Evaluation of Radiation Effects in Flash Memories

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Introduction

- **Features of flash memories**

  Flash memories are non-volatile, that is they do not require power to retain the information in its memory. They can also be erased and written to while the device is still in the circuit.

- **An alternative high-density storage**

  By using a single transistor per bit memory cell, the flash memories are nearly as dense as DRAMs.

- **Power savings when not in use**

  Because flash memories are non-volatile, power to the device can be turned off when not in use, saving power.

- **Downside of using flash memories in space**

  As in most solid state devices, flash memories is sensitive to total dose and single event effects.

X2000 Project

- **At JPL, X2000 Project is driving the flash memory survey**

  There are currently three missions proposed for X2000 platform. (Europa, Pluto, and Solar Probe). If we are able to find a suitable flash memory, the X2000 spacecrafts are expects to use about eight giga bits or one giga byte of flash memory.

- **Europa spacecraft**

  The Radiation Effects Group at JPL is primarily concerned with the Europa spacecraft because of its severe radiation environment.
  The spacecraft is expected to see about a Megarad for the expected duration of the mission. With shielding, they are hoping to reduce the exposure to about 4 kilorads.

Summary

- NAND and NOR architecture
  Almost all of the flash memories come in one of two architectures (NAND and NOR). We chose Samsung flash memories to represent the NAND architecture and Intel flash memories to represent the NOR architecture.

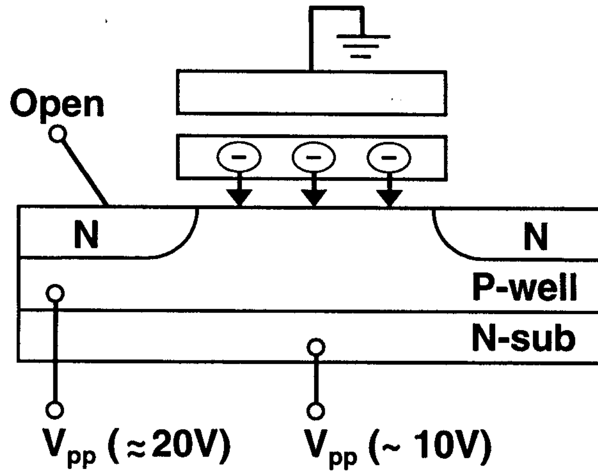
- Total Integrated Dose (TID) test
  Both manufacturers use a charge pump get the higher voltage required for programming. Degradation of the charge pump had a significant effect radiation sensitivity of these devices.

- Single Event Effects (SEE) tests
  The memory cells themselves were immune to upsets.
  The memory erase, write, and read electronics were very sensitive to upsets.

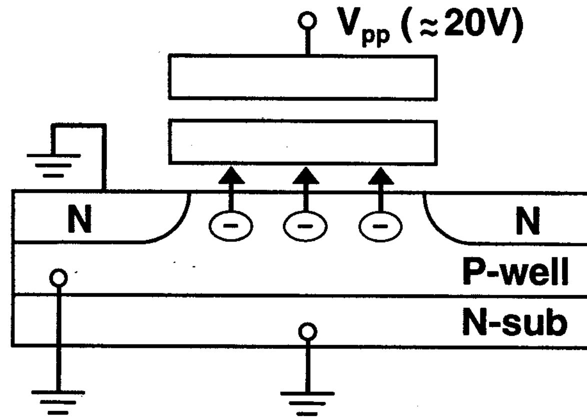
Flash Memories Used in This Study

Device	Description	Manufac-turer	Cell Technology	Special Features
28F016SA	16-M Flash	Intel	NOR	
28F016SV	16-M Flash	Intel	NOR	"SV smart voltage" allows transparent operation with several power supply voltage options
KM29N16000	16-M Flash	Samsung	NAND	
KM29N32000	32-M Flash	Samsung	NAND	Scaled device with twice the density
KM29V64000	64-M Flash	Samsung	NAND	No Latch Up
TC5816AFT	16-M Flash	Toshiba	NAND	No Latch Up

Samsung NAND Device

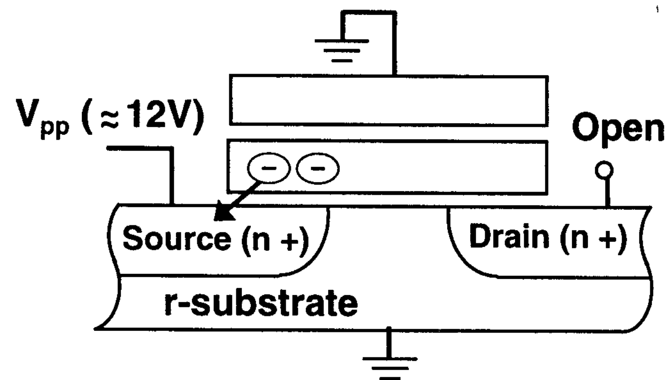


(a) Erase mode (F-N tunneling to body)

