]. Testing was carried out in May 1994 (PSI9405).

4.4 TOTAL IONISING DOSE

TID testing was carried out using the ESTEC GAMMABEAM 150C Co-60 facility (original activity 2040 Curies) at dose rates ranging from 0.9 to 2.2 Krads(Si)/hour [1]. Testing was carried out in October 1992 (ESA9210), in January 1993 (ESA9301) and in October 1994 (ESA9410).

5. RADIATION TEST RESULTS

5.1 UV-EPROMs

Initial experience in testing PROMs were obtained during a number of tests performed at ESTEC using the "CASE" system. Results from these tests, which covered 9 different UV-EPROM types, showed for read mode of testing only transient errors (read cycle corrupted) with no loss of the memory content. Test details and results obtained have been summarized in Table 2.

UV-EPROMs, "CASE" SEE RESULTS					
Manufacturer, Type & Serial Number Tested	Fluence ion/ cm^2	Upset's SEU/ SEL	Test Mode	Cross Section cm^2	
				Device	Per Bit
HITACHI 32Kx8 s/n HE5	145899	0/0	READ	<6.9E-6	<2.6E-11
MITSUBISHI 32Kx8 s/n M05	187824	*(1)/0	READ	<5.3E-6	<2.0E-11
TOSHIBA 32Kx8 s/n T06	404157	0/0	READ	<2.5E-6	<9.3E-12
HITACHI 128Kx8 s/n H05	154284	0/0	READ	<6.5E-6	<6.2E-12
MITSUBISHI 128Kx8 s/n M05	110682	0/0	READ	<9.0E-6	<8.6E-12
TEXAS INSTR. 128Kx8 s/n TI5	1571349	*(1)/0	READ	<6.4E-7	<6.1E-13
INTEL 128Kx8 s/n I05	171054	0/0	READ	<5.9E-6	<5.6E-12
TEXAS INSTR. 512Kx8 s/n TI5	355524	0/0	READ	<2.8E-6	<6.7E-13
TOSHIBA 512Kx8 s/n T45	149253	0/0	READ	<6.7E-6	<1.6E-12

* Transient errors (read cycle corrupted).

Table 2. "CASE" SEE results for UV-EPROMs tested in read mode.

Further heavy ion testing of all 16 types, first in unbiased mode and later in read mode, was carried out with the following results. In unbiased mode, each type was irradiated with ^{197}Au ions at 341 MeV having a LET of 81.8 MeV/(mg/cm²) to a fluence of 5.0E6 ions/cm². Following irradiation, their functionality and memory content were checked. As can be seen in Table 3, no errors were seen in any of the UV-EPROM types tested.

Read mode of testing revealed transient errors only with no permanent failures. However, latch-up occurred in 7 of the 16 UV-PROM types tested. Table 4A and 4B gives details of all tests performed and results obtained. As detailed, none of the UV-EPROMs showed SEUs to levels as given in the tables whereas transient errors (one read cycle corrupted) occurred in most tests. Where a latch-up corrupted the testing the term LATCH has been used. Otherwise latch-up sensitivities can also be read from these tables. Six of the latch-up sensitive types were later re-tested with 300 MeV protons at PSI. Test details and results obtained have been summarized in Table 5. None of these six types tested showed latch-ups whereas only five types can be reported free of transient errors or SEUs to test fluences of >1.0E10 protons/cm². Both CYPRESS tested devices showed address failures, 22 in the first device and one in the second device. We have no real explanation for these address errors at the moment. We can only report these observations and stress the need for further testing if clarification is required.

UV-EPROMs, HEAVY ION SEE RESULTS				
Manufacturer, Type & Serial Number Tested	Fluence ion/ cm²	Upset's SEU	LET MeV mg/cm²	Cross Section cm² Device
CYPRESS 8Kx8 s/n C01	5.0E6	0	81.8	<2.0E-7
HITACHI 32Kx8 s/n HE5	5.0E6	0	81.8	<2.0E-7
MITSUBISHI 32Kx8 s/n M05	5.0E6	0	81.8	<2.0E-7
SGS-THOMSON 32Kx8 s/n S05	5.0E6	0	81.8	<2.0E-7
TOSHIBA 32Kx8 s/n T06	5.0E6	0	81.8	<2.0E-7
SGS-THOMSON 64Kx8 s/n S57	5.0E6	0	81.8	<2.0E-7
TEXAS INSTR. 64Kx8 s/n TI9	5.0E6	0	81.8	<2.0E-7
HITACHI 128Kx8 s/n H15	5.0E6	0	81.8	<2.0E-7
MITSUBISHI 128Kx8 s/n M15	5.0E6	0	81.8	<2.0E-7
TEXAS INSTR. 128Kx8 s/n TI5	5.0E6	0	81.8	<2.0E-7
INTEL 128Kx8 s/n I05	5.0E6	0	81.8	<2.0E-7
SGS-THOMSON 128Kx8 s/n S65	5.0E6	0	81.8	<2.0E-7
NEC 256Kx8 s/n N06	5.0E6	0	81.8	<2.0E-7
SGS-THOMSON 512Kx8 s/n S46	5.0E6	0	81.8	<2.0E-7
TEXAS INSTR. 512Kx8 s/n TI7	5.0E6	0	81.8	<2.0E-7
TOSHIBA 512Kx8 s/n T56	5.0E6	0	81.8	<2.0E-7

Table 3. Heavy ion SEE results for UV-EPROMs tested in Unbiased mode.

UV-EPROMs, HEAVY ION SEE RESULTS						
Manufacturer Capacity Device I.D.	Fluence ion cm^2	Upset's TRANS./ SEU/SEL	LET MeV mg/cm^2	Cross Section cm^2		
				Transient	SEU	SEL
CYPRESS 8Kx8 s/n C01	4.3E5	?/0/1	81.8	-	<2.3E-6	**LATCH**
	-	?/0/1	59.7	-	-	**LATCH**
	5.0E5	?/0/10	26.6	-	<2.0E-6	**2.0E-5**
HITACHI 32Kx8 s/n HE5	5.0E6	2/0/3	81.8	4.0E-7	<2.0E-7	**6.0E-7**
	5.0E6	2/0/0	59.7	4.0E-7	<2.0E-7	<2.0E-7
	5.0E6	1/0/0	26.6	2.0E-7	<2.0E-7	<2.0E-7
MITSUBISHI 32Kx8 s/n M05	5.0E6	15/0/0	81.8	3.0E-6	<2.0E-7	<2.0E-7
	5.0E6	20/0/0	59.7	4.0E-6	<2.0E-7	<2.0E-7
	5.0E6	15/0/0	26.6	3.0E-6	<2.0E-7	<2.0E-7
SGS-THOMSON 32Kx8 s/n S05	2.5E6	?/0/9	81.8	-	<4.0E-7	**3.6E-6**
	2.9E5	?/0/4	59.7	-	<3.5E-6	**1.4E-5**
	5.0E6	?/0/19	26.6	-	<2.0E-7	**3.8E-6**
TOSHIBA 32Kx8 s/n T06	1.0E7	26/0/0	81.8	2.6E-6	<1.0E-7	<1.0E-7
	5.0E6	6/0/0	59.7	1.2E-6	<2.0E-7	<2.0E-7
	5.0E6	3/0/0	26.6	6.0E-7	<2.0E-7	<2.0E-7
SGS-THOMSON 64Kx8 s/n S57	4.6E5	?/0/3	81.8	-	<2.2E-6	**6.5E-6**
	6.7E5	?/0/6	59.7	-	<1.5E-6	**9.0E-6**
	3.5E5	?/0/1	26.6	-	<2.9E-6	**LATCH**
TEXAS INSTR. 64Kx8 s/n TI9	5.0E6	29/0/0	81.8	5.8E-6	<2.0E-7	<2.0E-7
	5.0E6	18/0/0	59.7	3.6E-6	<2.0E-7	<2.0E-7
	5.0E6	5/0/0	26.6	1.0E-6	<2.0E-7	<2.0E-7
HITACHI 128Kx8 s/n H15	1.0E7	1/0/0	81.8	1.0E-7	<1.0E-7	<1.0E-7
	5.0E6	1/0/0	59.7	2.0E-7	<2.0E-7	<2.0E-7
	5.0E6	0/0/0	26.6	<2.0E-7	<2.0E-7	<2.0E-7

Table 4A. Heavy ion SEE results for UV-EPROMs tested in Read mode.

UV-EPROMs, HEAVY ION SEE RESULTS						
Manufacturer Capacity Device I.D.	**Fluence ion cm²**	**Upset's TRANS./ SEU/SEL**	**LET MeV mg/cm²**	**Cross Section cm²**		
				Transient	**SEU**	**SEL**
MITSUBISHI 128Kx8 s/n M15	5.0E6	11/0/0	81.8	2.2E-6	<2.0E-7	<2.0E-7
	5.0E6	7/0/0	59.7	1.4E-6	<2.0E-7	<2.0E-7
	5.0E6	2/0/0	26.6	4.0E-7	<2.0E-7	<2.0E-7
TEXAS INSTR. 128Kx8 s/n TI5	1.4E6	?/0/7	81.8	-	<7.1E-7	**5.0E-6**
	8.3E5	?/0/3	59.7	-	<1.2E-6	**3.6E-6**
	5.0E6	?/0/17	26.6	-	<2.0E-7	**3.4E-6**
INTEL 128Kx8 s/n I05	5.0E5	?/0/1	81.8	-	<2.0E-6	**LATCH**
	3.7E5	?/0/2	59.7	-	<2.7E-6	**5.4E-6**
	5.0E6	?/0/4	26.6	-	<2.0E-7	**8.0E-7**
SGS-THOMSON 128Kx8 s/n S65	1.0E7	8/0/0	81.8	8.0E-7	<1.0E-7	<1.0E-7
	5.0E6	2/0/0	59.7	4.0E-7	<2.0E-7	<2.0E-7
	5.0E6	2/0/0	26.6	4.0E-7	<2.0E-7	<2.0E-7
NEC 256Kx8 s/n N06	4.7E5	?/0/2	81.8	-	<2.1E-6	**4.3E-6**
	3.4E5	?/0/1	59.7	-	<2.9E-6	**LATCH**
	5.0E6	?/0/76	26.6	-	<2.0E-7	**1.5E-5**
SGS-THOMSON 512Kx8 s/n S46	5.0E6	4/0/0	81.8	8.0E-7	<2.0E-7	<2.0E-7
	5.0E6	4/0/0	59.7	8.0E-7	<2.0E-7	<2.0E-7
	5.0E6	3/0/0	26.6	6.0E-7	<2.0E-7	<2.0E-7
TEXAS INSTR. 512Kx8 s/n TI7	5.0E6	5/0/0	81.8	1.0E-6	<2.0E-6	<2.0E-7
	5.0E6	4/0/0	59.7	8.0E-7	<2.0E-7	<2.0E-7
	5.0E6	0/0/0	26.6	<2.0E-7	<2.0E-7	<2.0E-7
TOSHIBA 512Kx8 s/n T56	5.0E6	1/0/0	81.8	2.0E-7	<2.0E-7	<2.0E-7
	5.0E6	0/0/0	59.7	<2.0E-7	<2.0E-7	<2.0E-7
	-	-	-	-	-	-

Table 4B. Heavy ion SEE results for UV-EPROMs tested in Read mode.

