SEE Measurement of SDRAMs

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I. Introduction and Overview

This report describes the testing of various SDRAMs at the Brookhaven National Laboratory (BNL) and the Texas A&M Cyclotron (TAM). This section describes the basics of the test. The description of the BNL and TAM test area and facility are contained in section II. Section III contains the test setup and conditions of the test. Section IV contains the results and analyses and the conclusion is in section V.

The purpose of this test was to determine the SEE characteristics of various SDRAMs under heavy ion radiation. The cross section of each device, for both Single Event Upsets (SEU) and Single Event Latch-up (SEL), as a function of ion Linear Energy Transfer (LET) was the primary goal. The SEU and SEL threshold of these devices was also determined.

The devices tested were 256Mbit SDRAMs. A table of the devices is shown in Table 1. The devices specify similar reading and programming protocols.

Table 1. The devices tested in this study.

Device	Manufacturer	Memory	Package Stamp
SDRAM	Hitachi	8Mx4x8	JAPAN 012N 0049 SNN 5225805BTT75
SDRAM	Hyundai	8Mx4x8	HYUNDAI 048A HY57V56820T-5 KOREA
SDRAM	IBM	8Mx4x8	0325804CT3A 75A 09K3983 IBM 14 BM A0800677 PQ

II. Facility Overview

BNL

The SEU test facility at BNL is located in a dedicated target room in the Twin Tandem Van de Graff Accelerator (Room 4 – Building 901-A). The facility was built as a collaborative effort of several government agencies, including NASA, NSA, NRL, and USASDC, called the Single Event Facility Group. The facility was designed to provide a user friendly and efficient testing station for SEE studies.

The accelerator provides a wide range of ions and energies for SEE testing. Ion species can be changed in approximately 30 minutes while ion energies can be changes in approximately 10 minutes. The ions interact with the target in an approximately 10^{-4} torr chamber. The chamber can be pressurized and evacuated in approximately 10 minutes when a device change is desired. A list of ions used in this study is shown in Table 2.

Table 2.

Ion @ Energy	LET (MeV cm^2/mg)	Range in Si (microns)
Carbon @ 99MeV	1.4	106
Fluorine @ 125 MeV	3.634	102
Chlorine @ 210MeV	11.4	63.5
Iodine @ 329MeV	59.8	31.6
Nickel @ 265MeV	26.6	42.2

The interior of the chamber is electrically connected to the test area through an airtight bulkhead. The board on which the Devices Under Test (DUTs) reside is mounted on a moveable stage. The DUT maybe be moved in any of three directions. The DUT may also be rotated. An iris can change the diameter of the beam from 0.1 cm to 4 cm. The iris can rotate with the DUT to ensure beam profile. The beam can be completely positioned from the user console and all positioning information can be saved.

The calculation of the beam LET and range in a desired material is done automatically for each run and saved. Other saved information is the energy, fluence, and time of the run as well as the angle. The system recalculates the LET and adjusts for the fluence when the angle is changed. Hardcopies also are made for redundancy. SEU cross-section curves are generated as the experiment proceeds for easy double monitoring of the experiment.

TAMU

The SEU test facility at the Texas A&M cyclotron is located on the main campus of the university. The DOE and the State of Texas jointly support the facility. Institute staff constructed, and now operate, a K500 superconducting cyclotron and its advanced Electron-Cyclotron Resonance (ECR) ion sources. The facility was designed to provide a user friendly and efficient testing station for SEE studies. The ECR Ion Source is highly charged ions for injection into the cyclotron are produced by electron-ion collisions in magnetically confined plasma excited by microwave radiation. These ions are also used for atomic physics experiments on an adjacent high vacuum beamline.

The cyclotron has a dedicated SEE Testing Facility which is designed for advanced radiation testing of Very Large Scale Integrated (VLSI) circuits This facility features a large-volume target chamber with a versatile target positioning assembly, and a variety of industry standard vacuum feed through connectors. The chambers upstream from the target chamber provide for the beam control, diagnostic and dosimetry measurements. A large variety of high-energy beams covering a broad range of LETs have been developed specifically for this purpose. These beams have a high degree of uniformity over a large cross sectional area. More information can be found at http://cyclotron.tamu.edu/.