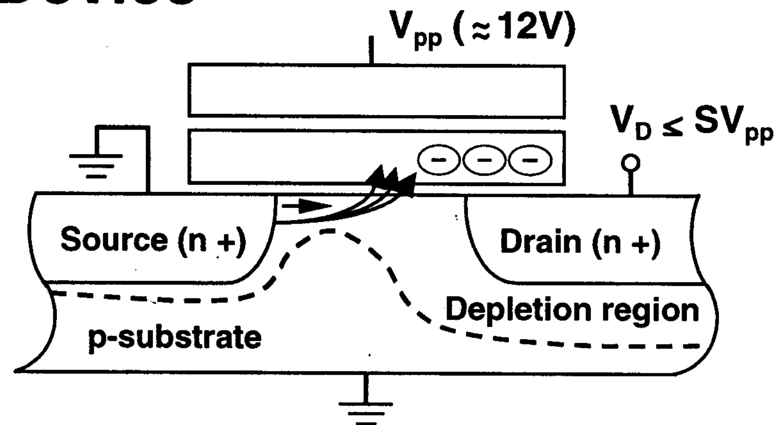


(b) Write mode (F-N tunneling to body)

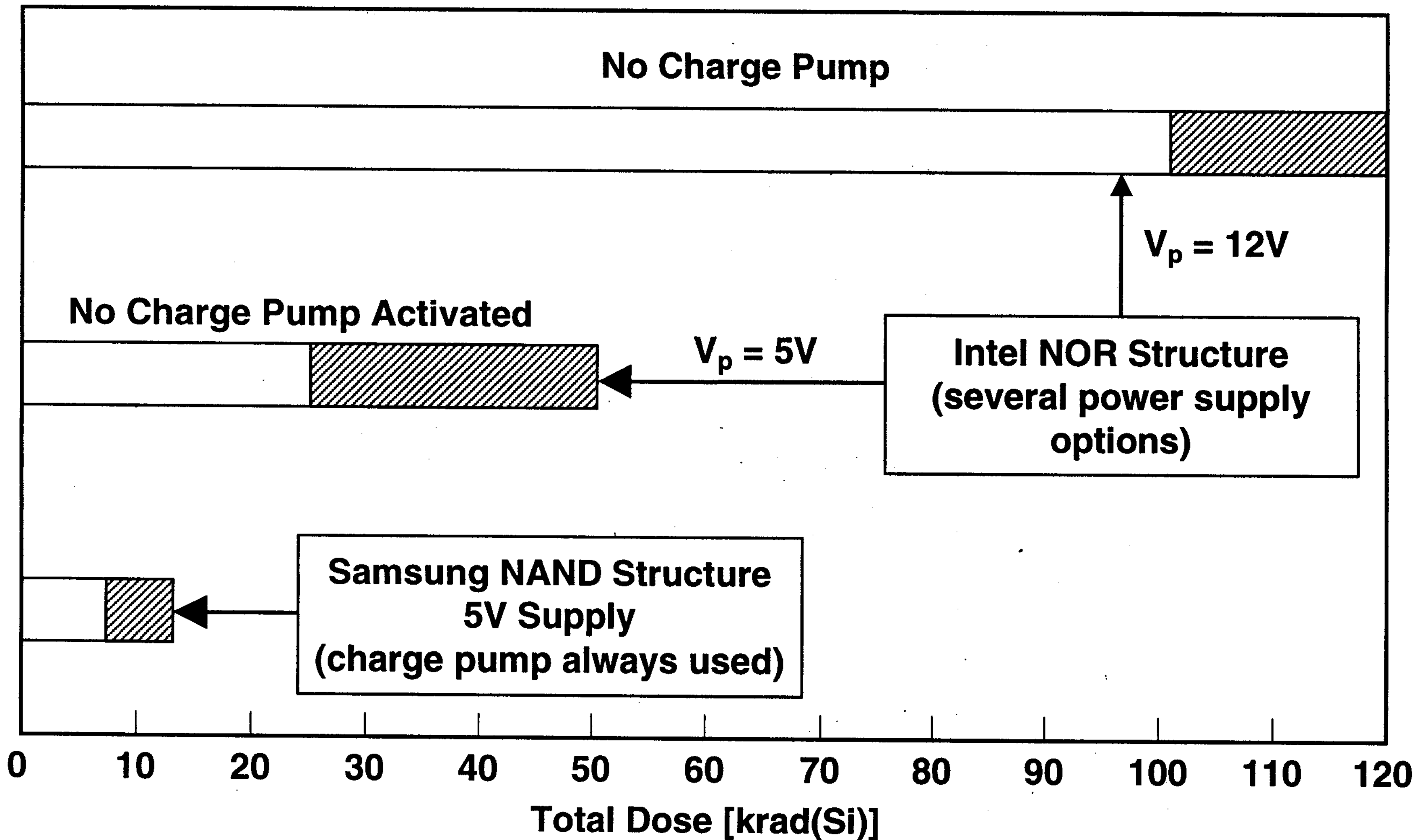