UV-EPROMs, 300MeV PROTON SEE RESULTS					
Manufacturer, Type & Serial Number Tested	Fluence protons /cm²	Upset's SEU/ SEL	Test Mode	Cross Section cm²	
				Device	Per Bit
CYPRESS 8Kx8 s/n C81	1.08E10	*22/0	READ	2.0E-9	3.1E-14
CYPRESS 8Kx8 s/n C82	1.08E10	*1/0	READ	9.3E-11	1.4E-15
SGS-THOMSON 32Kx8 s/n SU9	1.10E10	0/0	READ	<9.1E-11	<3.5E-16
SGS-THOMSON 64Kx8 s/n ST8	1.10E10	0/0	READ	<9.1E-11	<1.7E-16
INTEL 128Kx8 s/n IU5	1.08E10	0/0	READ	<9.3E-11	<8.8E-17
TEXAS INSTR. 128Kx8 s/n TI6	1.08E10	0/0	READ	<9.3E-11	<8.8E-17
NEC 256Kx8 s/n N25	1.15E10	0/0	READ	<8.7E-11	<4.2E-17

* Address failures (0x0000 instead of 0x0080).

Table 5. Proton SEE results for UV-EPROMs tested in Read mode.

Co-60 TID data for UV-EPROMs are presented in a summary format in Figure 1 and in details in Tables 6A and 6B. Figure 1 presents the TID levels in Krad(Si) as a function of ID number and manufacturer. The Krad(Si) levels given are averaged for the number of devices tested (see Table 1A and/or Tables 6A and 6B). Three failure criteria can be found in this graph: a) the level from which the ICC stand-by current starts to increase (plus 20% level), b) the first functional error level (one error) and c) the final functional failure level (1024 errors in one single test run). In Tables 6A and 6B details of all tests can

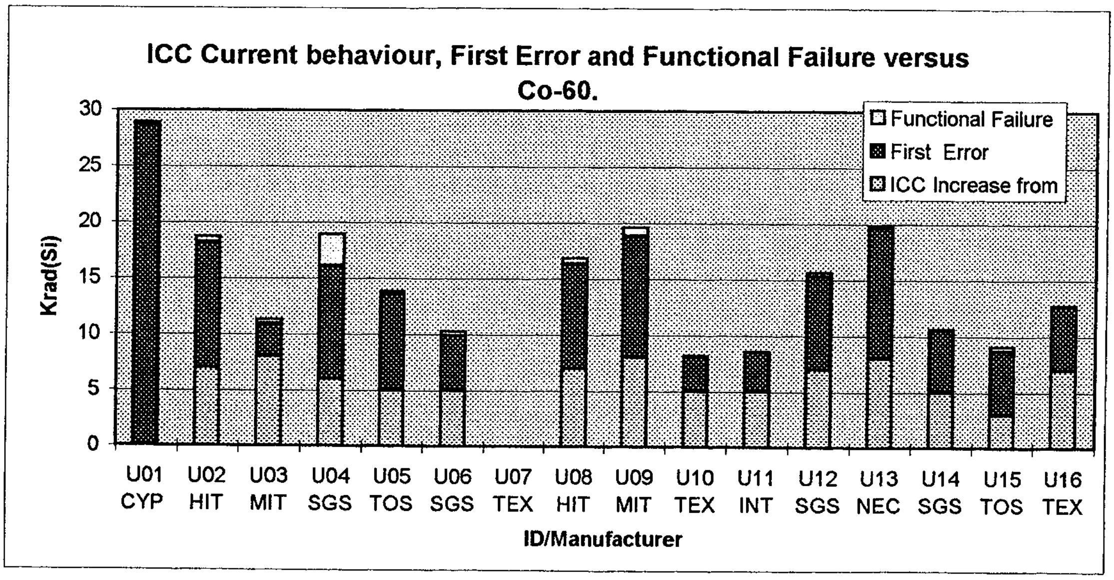

Figure 1. Co-60 TID results for UV-EPROMs.

DEVICE FUNCTION	S/N	D.RATE rad/hr	FUNC. FAILURE Krad(Si)		ICCSB INITIAL mA	ICCOP INITIAL mA	ICCSB FINAL	ICCOP FINAL	ANNEA-LING	REMARKS
UV-EPROMs, Co-60 RESULTS										
CYPRESS CY7C263-25PC 8Kx8	C81	1800	29.5	29.6	26.40	34.43	*45.40	*49.51	FAIL	ICC increase from ? Krad * ICC measuring problems, tester
	C82	1800	27.9	28.2	26.40	34.43	*45.40	*49.51	FAIL	
HITACHI HN27C256HG-70 32Kx8	H01	1900	18.2	18.7	*	*	8.31	12.94	FAIL	ICC increase from 7 Krad * ICC measuring problems, tester
	H02	1900	18.2	18.7	*	*	8.31	12.99	FAIL	
	H03	1900	18.2	18.7	*	*	8.31	12.90	WORK	
	H04	1900	18.2	18.7	*	*	8.31	12.99	FAIL	
MITSUBISHI M5M27C256K-12 32Kx8	M01	2960	10.9	11.3	0.01	0.31	0.60	0.77	FAIL	ICC increase from 8 Krad
	M02	2960	11.3	11.6	0.01	0.26	0.60	0.82	FAIL	
	M03	2960	10.6	11.3	0.01	0.26	0.60	0.87	FAIL	
	M04	2960	10.6	10.9	0.01	0.26	0.60	0.87	FAIL	
SGS-THOMSON M27C256B-15 32Kx8	S21	910	20.2	21.4	0.05	0.39	18.86	19.50	WORK	ICC increase from 6 Krad
	S22	910	10.9	18.2	0.05	0.39	18.86	14.68	FAIL	
	S23	910	15.3	16.5	0.05	0.39	18.86	11.81	WORK	
	S24	910	17.9	19.3	0.05	0.39	18.86	16.29	WORK	
TOSHIBA TC57256AD-12 32Kx8	T01	1900	12.7	13.2	0.00	0.20	7.45	6.45	FAIL	ICC increase from 5 Krad
	T02	1900	13.5	14.4	0.00	0.15	7.45	7.55	FAIL	
	T03	1900	13.2	12.7	0.00	0.20	7.45	7.05	FAIL	
	T04	1900	14.5	15.0	0.00	0.15	7.45	7.50	FAIL	
SGS-THOMSON M27C512-15FI 64Kx8	S51	1250	10.5	11.0	0.05	0.45	8.77	8.31	WORK	ICC increase from 5 Krad
	S52	1250	10.8	11.6	0.05	0.54	8.77	9.16	WORK	
	S53	1250	9.4	9.7	0.05	0.49	8.77	5.42	WORK	
	S54	1250	9.0	9.0	0.05	0.44	8.77	4.15	WORK	
HITACHI HN27C101AG-15 128Kx8	H01	1120	15.5	16.2	0.00	0.29	7.66	5.22	WORK	ICC increase from 7 Krad
	H02	1120	18.8	19.3	0.00	0.24	7.66	7.95	WORK	
	H03	1120	16.5	16.9	0.00	0.29	7.66	5.78	WORK	
	H04	1120	14.2	14.6	0.00	0.24	7.66	4.20	WORK	
MITSUBISHI M5M27C101K-15 128Kx8	M01	2960	18.8	20.0	0.00	0.39	12.37	11.37	FAIL	ICC increase from 8 Krad
	M02	2960	18.7	19.3	0.00	0.44	12.37	9.96	FAIL	
	M03	2960	17.9	18.6	0.00	0.39	12.37	10.00	FAIL	
	M04	2960	19.8	20.4	0.00	0.44	12.37	12.76	FAIL	

Table 6A. Co-60 TID results for UV-EPROMs.

DEVICE FUNCTION	S/N	D.RATE rad/hr	FUNC. FAILURE Krad(Si)		ICCSB INITIAL mA	ICCOP	ICCSB FINAL	ICCOP	ANNEA-LING	REMARKS
UV-EPROMs, Co-60 RESULTS										
TEXAS INSTR. TM27C010A-15 128Kx8	T01	1120	7.2	7.2	0.09	0.33	13.91	5.39	WORK	ICC increase from 5 Krad
	T02	1120	7.7	7.8	0.09	0.33	13.91	6.77	WORK	
	T03	1120	8.6	8.7	0.09	0.33	13.91	13.76	WORK	
	T04	1120	8.7	8.8	0.09	0.33	13.91	13.81	WORK	
INTEL D27C010-150V 128Kx8	I01	1900	10.8	10.8	0.06	0.21	18.12	18.17	WORK	ICC increase from 5 Krad
	I02	1900	7.9	7.9	0.06	0.21	18.12	2.32	WORK	
	I03	1900	7.9	7.9	0.06	0.21	18.12	2.32	WORK	
	I04	1900	7.2	7.2	0.06	0.21	18.12	1.02	WORK	
SGS-THOMSON M27C1001-15FI 128Kx8	S11	910	14.2	14.4	0.00	0.34	10.44	7.89	FAIL	ICC increase from 7 Krad
	S12	910	14.6	17.2	0.00	0.34	10.44	11.49	WORK	
	S13	910	16.2	18.8	0.00	0.29	10.44	12.20	FAIL	
	S14	910	16.1	16.1	0.00	0.29	10.44	11.03	FAIL	
NEC D27C2001D-15 256Kx8	N01	1460	16.6	16.9	0.00	0.20	25.00	24.51	FAIL	ICC increase from 8 Krad
	N02	1460	17.0	17.4	0.00	0.20	25.00	24.51	FAIL	
	N03	1460	20.5	20.7	0.00	0.20	25.00	24.51	WORK	
	N04	1460	24.2	24.6	0.00	0.20	25.00	24.51	WORK	
SGS-THOMSON M27C4001-12FI 512Kx8	S41	2080	10.8	10.9	0.02	0.37	19.24	20.51	WORK	ICC increase from 5 Krad
	S42	2080	10.2	10.2	0.02	0.37	19.24	18.30	WORK	
	S43	2080	10.4	10.5	0.02	0.32	19.24	21.05	WORK	
	S44	2080	10.4	10.4	0.02	0.41	19.24	19.03	WORK	
TEXAS INSTR. SMJ27C040-12J 512Kx8	TU1	1900	9.1	9.1	0.00	0.54	37.00	24.77	WORK	ICC increase from 3 Krad
	TU2	1900	8.1	8.3	0.00	0.44	37.00	24.67	FAIL	
	TU3	1900	7.8	8.9	0.00	0.49	37.00	24.67	FAIL	
	TU4	1900	9.6	9.9	0.00	0.34	37.00	24.67	WORK	
TOSHIBA TC574000D-150 512Kx8	T41	1900	11.8	12.0	0.06	0.55	19.73	19.87	WORK	ICC increase from 7 Krad
	T42	1900	12.3	12.5	0.06	0.60	19.73	19.87	WORK	
	T43	1900	12.8	12.8	0.06	0.50	19.73	16.54	WORK	
	T44	1900	13.3	13.4	0.06	0.45	19.73	13.36	WORK	

Table 6B. Co-60 TID results for UV-EPROMs.

be found. Device function, serial number, dose rate in rad(Si)/hour, functional failure levels for the first bit error and for 1Kbit errors, initial and final standby (ICCSB) and operating (ICCOP) current and annealing behaviour, are given. However, functional failure levels should always be seen in respect to current behaviour as given in the last column "Remarks". The annealing results, "FAIL" or "WORK", are given as measured after one week unbiased at room temperature.