The accelerator provides a wide range of ions and energies for SEE testing. Ion species can be changed in approximately 180 minutes while ion energies cannot be changed mid-run. The ions interact with the target in an approximately 10^{-4} torr chamber. The chamber can be depressurized and evacuated in approximately 15 minutes when a device change is desired. Adjustable degraders vary the LET between the values shown in the third and fifth columns. Tilting the device with respect to the beam allows the effective LET of the device to gain a factor of two. A list of ions used in this study is shown in Table 2.

The interior of the chamber is electrically connected to the test area through an airtight bulkhead. The board on which the Devices Under Test (DUTs) reside is mounted on a moveable stage. The DUT maybe be moved in any of three directions. The DUT may also be rotated. A rectangular iris can changed the diameter of the beam from 0.1 cm to 4 cm in either direction. The DUT can be completely positioned in the beam from the user console and all positioning information is automatically logged.

The calculation of the beam LET and range in a desired material is done automatically for each run and saved. Other saved information is the energy, fluence, and time of the run as well as the angle. The system recalculates the LET and adjusts for the fluence when the angle is changed. Hardcopies can be made for redundancy.

Table 2

Particle	Energy (MeV)	InitialLET(Si) (MeV cm^2/mg)	Range [µm]	LETmax (MeV cm^2/mg)	Range (LETmax) [µm]
Ne	546	1.74	799	9.65	790
Ne	799.5	1.2	1655	9.65	1648
Ar	1000	5.41	500	20.1	491
Ar	1598	3.8	1079	20.1	1070
Kr	2100	19.2	336	41.4	315
Kr	3120	14.2	622	41.4	610
Xe	3200	37.9	286	63.4	254

III. Test Setup and Procedure

The test was comprised of two PCs, a power supply, and a specially designed test board. One PC controlled a HP6629A power supply. This allowed precision voltage control and latch-up detection and protection since the PC had millisecond control over the operation of the power supply. Latch-ups were recorded in a separate file.

A dedicated PC controls the test circuit board designed specifically for this SDRAM test to read and write to the DUTs. The address of each DUT can be accessed randomly. This setup allows complete freedom to interact with the DUT. The address of a failure and the value at that address are recorded in a file for each run. This would allow for any structure in the SEEs or predilection for certain pattern failure or type of SEU to be seen. A depiction of the setup used is shown in Figure 1.

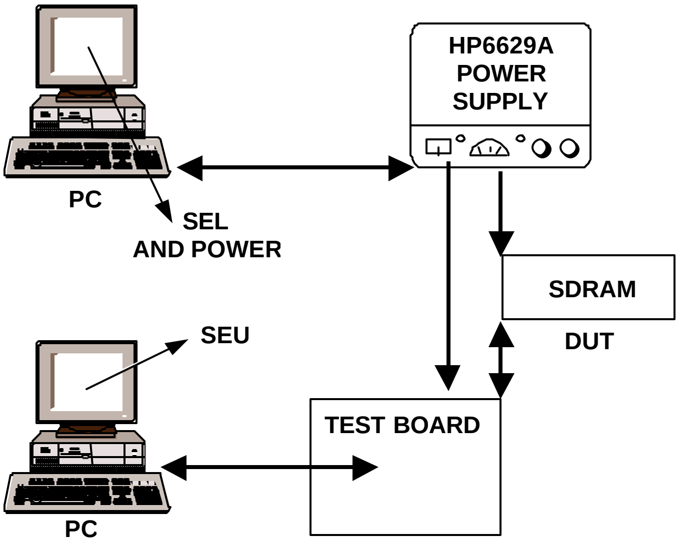

Figure 1. A schematic of the test system.

For this test, most of the radiation runs are done when the DUT is standing by with a known pattern written in the DUT. The PC cycles through the address space of the DUT, stores an address which has an error, along with the error value. The most common pattern written to the device is a "bleed down" pattern. To record the bleed down pattern, the SDRAM is then left in a mode where it does not refresh the cells. The pattern that the memory generates is the relaxed state of the SDRAM bit. Bits will only upset to this state. Therefore to get maximum response, the SDRAM is programmed with inverted bleed-down state. Some tests were done while reading or writing data to test for susceptibility to SEE during such processes.

The Vdd voltage was always set to 3.3 volts and the operating temp was approximately 25 °C throughout the study.

IV. Results

SEU

All of the devices had similar results. All of the devices were programmed and read using the same handshaking protocol. Some exposures were done during programming or reading to determine any contribution these processes. No dependence was seen. One of each device was rotated around a different axis to determine if there were any changes in the angular effects. None was seen. Figure 2 through 7 show the three different devices.

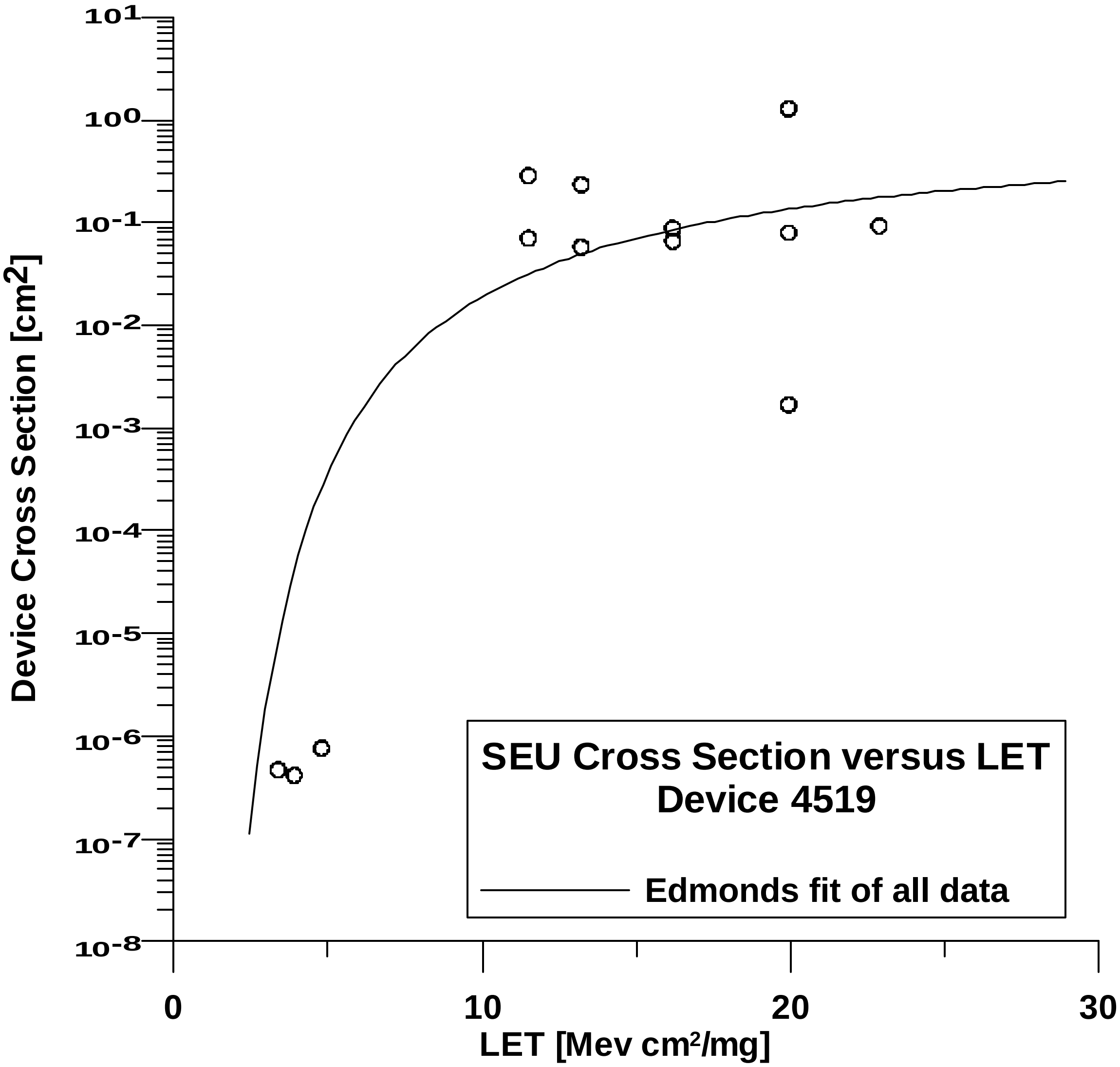

Figure 2. SEU cross section curve for an IBM SDRAM. This device was rotated along the short axis of the device to emulate higher LET.