All UV-EPROMs showed ICC current increases during the tests but no levels are given for the Cypress 8Kx8 (U01). Strong current increase occurred but the starting value could not be identified due to measuring problems with the memory tester. Also Hitachi 32Kx8 (U02) experienced ICC measuring problems but only with the initial values. Otherwise quite acceptable TID levels were found for several of the tested types with ICC current levels, first error levels and functional failure levels as presented in Figure 1, Tables 6A and 6B.

5.2 FLASH-EPROMs

Having no FLASH-EPROMs available during the initial "CASE" testing the first set of radiation data comes from the heavy ion testing. In unbiased mode, three FLASH-EPROMs, Intel 64Kx8 (F02), Catalyst 128Kx8 (F05) and Intel 128Kx8 (F06), were tested with ^{79}Br ions at 285 MeV having a LET of 74.4 MeV/(mg/cm^2). Testing and checking was carried out as for the UV-EPROMs. As can be seen in Table 7, no errors were seen in any of these devices up to a fluence of 1.0E6 ions/cm^2 or a cross section level of <1.0E-6 cm^2/device.

FLASH-EPROMs, HEAVY ION SEE RESULTS				
Manufacturer, Type & Serial Number Tested	**Fluence ion/cm^2**	**Upset's SEU**	**LET MeV mg/cm^2**	**Cross Section cm^2 Device**
INTEL 64Kx8 s/n I05	1.0E6	0	74.4	<1.0E-6
CATALYST 128Kx8 s/n C01	1.0E6	0	74.4	<1.0E-6
INTEL 128Kx8 s/n IF6	1.0E6	0	74.4	<1.0E-6

Table 7. Heavy ion SEE results for FLASH-EPROMs tested in Unbiased mode.

Read mode of testing gave quite different results for the 7 FLASH-EPROM types tested. Table 8 give details of all tests performed and results obtained. As shown, Intel 64Kx8 (F02) and Intel 128Kx8 (F06) suffered from latch-up at LET from 22.9 MeV/(mg/cm^2) but did not lose their stored content. AMD 128Kx8 (F04) lost its content when irradiated with ions having LETs of 37.5 MeV/(mg/cm^2) and 11.7 MeV/(mg/cm^2) but worked when tested at a LET of 6.9 MeV/(mg/cm^2). Catalyst 128Kx8 (F05) showed several error modes but no latch-up. Single bit, 1K page errors and complete erasure happened at a LET of 74.4 MeV/(mg/cm^2), 1K page errors at a LET of 11.4 MeV/(mg/cm^2) and word errors at a LET of 2.9 MeV/(mg/cm^2). T.I. 64Kx8 (F03), Mitsubishi 128Kx8 (F07) and SGS-Thomson 128Kx8 (F08) showed only transient errors when irradiating with high LET ^{79}Br ions.

Apart from the AMD 128Kx8 (F04), the other seven FLASH types went through a 300 MeV proton exposure to fluences of >1.0E10 protons/cm^2. As detailed in Table 9, none of the FLASH types showed latch-ups, transient errors or SEUs during these tests.

FLASH-EPROMs, HEAVY ION SEE RESULTS						
Manufacturer Capacity Device I.D.	Fluence ion cm^2	Upset's TRANS./ SEU/SEL	LET MeV mg/cm^2	Cross Section cm^2		
				Transient	SEU	SEL
INTEL 64Kx8 s/n I05	5.1E5	0/0/1	37.2	<2.0E-6	<2.0E-6	**LATCH**
	1.0E6	0/0/0	22.9	<1.0E-6	<1.0E-6	<1.0E-6
	1.0E6	0/0/0	16.2	<1.0E-6	<1.0E-6	<1.0E-6
	1.0E6	0/0/0	11.4	<1.0E-6	<1.0E-6	<1.0E-6
TEXAS INST. 64Kx8 s/n TF3/TF4	2.0E6	0/0/0	75.0	<5.0E-7	<5.0E-7	<5.0E-7
	2.0E6	3/0/0	37.5	1.5E-6	<5.0E-7	<5.0E-7
	-	-	-	-	-	-
AMD 138Kx8 s/n A01	3.0E5	0/1/0	37.5	<2.0E-6	ERASED	<2.0E-6
	7.0E5	0/1/0	11.7	<1.4E-6	ERASED	<1.4E-7
	1.0E6	0/0/0	6.9	<1.0E-6	<1.0E-6	<1.0E-6
CATALYST 128Kx8 s/n C01	1.0E6	0/6/0	74.4	<1.0E-6	ERASED	<1.0E-6
	8.2E5	0/3/0	11.4	<1.2E-6	3.7E-6	<1.2E-6
	1.0E6	0/2/0	2.9	<1.0E-6	2.0E-6	<1.0E-6
	1.0E6	0/0/0	1.5	<1.0E-6	<1.0E-6	<1.0E-6
INTEL 128Kx8 s/n IF6	7.3E4	0/0/1	37.2	<1.4E-5	<1.4E-5	**LATCH**
	6.4E5	0/0/1	22.9	<1.6E-6	<1.6E-6	**LATCH**
	1.0E6	0/0/0	16.2	<1.0E-6	<1,0E-6	<1.0E-6
	1.0E6	0/0/0	11.4	<1.0E-6	<1.0E-6	<1.0E-6
MITSUBISHI 128Kx8 s/n M01/M02	2.0E6	1/0/0	75.0	5.0E-7	<5.0E-7	<5.0E-7
	2.0E6	0/0/0	37.5	<5.0E-7	<5.0E-7	<5.0E-7
	-	-	-	-	-	-
SGS-THOMSON 128Kx8 s/n ST1/ST2	2.0E6	3/0/0	75.0	1.5E-6	<5.0E-7	<5.0E-7
	2.0E6	3/0/0	37.5	1.5E-6	<5.0E-7	<5.0E-7
	-	-	-	-	-	-

Table 8. Heavy ion SEE results for FLASH-EPROMs tested in Read mode.

FLASH-EPROM, 300MeV PROTON SEE RESULTS					
Manufacturer, Type & Serial Number Tested	Fluence protons /cm^2	Upset's SEU/ SEL	Test Mode	Cross Section cm^2	
				Device	Per Bit
SGS-THOMSON 32Kx8 s/n S25	1.09E10	0/0	READ	<9.2E-11	<3.5E-16
INTEL 64Kx8 s/n I06	1.26E10	0/0	READ	<7.9E-11	<1.5E-16
TEXAS INSTR. 62Kx8 s/n TF1	1.09E10	0/0	READ	<9.2E-11	<1.8E-16
CATALYST 128Kx8 s/n CF1	1.09E10	0/0	READ	<9.2E-11	<8.8E-17
INTEL 128Kx8 s/n IF5	1.26E10	0/0	READ	<7.9E-11	<7.6E-17
MITSUBISHI 128Kx8 s/n MF8	1.09E10	0/0	READ	<9.2E-11	<8.8E-17
SGG-THOMSON 128Kx8 s/n S4	1.09E10	0/0	READ	<9.2E-11	<8.8E-17

Table 9. Proton SEE results for FLASH-EPROMs tested in read mode.

Co-60 TID data for FLASH-EPROMs are presented in a summary format in Figure 2 and in details in Table 10. Testing was carried out on the same seven FLASH types as were proton tested. Figure 2 presents the TID levels in Krad(Si) as a function of ID number and manufacturer. The Krad(Si) levels given are averaged for the number of devices tested (see Table 1B and/or Table 10). Again three failure criteria can be found: a) the level from which the ICC stand-by current starts to increase (plus 20% level), b) the first functional error level (one error) and c) the final functional failure level (1024 errors in one single test run). In Table 10 test details and results are presented in the same way as for UV-EPROMs. Device type, serial number, dose rate in rad(Si)/hour, functional failure levels for the first bit error and for 1Kbit errors, initial and final standby (ICCSB) and operating (ICCOP)

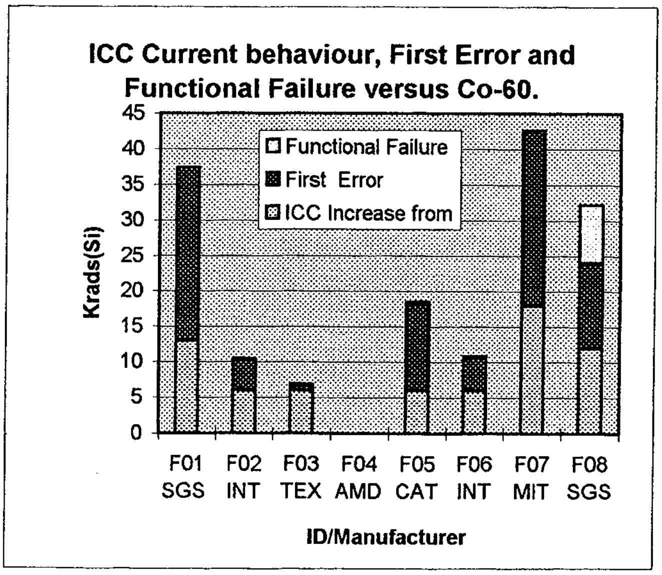

Figure 2. Co-60 TID results for FLASH-EPROMs.

current and annealing behaviour, are given. However, functional failure levels should always be seen in respect to current behaviour as given in the last column "Remarks". The annealing results, "FAIL" or "WORK", are given as measured after one week unbiased at room temperature.