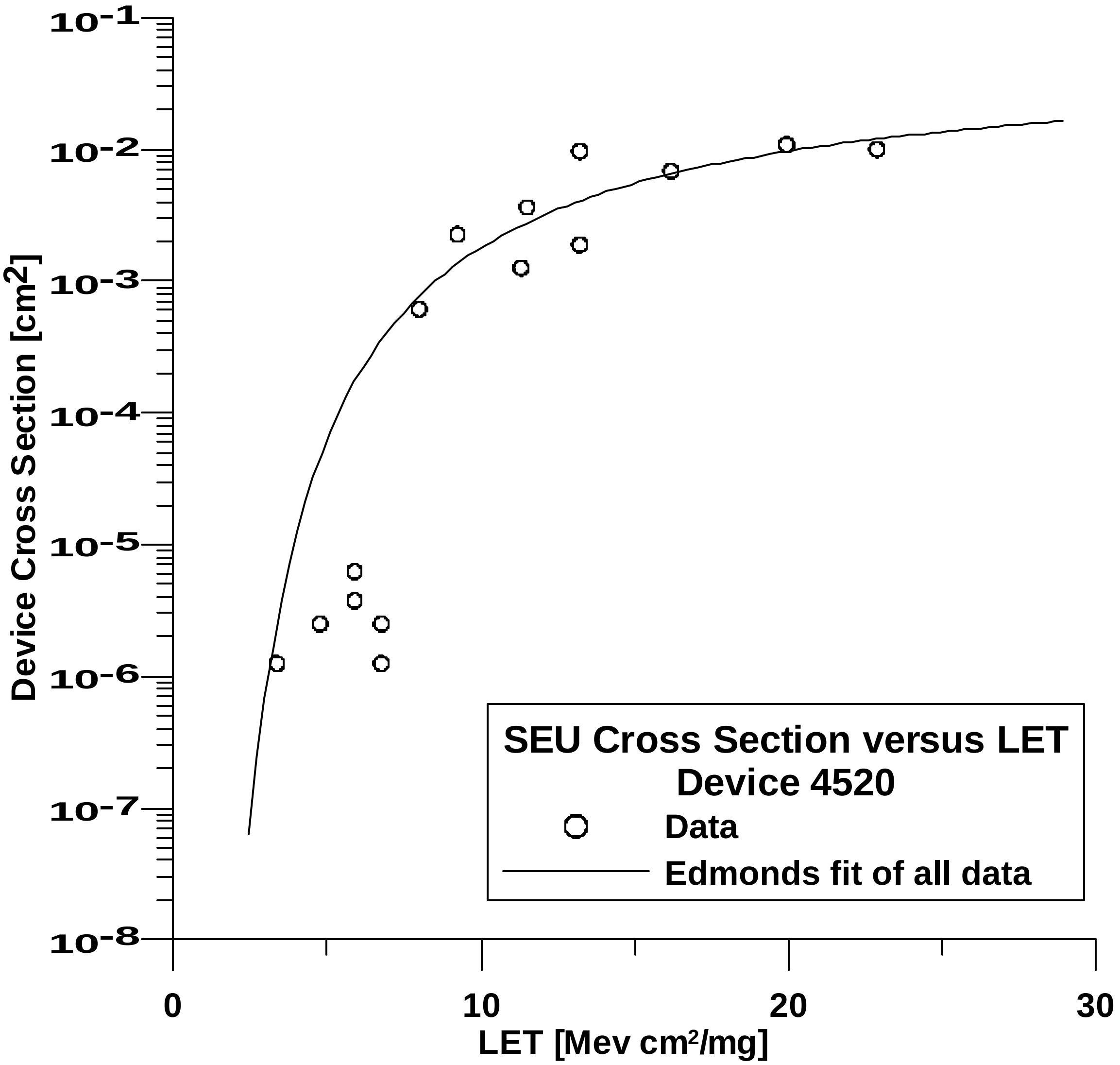

Figure 3. SEU cross section curve for a Hitachi SDRAM. This device was rotated along the long axis of the device to emulate higher LET.

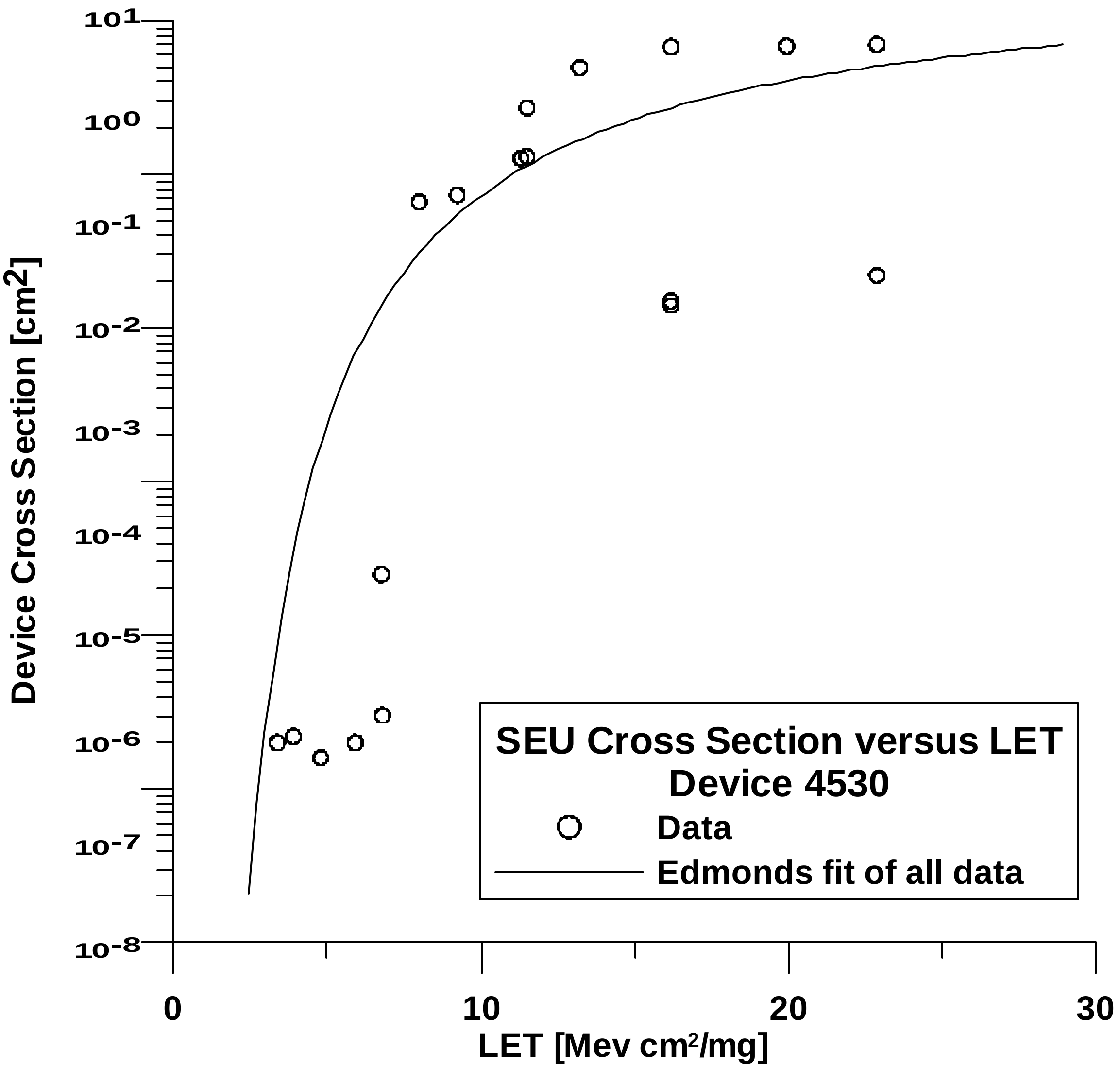

Figure 4. SEU cross section curve for a Hitachi SDRAM. This device was rotated along the long axis of the device to emulate higher LET.