Although higher functional failure levels were found for several of the TID tested FLASH-EPROMs they all showed ICC current increases which have to be considered. So for FLASH-EPROMs interesting TID levels can be reported with ICC current levels, first error and functional failure levels as presented in Figure 2 or Table 10.

DEVICE FUNCTION	S/N	D.RATE rad/hr	FUNC. FAILURE Krad(Si)		ICCSB INITIAL mA	ICCOP INITIAL mA	ICCSB FINAL	ICCOP FINAL	ANNEA-LING	REMARKS
FLASH-EPROMs, Co-60 RESULTS										
SGS-THOMSON M28F256-15BI 32Kx8	S24	1800	>37.4	>37.4	0.00	0.44	1.93	2.31	WORK	ICC increase from 13 Krad
	S25	1800	>37.4	>37.4	0.00	0.44	1.93	2.32	WORK	
INTEL P28F512-120 64Kx8	I01	1120	11.5	11.8	0.00	0.29	18.60	18.21	WORK	ICC increase from 6 Krad
	I02	1120	10.8	11.0	0.00	0.34	18.60	14.40	WORK	
	I03	1120	9.6	9.8	0.00	0.29	18.60	9.60	WORK	
	I04	1120	9.2	9.5	0.00	0.29	18.60	8.98	WORK	
TEXAS INSTR. TMS28F512-120 64Kx8	TF1	1460	5,6	5.9	0.00	0.15	0.81	0.95	FAIL	ICC increase from 6 Krad
	TF2	1460	5.7	6.0	0.00	0.15	0.81	0.95	FAIL	
	TF3	1460	5.9	6.3	0.00	0.15	0.81	0.95	FAIL	
	TF4	1460	9.0	9.4	0.00	0.15	0.81	0.95	WORK	
CATALYST CAT28F010P-12 128Kx8	CF1	1800	17.7	18.1	0.02	0.20	23.45	23.84	FAIL	ICC increase from 6 Krad
	CF2	1800	18.4	18.8	0.02	0.20	23.45	23.84	FAIL	
INTEL P28F010-120 128Kx8	IF1	1120	9.0	9.2	0.01	0.26	18.41	4.50	WORK	ICC increase from 6 Krad
	IF2	1120	10.0	10.1	0.01	0.16	18.41	8.32	WORK	
	IF3	1120	12.3	12.5	0.01	0.26	18.41	18.41	WORK	
	IF4	1120	10.9	11.1	0.01	0.26	18.41	11.33	WORK	
MITSUBISHI M5M28F101P-12 128Kx8	MF6	2170	>42.7	>42.7	0.01	0.34	7.76	7.94	WORK	ICC increase from 18 Krad
	MF7	2170	>42.7	>42.7	0.01	0.34	7.76	7.94	WORK	
	MF8	2170	>42.7	>42.7	0.01	0.34	7.76	7.94	WORK	
SGS-THOMSON M28F101-150PI 128Kx8	ST4	1800	25.9	33.9	0.00	0.20	2.90	3.25	FAIL	ICC increase from 12 Krad
	ST5	1800	22.0	30.5	0.00	0.20	2.90	3.25	FAIL	

Table 10. Co-60 TID results for FLASH-EPROMs.

5.3 EEPROMs

ESTEC "CASE" testing of several EEPROM types in either unbiased, read or write mode of operation showed errors only in the write mode as previously reported in [5]. Devices tested, test condition, fluence in particles cm², errors and cross section results in cm² for these tests are presented in Table 11. As can be seen, Hitachi 32Kx8 (E07) and Seeq 32Kx8 (E10) failed totally during these "write" tests whereas Xicor 128K8 (E16) needed a power off for recovery.

MANUFACTURER CAPACITY	TEST CONDITION	FLUENCE p. cm²	ERRORS SEU/SEL	CROSS SECTION cm² DEVICE	PER BIT
SEEQ 32Kx8	UNBIASED	1393218	0/0	<7.2E-07	<2.7E-12
SEEQ 32Kx8	READ	484428	0/0	<2.1E-06	<7.9E-12
SEEQ 32Kx8	WRITE	1529605	*48/0	3.1E-05	1.2E-10
HITACHI 32Kx8	UNBIASED	717315	0/0	<1.4E-06	<5.3E-12
HITACHI 32Kx8	READ	1378080	0/0	<7.3E-07	<2.8E-12
HITACHI 32Kx8	WRITE	180235	*11/0	6.1E-05	2.3E-10
HITACHI 8Kx8	READ	132483	0/0	<7.6E-06	<1.2E-10
SAMSUNG 8Kx8	READ	119067	0/0	<8.4E-06	<1.3E-10
ATMEL 64Kx16	READ	246519	0/0	<4.1E-06	<3.9E-12
HYBRID 32Kx8	WRITE	84535	5/0	5.9E-05	2.3E-10
XICOR 128Kx8	WRITE	20735	#1/0	4.8E-05	4.6E-11

* Re-programming failure # Reset only possible with power off

Table 11. "CASE" SEE summary results for EEPROMs.

Unbiased heavy ion testing of 9 EEPROM types, with either ^{127}I ions at a LET of 84.4 MeV/(mg/cm²) or with ^{79}Br ions at a LET of 74.4 MeV/(mg/cm²), showed no errors when checked after irradiation. EEPROMs tested, test levels, LET and cross section results can be found in Table 12.

Read mode of testing of the same 9 types revealed quite different error modes ranging from transient read errors to device erasures. Tables 13A and 13B give details of all tests performed and results obtained but for clarification errors per device type will be described. As detailed, Hitachi 8Kx8 (E02) only showed transient errors (error occurring

EPROMs, HEAVY ION SE RESULTS				
Manufacturer, Type & Serial Number Tested	**Fluence ion/ cm^2**	**Upset's SEU**	**LET MeV mg/cm^2**	**Cross Section cm^2 Device**
E02 HITACHI 8Kx8 s/n 661/62	2.0E6	0	84.5	<5.0E-7
E05 SGS-THOMSON 8Kx8 s/n S05	1.0E6	0	74.4	<1.0E-6
E07 HITACHI 32Kx8 s/n HE5	1.0E6	0	84.5	<1.0E-6
E10 SEEQ 32Kx8 s/n #10/13	2.0E6	0	84.5	<5.0E-7
E12 SEEQ 32Kx8 s/n S01/02	2.0E6	0	74.4	<5.0E-7
E14 XICOR 64Kx8 s/n X15	1.0E6	0	74.4	<1.0E-6
E15 ATMEL 64Kx16 s/n A01	1.0E6	0	74.4	<1.0E-6
E16 XICOR 128Kx8 s/n X05	1.0E6	0	74.4	<1.0E-6
E17 HYBRID 128Kx8 s/n H01/02	2.0E6	0	74.4	<5.0E-7

Table 12. Heavy ion SEE results for EEPROMs tested in Unbiased mode.

just once) with the first error at a LET of 53.2 MeV/(mg/cm^2) [6]. SGS-Thomson 8Kx8 (E05) showed Latch-up at a LET of 37.2 MeV/(mg/cm^2) and device erasure (re-writable) at a LET of 11.4 MeV/(mg/cm^2). Hitachi 32Kx8 (E07) only showed one transient error at a LET of 59.7 MeV/(mg/cm^2). Seeq 32Kx8 (E10) passed a LET of 59.7 MeV/(mg/cm^2) with no errors but latched all the way down to a LET of 26.6 MeV/(mg/cm^2). Seeq 32Kx8 (E12) showed transient bit errors at all four LET values and a word erasure at a LET of 37.2 MeV/(mg/cm^2). Xicor 64Kx8 (E14) showed device erasures at LETs of 11.4 MeV/(mg/cm^2) and 37.2 MeV/(mg/cm^2), however, a power off/on (without re-writing) returned the device to full functionality, thus reading without errors. This behaviour could possibly be related to a low current latch-up in the control circuitry preventing any read operations. Atmel 64Kx16 (E15) showed transient bit, word and block errors and device erasure (re-writable) over the LET range of 22.9 to 74.4 MeV/(mg/cm^2). The other Xicor, the 128Kx8 (E16), showed read errors which possibly could be classified as "chessboard errors". These address errors were observed at both tested LETs. Finally the Hybrid 128Kx8 (E17) showed only one transient word error at a LET of 52.6 MeV/(mg/cm^2). In summary for these read tests, a surprisingly large number of devices showed unexpected erasures or failures which need further attention. Any EEPROM type considered for space should also be evaluated in detail against possible "read" errors, failures or erasures.

In write mode of testing all 9 EEPROM types showed errors or loss of functionality as detailed in Tables 14A and 14B. Results for Hitachi 8Kx8 (E02) were previously reported in [6] and for Hitachi 32Kx8 (E07) and Seeq 32Kx8 (E10) in [5]. These data, together with Seeq 32Kx8 (E12) and Hybrid M.P. 128Kx8 (E17) results, can also be found in a graphical form in Appendix A. Otherwise we can report that Hitachi 8Kx8 (E02) showed quite a

EEPROMs, HEAVY ION SEE RESULTS						
Manufacturer Capacity Device I.D.	Fluence ion cm^2	Upset's TRANS./ SEU/SEL	LET MeV mg/cm^2	Cross Section cm^2		
				Transient	SEU	SEL
E02 HITACHI 8Kx8 s/n 661/62	2.0E6	7/0/0	59.7	3.5E-6	<5.0E-7	<5.0E-7
	2.0E6	1/0/0	53.2	5.0E-7	<5.0E-7	<5.0E-7
	2.0E6	0/0/0	37.6	<5.0E-7	<5.0E-7	<5.0E-7
	2.0E6	0/0/0	37.6	<5.0E-7	<5.0E-7	<5.0E-7
E05 SGS-THOMSON 8Kx8 s/n S05	2.1E5	0/0/1	37.2	<4.8E-6	<4.8E-6	**4.8E-6**
	7.7E5	0/1/0	11.4	<1.3E-6	1.3E-6	1.3E-6
	-	-	-	-	-	-
E07 HITACHI 32Kx8 s/n HE5	5.9E5	1/0/0	59.7	1.7E-6	<1.7E-6	<1.7E-6
	1.0E5	0/0/0	37.6	<1.0E-5	<1.0E-5	<1.0E-5
	1.0E5	0/0/0	26.6	<1.0E-5	<1.0E-5	<1.0E-5
E10 SEEQ 32Kx8 s/n #10/13	2.5E5	**0/0/14**	59.7	<4.0E-6	<4.0E-6	**5.6E-5**
	1.4E6	**0/0/62**	53.2	<7.2E-7	<7.2E-7	**4.5E-5**
	2.0E6	**0/0/48**	37.6	<5.0E-7	<5.0E-7	**2.4E-5**
	2.0E6	**0/0/15**	26.6	<5.0E-7	<5.0E-7	**7.5E-6**
E12 SEEQ 32Kx8 s/n S01/02	2.0E6	4/0/0	74.4	2.0E-6	<5.0E-7	<5.0E-7
	2.0E6	2/0/0	52.6	1.0E-6	<5.0E-7	<5.0E-7
	2.2E6	1/1/0	37.2	4.6E-7	4.6E-7	<4.6E-7
	2.0E6	2/0/0	26.6	1.0E-6	<5.0E-7	<5.0E-7

Table 13A. Heavy ion SEE results for EEPROMs tested in Read mode.

EEPROMs, HEAVY ION SEE RESULTS						
Manufacturer Capacity Device I.D.	Fluence ion cm^2	Upset's TRANS./ SEU/SEL	LET MeV mg/cm^2	Cross Section cm^2		
				Transient	SEU	SEL
E14 XICOR 64Kx8 s/n X15	4.1E5	0/(1)/0	37.2	<2.4E-6	2.4E-6	<2.4E-6
	4.8E5	0/(1)/0	11.4	<2.1E-6	2.1E-6	<2.1E-6
	-	-	-	-	-	-
E15 ATMEL 64Kx16 s/n A01	7.8E5	5/1/0	74.4	6.4E-6	1.3E-6	<1.3E-6
	2.2E5	2/1/0	52.6	9.1E-6	4.6E-6	<4.6E-6
	1.0E6	3/0/0	37.2	3.0E-6	<1.0E-6	<1.0E-6
	8.3E5	11/1/0	22.9	1.3E-5	1.2E-6	<1.2E-6
	1.0E6	0/0/0	16.2	<1.0E-6	<1.0E-6	<1.0E-6
	1.0E6	0/0/0	11.4	<1.0E-6	<1.0E-6	<1.0E-6
E16 XICOR 128Kx8 s/n X05	4.3E5	?/Many/?	37.2	?	?	?
	3.2E5	?/Many/?	22.9	?	?	?
	-	-	-	-	-	-
E17 HYBRID 128K8 s/n H01/02	2.0E6	0/0/0	74.4	<5.0E-7	<5.0E-7	<5.0E-7
	2.0E6	1/0/0	52.6	5.0E-7	<5.0E-7	<5.0E-7
	2.0E6	0/0/0	37.2	<5.0E-7	<5.0E-7	<5.0E-7
	2.0E6	0/0/0	22.9	<5.0E-7	<5.0E-7	<5.0E-7

Table 13B. Heavy ion SEE results for EEPROMs tested in Read mode.

EEPROMs, HEAVY ION SEE RESULTS						
Manufacturer Capacity Device I.D.	Fluence ion cm²	Upset's TRANS./ SEU/SEL	LET MeV mg/cm²	Cross Section cm²		
				Transient	SEU	SEL
E02 HITACHI 8Kx8 s/n 661/62	2.0E6	0/1147/0	53.2	-	5.7E-4	<5.0E-7
	2.0E6	0/708/0	37.6	-	3.5E-4	<5.0E-7
	2.0E6	0/447/0	26.6	-	2.2E-4	<5.0E-7
	2.0E5	0/32/0	23.2	-	1.6E-4	<5.0E-6
	2.0E5	0/20/0	16.4	-	1.0E-4	<5.0E-6
	2.0E5	0/9/0	11.4	-	4.5E-5	<5.0E-6
	4.2E6	0/0/0	6.9	-	<2.4E-7	<2.4E-7
E05 SGS-THOMSON 8Kx8 s/n S05	1.0E6	0/0/0	2.9	-	<1.0E-6	<1.0E-6
	1.0E6	0/0/0	1.5	-	<1.0E-6	<1.0E-6
	-	-	-	-	-	-
E07 HITACHI 32Kx8 s/n HE5	1.0E5	0/36/0	53.2	-	3.6E-4	<1.0E-5
	6.0E4	0/13/0	37.6	-	2.2E-4	<1.7E-5
	1.0E5	0/20/0	26.6	-	2.0E-4	<1.0E-5
	1.0E6	0/48/0	23.2	-	4.8E-5	<1.0E-6
	1.0E6	0/16/0	16.4	-	1.6E-5	<1.0E-6
	1.0E6	0/4/0	11.6	-	4.0E-6	<1.0E-6
	3.5E6	0/0/0	6.9	-	<2.9E-7	<2.9E-7
E10 SEEQ 32Kx8 s/n #10/13	2.0E6	0/100/1	26.6	-	5.0E-5	**5.0E-7**
	3.0E5	0/9/0	23.2	-	3.0E-5	<3.3E-6
	2.0E5	0/5/0	16.4	-	2.5E-5	<5.0E-6
	2.0E5	0/0/0	11.6	-	<5.0E-6	<5.0E-6
	5.4E6	0/7/0	6.9	-	1.3E-6	<1.9E-7
E12 SEEQ 32Kx8 s/n S01/02	2.1E5	0/324/0	52.6	-	1.6E-3	<4.8E-6
	1.5E5	0/244/0	37.2	-	1.7E-3	<6.8E-6
	7.2E4	0/97/0	26.6	-	1.4E-3	<1.4E-5
	4.1E5	0/246/0	11.4	-	5.9E-4	<2.4E-6
	2.0E6	0/1/0	2.9	-	5.0E-7	<5.0E-7

Table 14A. Heavy ion SEE results for EEPROMs tested in Write mode.

EEPROMs, HEAVY ION SEE RESULTS						
Manufacturer Capacity Device I.D.	Fluence ion cm²	Upset's TRANS./ SEU/SEL	LET MeV mg/cm²	Cross Section cm²		
				Transient	SEU	SEL
E14 XICOR 64Kx8 s/n X15	1.0E6	0/27/0	2.9	-	2.7E-5	<1.0E-6
	1.0E6	0/15/0	1.5	-	1.5E-5	<1.0E-6
	-	-	-	-	-	-
E15 ATMEL 64Kx16 s/n A01	3.1E5	0/11/0	37.2	-	3.5E-5	<3.2E-6
	9.9E5	0/44/0	16.2	-	4.5E-5	<1.0E-6
	1.0E6	0/6/0	11.4	-	6.0E-6	<1.0E-6
E16 XICOR 128Kx8 s/n X05	1.0E6	0/47/0	2.9	-	4.7E-5	<1.0E-6
	1.0E6	0/25/0	2.1	-	2.5E-5	<1.0E-6
	8.8E5	0/23/0	1.5	-	2.6E-5	<1.1E-6
E17 HYBRID 128K8 s/n H01/02	6.5E5	0/150/0	52.6	-	2.3E-4	<1.5E-6
	1.8E6	0/306/0	37.2	-	1.7E-4	<5.6E-7
	3.0E5	0/97/0	26.6	-	1.3E-4	<3.3E-6
	1.0E6	0/72/0	22.9	-	7.2E-5	<1.0E-6
	1.0E6	0/29/0	16.2	-	2.9E-5	<1.0E-6
	1.0E6	0/5/0	11.4	-	5.0E-6	<1.0E-6

Table 14B. Heavy ion SEE results for EEPROMs tested in Write mode.

sensitive behaviour with a write LET threshold between 6.9 and 11.6 MeV/(mg/cm²) and a saturated cross section of about 1.0E-3 cm². SGS-Thomson 8Kx8 (E05), only tested with Carbon ions having a LET of 2.9 MeV/(mg/cm²), passed without errors a fluence of 1.0E6 ions/cm². Seeq 32Kx8 (E10) still latched in write mode at a LET of 26.6 MeV/(mg/cm²) but passed a LET of 23.2 MeV/(mg/cm²). Write mode errors point in the direction of a threshold value of about 6.0 MeV/(mg/cm²) whereas no saturated value can be given due to lack of reliable test data above a LET level of 26.6 MeV/(mg/cm²). Seeq 32Kx8 (E12) showed no latch-ups up to a LET of 52.6 MeV/(mg/cm²) but bit, byte and block errors down to a LET of 2.9 MeV/(mg/cm²). Limited testing of Xicor 64Kx8 (E14) and 128Kx8 (E16) showed bit errors even down to LETs of 1.45 and 2.9 MeV/(mg/cm²), thus very sensitive types. Atmel 64Kx16 (E15) showed a slightly better performance with bit, byte and block errors down to the lowest LET value tested at, a LET value of 11.4 MeV/(mg/cm²) but showed address failure at a LET of 37.2 MeV/(mg/cm²). Hybrid 128Kx8 (E17) also showed bit, byte and block errors down to a LET of 11.4 MeV/(mg/cm²) with device failure at a LET of 52.6 MeV/(mg/cm²), a LET level which only a few EEPROM types were tested too. So in summary for these write tests, the same warning as for read tests can be repeated with the recommendation of detailed evaluation against possible "write" errors, erasures or permanent failures. Recent testing by Matra Marconi Space [7] and by NASA [8] on similar EEPROM types also confirmed these findings and recommendations.

Based on our heavy ion results, only write mode of testing was carried out at the proton facility at PSI. The 10 EEPROM types tested always started with 300 MeV protons and continued down to 29 MeV if still upsetting. Details of these tests can be found in Table 15. Types tested, fluence in protons/cm², upsets, proton energy in MeV and cross section results in cm² per device and per bit are given. As can be seen only Hitachi 8Kx8 (E02), Hybrid 32Kx8 (E08) and Seeq 32Kx8 (E12) passed the 300 MeV testing without errors, all other types showed errors as given in the table. Detailed error analysis revealed the following types of errors. Samsung 8Kx8 (E03) primarily showed single bit errors with one word error at 300 MeV and one at 29 MeV. SGS-Thomson 8Kx8 (E05) only showed errors at 300 MeV, two single bit errors. Hitachi 32Kx8 (E7) showed one single bit error whereas Samsung 32Kx8 (E09) showed a total of 8 single bit errors and 15 word errors. Seeq 32Kx8 (E12) was the only type which showed a page error in addition to one single bit error. The two larger types tested, Xicor 64Kx8 (E14) and 128Kx8 (E16), both showed single bit errors with a distribution as shown in Table 15. So in summary, no device failures, erasures or any other catastrophic effects were experienced in any of these proton tests. However, the low number of errors, thus poor statistics, should be remembered when using these cross section results.