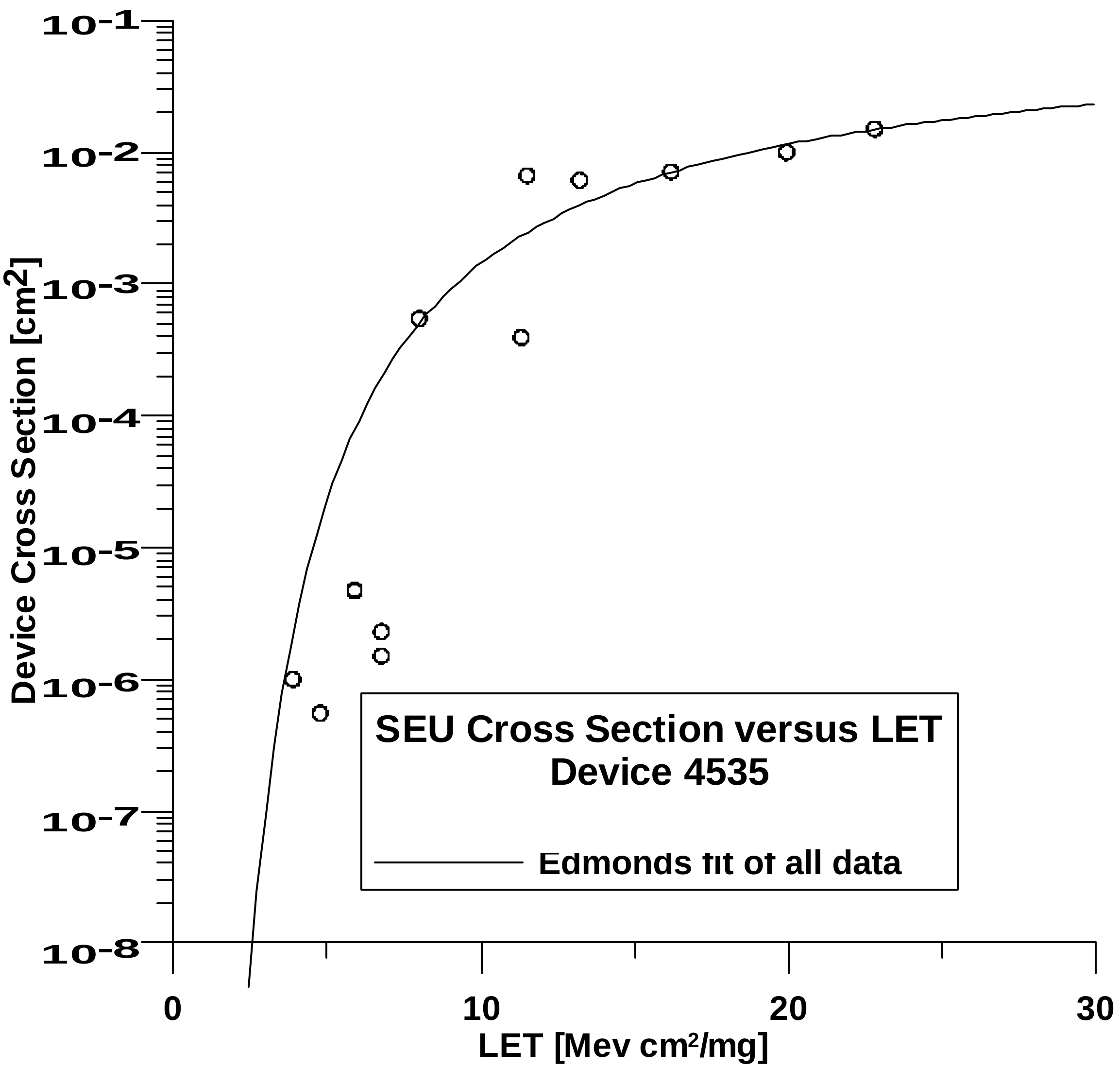

Figure 5. SEU cross section curve for a Hyundai SDRAM.