Co-60 TID data for EEPROMs are presented in a summary format in Figure 3 and in details in Tables 16A and 16B. One type, Seeq 32Kx8 (E12), was not tested by ESTEC but by Deutsche Aerospace. For the other types the TID levels in Krad(Si) as a function of

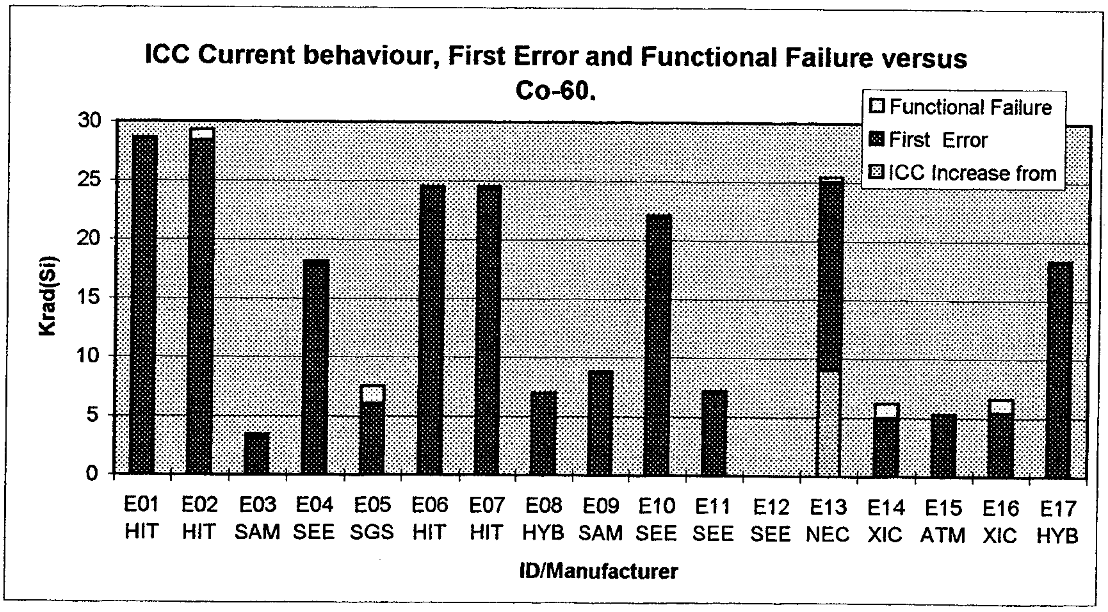

Figure 3. Co-60 TID results for EEPROMs.

EEPROM - PROTON SEE RESULTS					
Manufacturer, Type & Serial Number Tested	Fluence protons /cm^2	Upset's SEU/ SEL	Proton Energy MeV	Cross Section cm^2	
				Device	Per Bit
E02 HITACHI 8Kx8 s/n 668	1.1E10	0/0	300	<9.5E-11	<1.4E-15
E03 SAMSUNG 8Kx8 s/n S61	1.1E10	16/0	300	1.5E-09	2.3E-14
	4.8E09	17/0	100	3.5E-09	5.4E-14
	4.4E09	11/0	51	2.5E-09	3.8E-14
	2.1E09	5/0	29	2.4E-09	3.7E-14
E05 SGS-THOMSON 8Kx8 s/n S03	1.1E10	2/0	300	1.9E-10	2.8E-15
	4.8E09	0/0	100	<2.1E-10	<3.2E-15
	4.4E09	0/0	51	<2.3E-10	<3.5E-15
	2.1E09	0/0	29	<3.5E-10	<5.4E-15
E07 HITACHI 32Kx8 s/n SA7	1.1E10	1/0	300	9.4E-11	3.6E-16
E08 HYBRID 32Kx8 s/n HY5	1.1E10	0/0	300	<9.2E-11	<3.5E-16
E09 SAMSUNG 32Kx8 s/n SA7 & SA8	2.5E10	11/0	300	4.3E-10	1.6E-15
	1.6E10	2/0	200	1.2E-10	4.7E-16
	9.8E09	4/0	100	4.1E-10	1.6E-15
	8.1E09	6/0	51	7.4E-10	2.8E-15
E10 SEEQ 32Kx8 s/n 012	1.1E10	0/0	300	<9.3E-11	<3.5E-16
E12 SEEQ 32Kx8 s/n S01	1.1E10	2/0	300	1.8E-10	7.0E-16
	7.7E09	0/0	200	<1.3E-10	<5.0E-16
	4.5E09	0/0	100	<2.2E-10	<8.6E-16
E14 XICOR 64Kx8 s/n X16	1.1E10	1/0	300	9.0E-11	1.7E-16
E16 XICOR 128Kx8 s/n X06	1.1E10	5/0	300	4.6E-10	4.4E-16
	8.7E09	2/0	200	2.3E-10	2.2E-16
	4.3E09	5/0	100	1.2E-09	1.1E-15
	4.3E09	2/0	51	4.7E-10	4.5E-16

Table 15. Proton SEE results for EEPROMs tested in Write mode.

DEVICE FUNCTION	S/N	D.RATE rad/hr	FUNC. FAILURE Krad(Si)		ICCSB INITIAL mA	ICCOP	ICCSB FINAL	ICCOP	ANNEA-LING	REMARKS
EEPROMs, Co-60 RESULTS										
HITACHI	H51	2960	28.8	28.9	0.28	0.48	0.28	0.48	FAIL	
HN58C65P-25	H52	2960	28.8	28.9	0.28	0.43	0.28	0.43	FAIL	
8Kx8	H53	2960	27.4	27.4	0.28	0.43	0.28	0.43	FAIL	
E01	H54	2960	28.8	28.9	0.28	0.48	0.28	0.48	FAIL	
HITACHI	H61	2960	28.5	30.1	0.23	0.48	0.23	0.48	FAIL	
HN58C66P-25	H62	2960	27.9	28.5	0.23	0.52	0.23	0.52	FAIL	
8Kx8	H63	2960	28.5	30.1	0.23	0.48	0.23	0.48	FAIL	
E02	H64	2960	28.4	28.5	0.23	0.52	0.23	0.52	FAIL	
SAMSUNG	S04	2960	3.1	3.3	0.05	0.63	0.05	0.63	WORK	
KM28C64-20	S05	2960	3.1	3.4	0.05	0.68	0.05	0.68	WORK	
8Kx8	S06	2960	3.1	3.4	0.05	0.59	0.05	0.59	WORK	
E03	S07	2960	3.1	3.4	0.05	0.63	0.05	0.63	WORK	
SEEQ			-	-	-	-	-	-		
LJ28C64H	#02	910	>20.4	>20.4	0.08	0.37	0.33	0.50	WORK	ICC slight in-
8Kx8	#03	910	18.8	19.2	0.08	0.37	0.33	0.67	WORK	crease during
E04	#04	910	14.2	14.7	0.08	0.37	0.33	0.72	WORK	test
SGS-THOMSON	S02	1460	6.7	8.9	0.00	0.15	0.00	0.15	FAIL	
M28C64C-20PI	S03	1460	6.0	7.5	0.00	0.15	0.00	0.15	WORK	
8Kx8	S06	1460	5.3	6.0	0.00	0.15	0.00	0.15	FAIL	
E05			-	-	-	-	-	-		
HITACHI	P01	1820	24.9	25.0	0.06	0.21	0.06	0.21	WORK	
HN58C256P-20	P02	1820	23.9	24.1	0.06	0.26	0.06	0.26	WORK	
32Kx8	P03	1820	24.1	24.6	0.06	0.26	0.06	0.26	WORK	
E06	P04	1820	23.9	24.1	0.06	0.26	0.06	0.26	WORK	
HITACHI	HE1	1120	>21.5	>21.5	0.04	0.23	0.04	0.23	WORK	
HN58C256P-20	HE2	1120	>21.5	>21.5	0.04	0.18	0.04	0.18	WORK	
32Kx8	HE3	1120	>21.5	>21.5	0.04	0.18	0.04	0.18	WORK	
E07	HE4	1120	>21.5	>21.5	0.04	0.18	0.04	0.18	WORK	
HITACHI	HE5	2960	24.0	24.2	0.05	0.20	0.05	0.20	WORK	
HN58C256P-20	HE6	2960	25.4	25.4	0.05	0.20	0.05	0.20	WORK	
32Kx8	HE7	2960	24.0	24.2	0.05	0.15	0.05	0.15	WORK	
E07	HE8	2960	24.0	24.2	0.05	0.24	0.05	0.24	WORK	
HYBRID M.P.			-	-	-	-	-	-		
MEM832VMB-20	A01	910	6.3	6.3	0.02	0.89	0.07	1.01	WORK	
32Kx8 (ATMEL	A02	910	7.1	7.2	0.02	0.89	0.07	1.04	WORK	
E08 DIE)	A03	910	7.2	7.2	0.02	0.89	0.07	0.94	WORK	

Table 16A. Co-60 TID results for EEPROMs.

DEVICE FUNCTION	S/N	D.RATE rad/hr	FUNC. FAILURE Krad(Si)		ICCSB INITIAL mA	ICCOP INITIAL mA	ICCSB FINAL	ICCOP FINAL	ANNEA-LING	REMARKS
EEPROMs, Co-60 RESULTS										
SAMSUNG	SA1	1900	8.7	8.8	0.05	0.63	0.05	0.63	WORK	
KM28C256-20	SA2	1900	8.7	8.8	0.05	0.63	0.05	0.63	WORK	
32Kx8	SA3	1900	8.7	8.8	0.05	0.63	0.05	0.63	WORK	
E09	SA4	1900	8.7	8.8	0.05	0.68	0.05	0.68	WORK	
SEEQ	S01	1250	7.3	7.3	0.05	0.44	0.15	0.49	FAIL	
DQ28C256-250	S02	1250	7.1	7.3	0.05	0.44	0.15	0.54	FAIL	
32Kx8	S03	1250	6.7	6.7	0.05	0.39	0.15	0.45	FAIL	
E10	S04	1250	7.3	7.3	0.05	0.44	0.15	0.54	FAIL	
SEEQ			-	-	-	-	-	-		Unbiased test,
DQ28C256-250	S05	2080	21.1	22.2	0.07	0.44	0.07	0.51	N.T.	re-programming
32Kx8	S06	2080	24.3	26.4	0.07	0.44	0.07	0.46	FAIL	every 30 min.
E10			-	-	-	-	-	-		
SEEQ			-	-	-	-	-	-		
5962-8852506	#01	910	>22.1	>22.1	0.11	0.85	0.11	0.89	WORK	
32Kx8	#02	910	21.5	>22.1	0.11	0.89	0.11	0.89	WORK	
E11	#03	910	>22.1	>22.1	0.11	0.85	0.11	0.89	WORK	
NEC	NE1	2960	25.0	25.4	0.04	0.48	3.44	4.27	WORK	ICC increase from
D28C256CZ-20	NE2	2960	25.0	25.4	0.04	0.43	3.44	4.22	FAIL	9 Krad
32Kx8	NE3	2960	25.0	25.4	0.04	0.48	3.44	4.27	WORK	
E13	NE4	2960	25.0	25.4	0.04	0.48	3.44	4.27	FAIL	
XICOR	X11	1250	5.3	5.9	0.27	0.66	0.31	0.76	FAIL	
X28C512D-15	X12	1250	5.3	6.7	0.27	0.61	0.31	1.18	FAIL	
64Kx8	X13	1250	4.7	7.3	0.27	0.85	0.31	0.85	FAIL	
E14	X14	1250	4.2	4.7	0.27	0.66	0.31	0.76	FAIL	
ATMEL			-	-	-	-	-	-		
AT28C1024	A02	1900	5.2	5.3	0.02	0.95	0.20	1.17	FAIL	ICC slight in-
64Kx16			-	-	-	-	-	-		crease during
E15	A04	1900	5.2	5.3	0.02	0.95	0.20	1.17	FAIL	test
XICOR	X01	910	6.0	6.5	0.32	1.01	0.34	1.07	FAIL	
X28C010D-20	X02	910	2.1	6.0	0.32	1.06	0.34	1.07	FAIL	
128Kx8	X03	910	6.5	6.9	0.32	1.06	0.34	1.07	FAIL	
E16	X04	910	6.9	6.9	0.32	1.11	0.34	1.12	FAIL	
HYBRID M.P.			-	-	-	-	-	-		
MEM8129W-20	001	2170	23.6	23.6	0.02	0.32	0.10	0.34	FAIL	
128Kx8 E17	003	2170	12.8	12.9	0.02	0.32	0.10	0.34	FAIL	
(HITACHI DIE)			-	-	-	-	-	-		

Table 16B. Co-60 TID results for EEPROMs.

ID number and manufacturer can be found in Figure 3. The Krad(Si) levels given are averaged for the number of devices tested (see Table 1C and/or Tables 16A and 16B). Again three failure criteria can be found: a) the level from which the ICC stand-by current starts to increase (plus 20% level), b) the first functional error level (one error) and c) the final functional failure level (1024 errors in one single test run). In Tables 16A and 16B test details and results are presented in the same way as for UV-EPROMs. Device type, serial number, dose rate in rad(Si)/hour, functional failure levels for the first bit error and for 1Kbit errors, initial and final standby (ICCSB) and operating (ICCOP) current and annealing behaviour, are given. The annealing results, "FAIL" or "WORK", are given as measured after one week unbiased at room temperature.

A large spread in functional failure levels ranging from 3.1 to 28 Krad(Si) were found for these TID tested EEPROM types whereas only a few types showed early ICC current increases. So in general for EEPROMs, variable TID levels can be reported with first error levels, functional failure levels and current behaviour as presented in Figure 3 or Tables 16A and 16B.

6. CONCLUSIONS

A large number of commercially available UV-EPROMs, FLASH-EPROMs and EEPROMs have been radiation characterised using "CASE", heavy ions, protons and Co-60. In general, many of the tested types showed radiation performance and behaviour as one would expect from MIL or Space qualified parts. On the other hand, a surprisingly large number of devices showed unexpected SEE erasures or failures which need further attention. Large variations were seen in TID levels with UV-EPROMs and FLASH-EPROMs showing ICC current increases in contrast to EEPROMs. It was also very surprising that none of the UV-EPROMs showed SEUs whereas read testing of FLASH-EPROMs and EEPROMs often showed errors, however, many UV-EPROMs showed latch-ups. In summary for the three groups we can state the following;

UV-EPROMs

SEE Unbiased mode of testing - No errors observed
Read mode of testing - Transient errors only, no SEUs or loss of memory content, however, latch-up occurred in 7 of the 16 types tested.

TID All types tested showed ICC current increases. Several types showed quite acceptable TID failure levels.

FLASH-EPROMs

SEE Unbiased mode of testing - No errors observed
Read mode of testing - All sorts of errors ranging from latch-up to loss of memory content, however, 3 out of the 7 types only showed transient errors.

TID All types tested showed ICC current increases. Several types showed fairly acceptable TID failure levels.

EEPROMs

SEE Unbiased mode of testing - No errors observed
Read mode of testing - Transient errors to device erasure and latch-up.
Write mode of testing - All types showed errors or loss of functionality.

TID Only a few types showed early ICC current increases. Although a large spread in failure levels (3.1 to 28 Krad(Si)), several types showed quite acceptable TID performance.

From the amount of radiation data presented here on UV-EPROMs, FLASH-EPROMs and EEPROMs, candidate types can be selected from each of the assessed groups but we have to stress the importance of re-testing, in particularly if date codes differ significantly from those tested. With the majority of PROMs being commercially available, with no process traceability, lot and die variations will often result in different radiation responses so types selected, should as a minimum be TID tested and the actual technology assessed against SEU/SEL effects.

7. REFERENCES

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APPENDIX - A.

EEPROM HEAVY ION RESULTS- GRAPHICAL PRESENTATION

ID	MANUF.	SIZE	PAGE
E02	HITACHI	8K x 8	APP. A-2.
E07	HITACHI	32K x 8	APP. A-3.
E10	SEEQ	32K x 8	APP. A-4.
E12	SEEQ	32K x 8	APP. A-5.
E17	HYBRID M.P.	128K x 8	APP. A-6.

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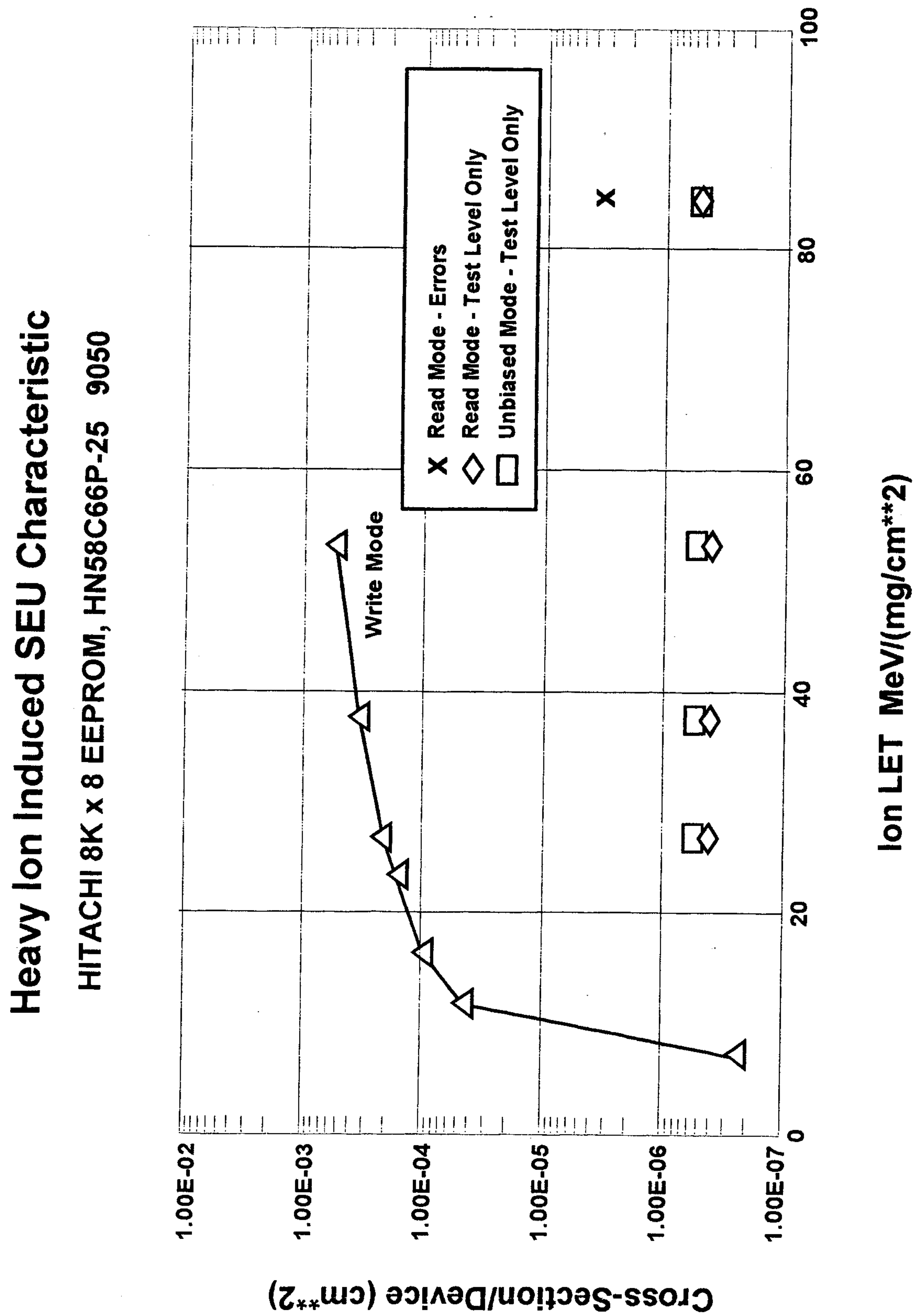
APP. A-2