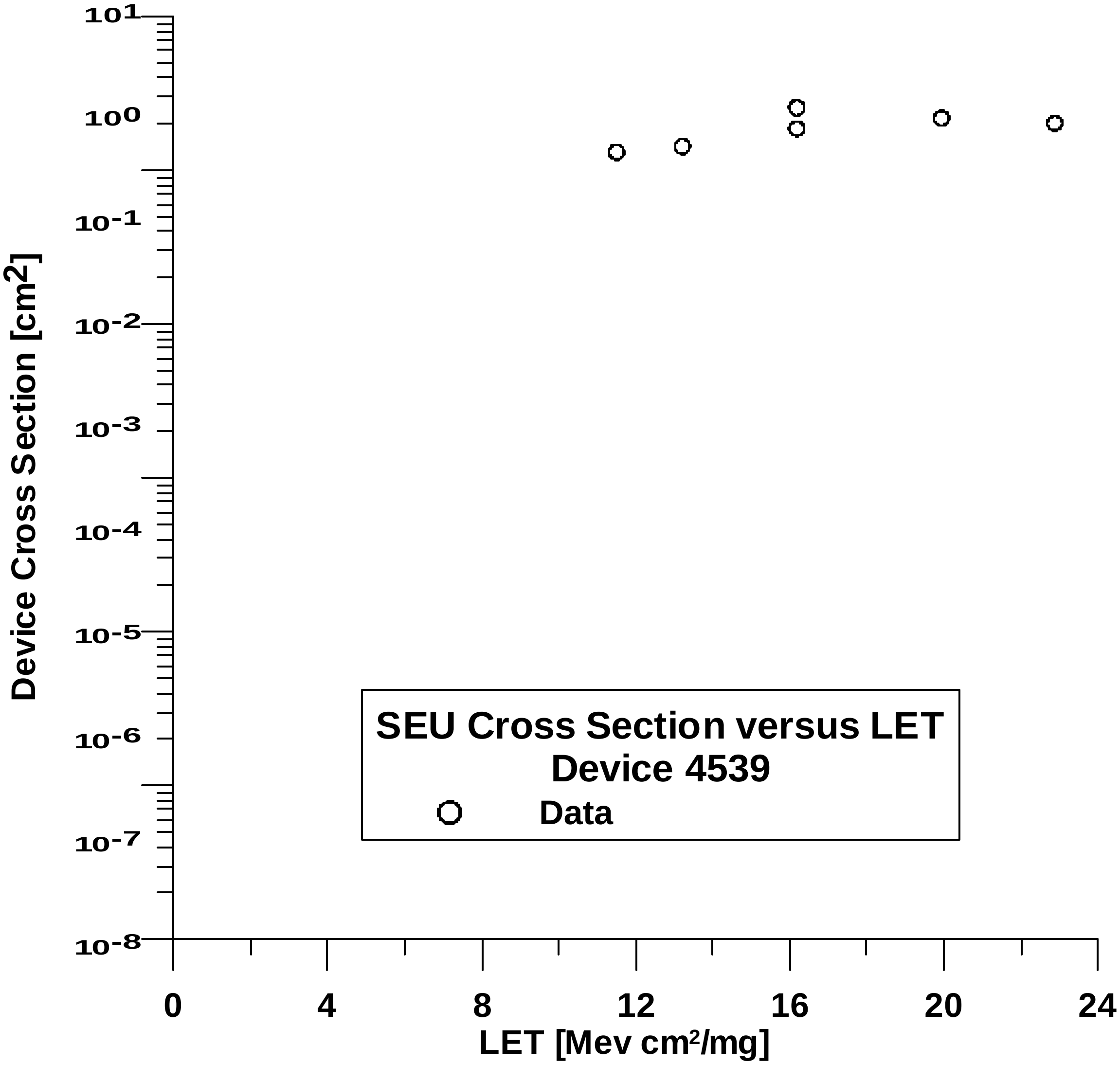

Figure 6. SEU cross section curve for a Hyundai SDRAM.