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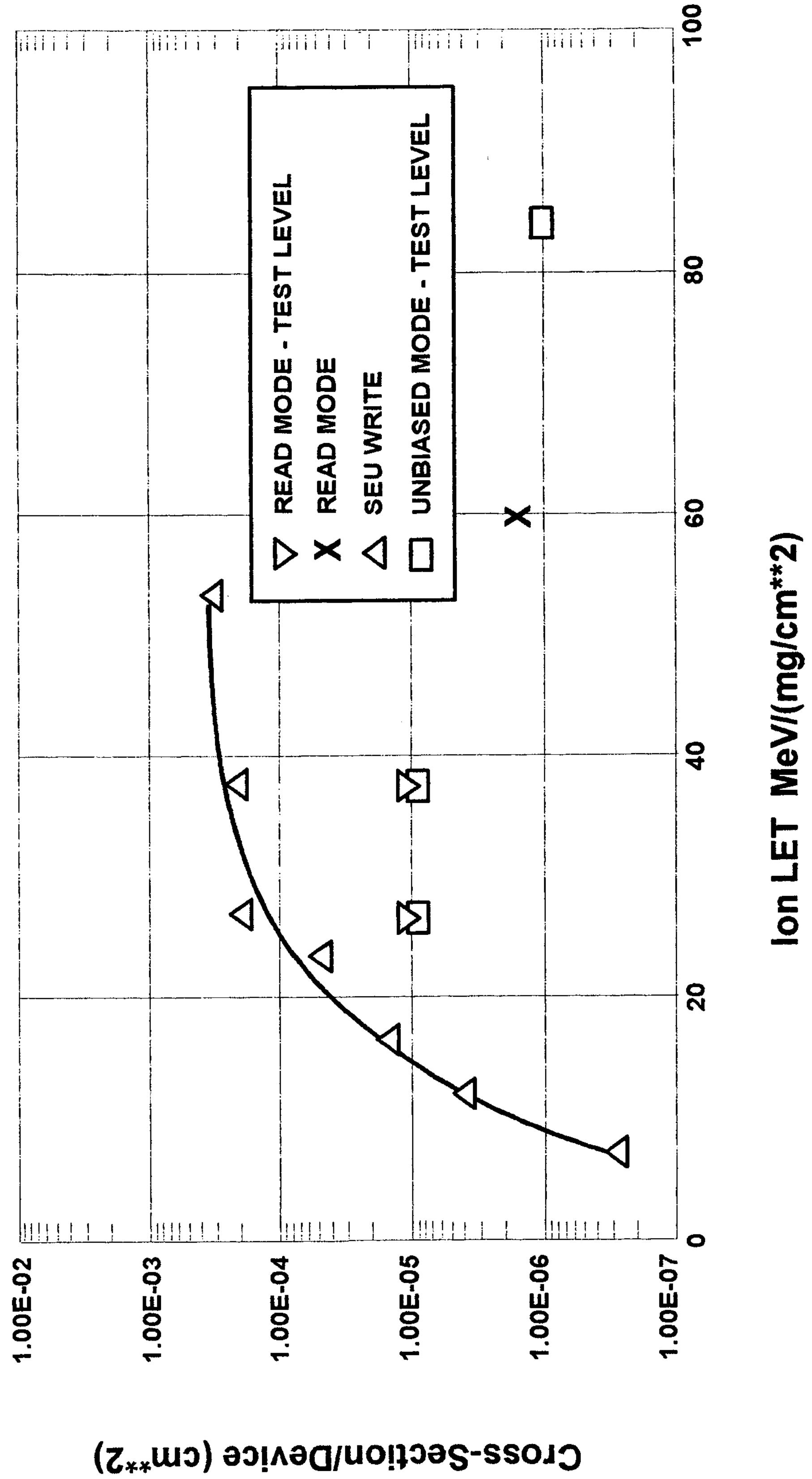
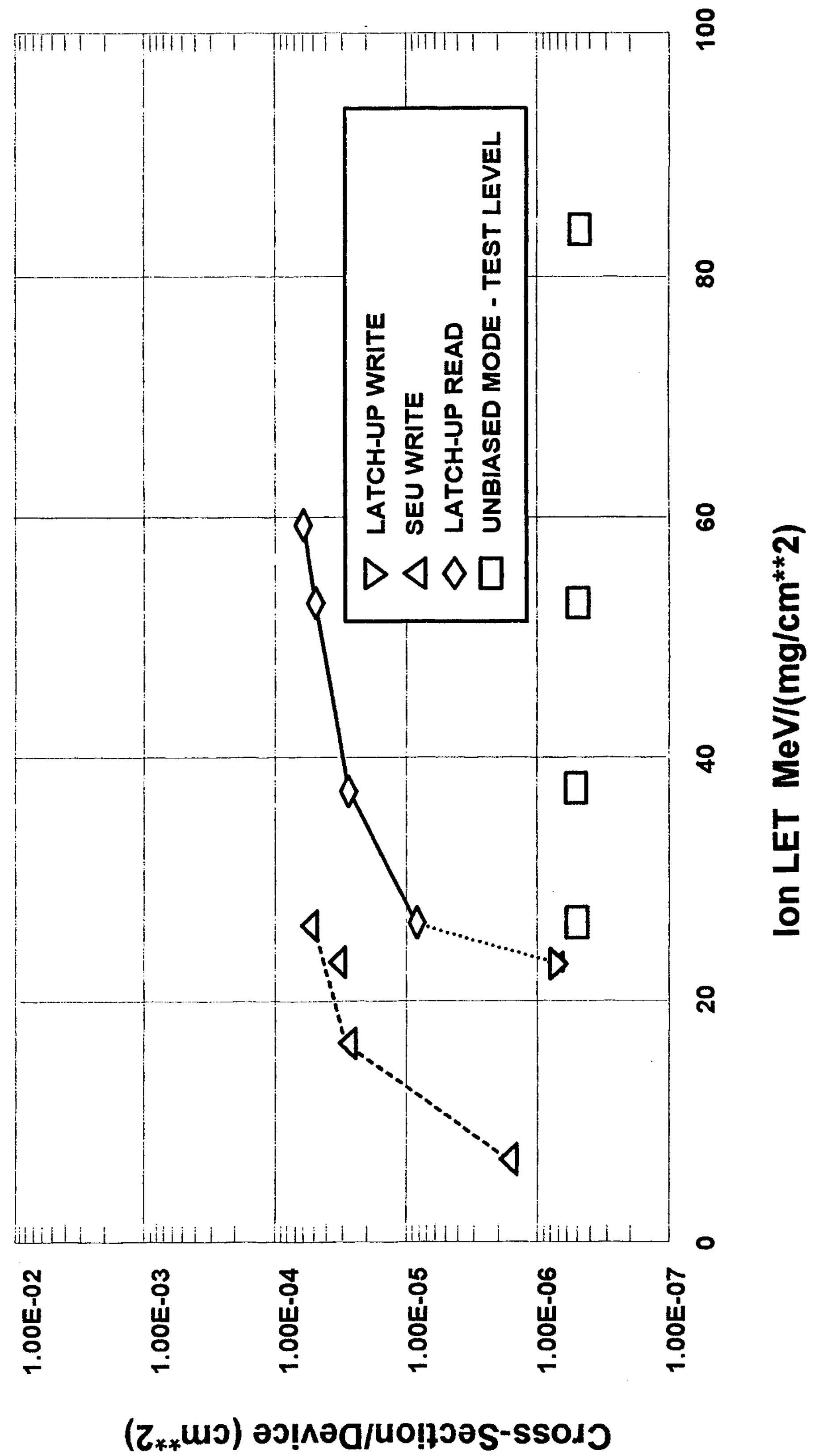
Heavy Ion Induced SEU Characteristic

HITACHI 32K x 8 EEPROM - HN58C256P-20 9232 (s/n HE5)



Heavy Ion Induced SEU Characteristic

MARS-94 - SEEQ 32K x 8 EEPROM 5962-8852506XA C9223B



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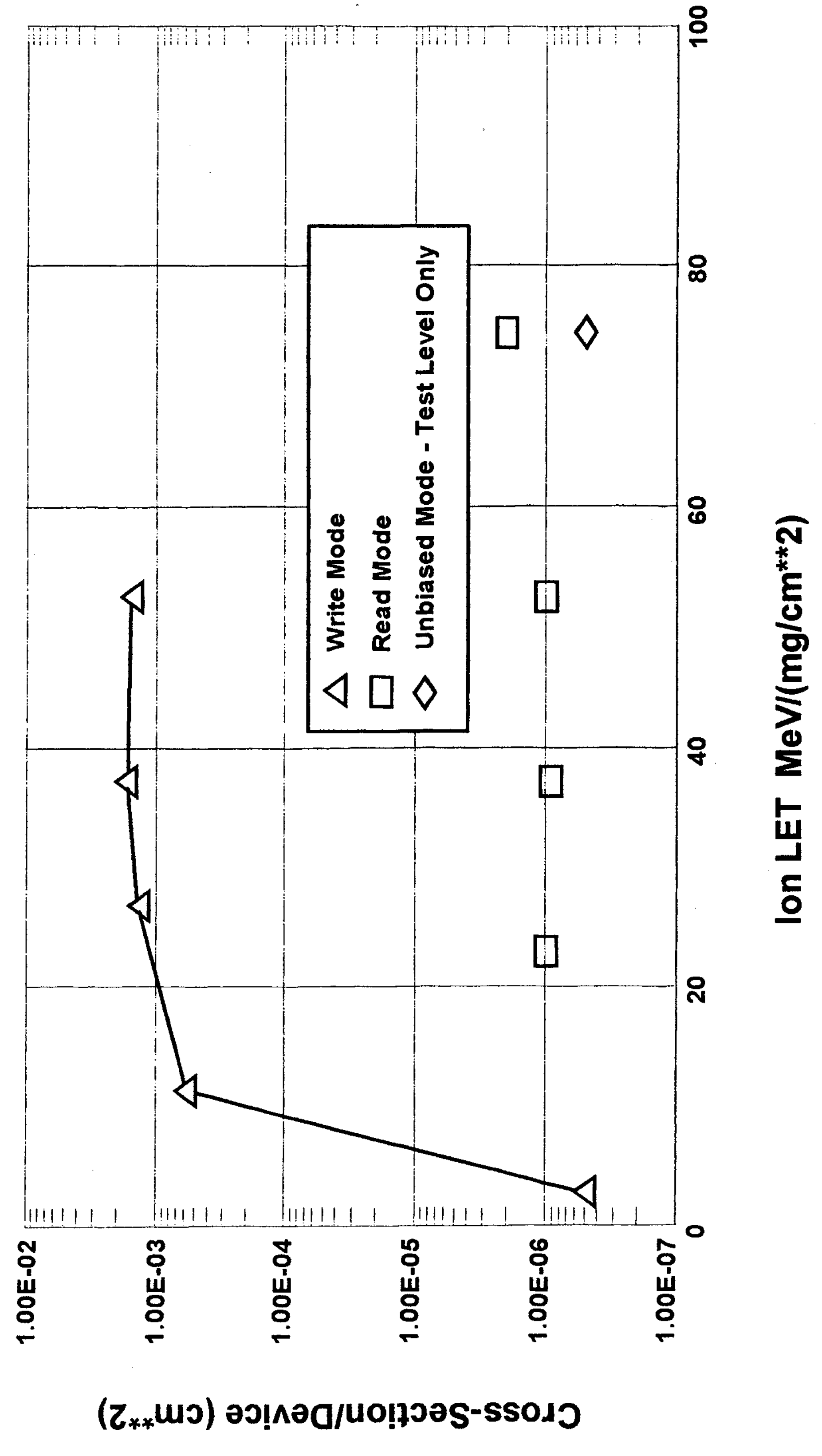
		APP. A-5

Heavy Ion Induced SEU Characteristic

SEEQ 32k x 8 EEPROM, FM28C256-200 9331 s/n:#01 & #02



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		APP. A-6