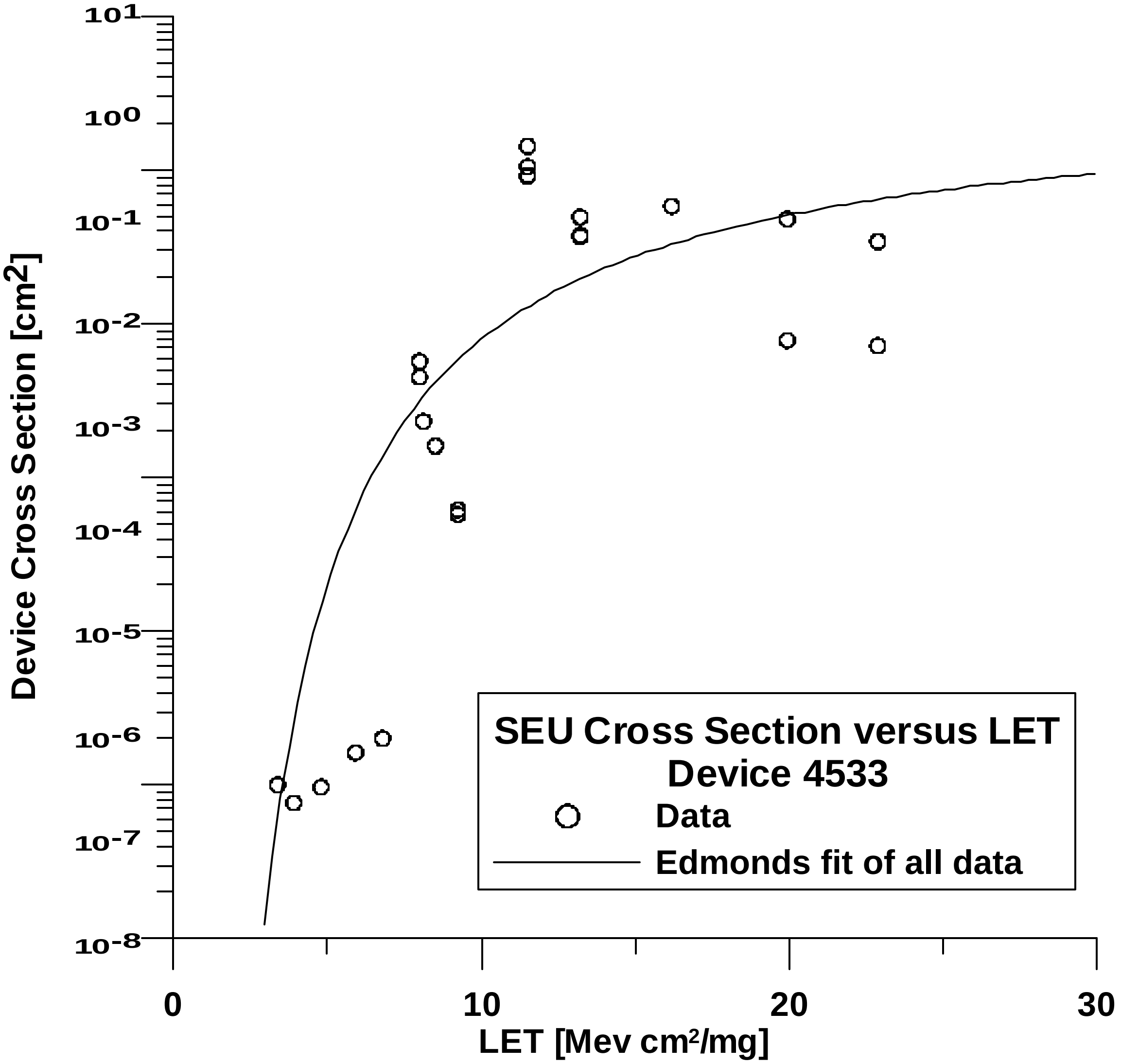

Figure 7. SEU cross section curve for a Hyundai SDRAM.

SEL

Of the three devices tested, only the Hitachi was seen not to latch. The IBM and Hyundai were seen to latch. The current threshold for latch was set at 200 mA. The Hitachi part was seen to go up 120 Mev-mg/cm^2 with no events. The IBM and Hyundai part experienced latch-up around 20 MeV-mg/cm^2.

V. Conclusion

Heavy ion data was obtained for each SDRAM type. All devices tested were very soft in terms of SEU susceptibility and demonstrated similar response. SEU thresholds for all three devices were all 5 MeV cm^2/mg. The devices were less prone to SELs than past devices have shown to be and the Hitachi was SEL immune. No devices were seen to self-destruct or have stuck bits, although the fluence was too low to get good statistics on this effect. Table 3 shows the approximate thresholds for the devices as well as the saturation cross-sections.

Table 3.

Device	SEL Threshold (MeV cm^2/mg)	SEU Threshold (MeV cm^2/mg)	SEU Saturation Device Cross-section[cm^2]
IBM	20	5	0.5
Hitachi	>120	5	0.5
Hyundai	20	5	0.5