Intel NOR Device

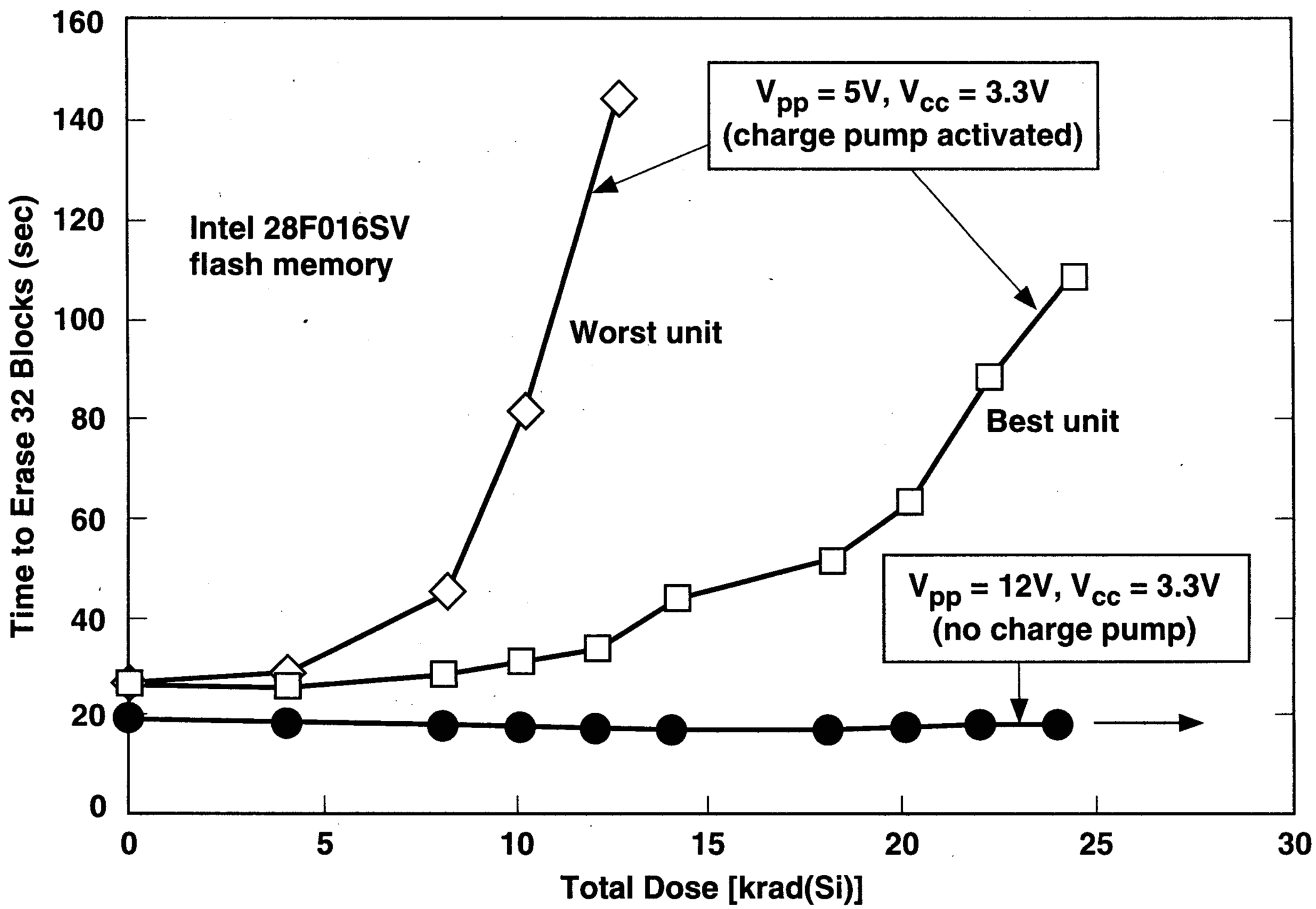


(a) Erase mode (F-N tunneling)

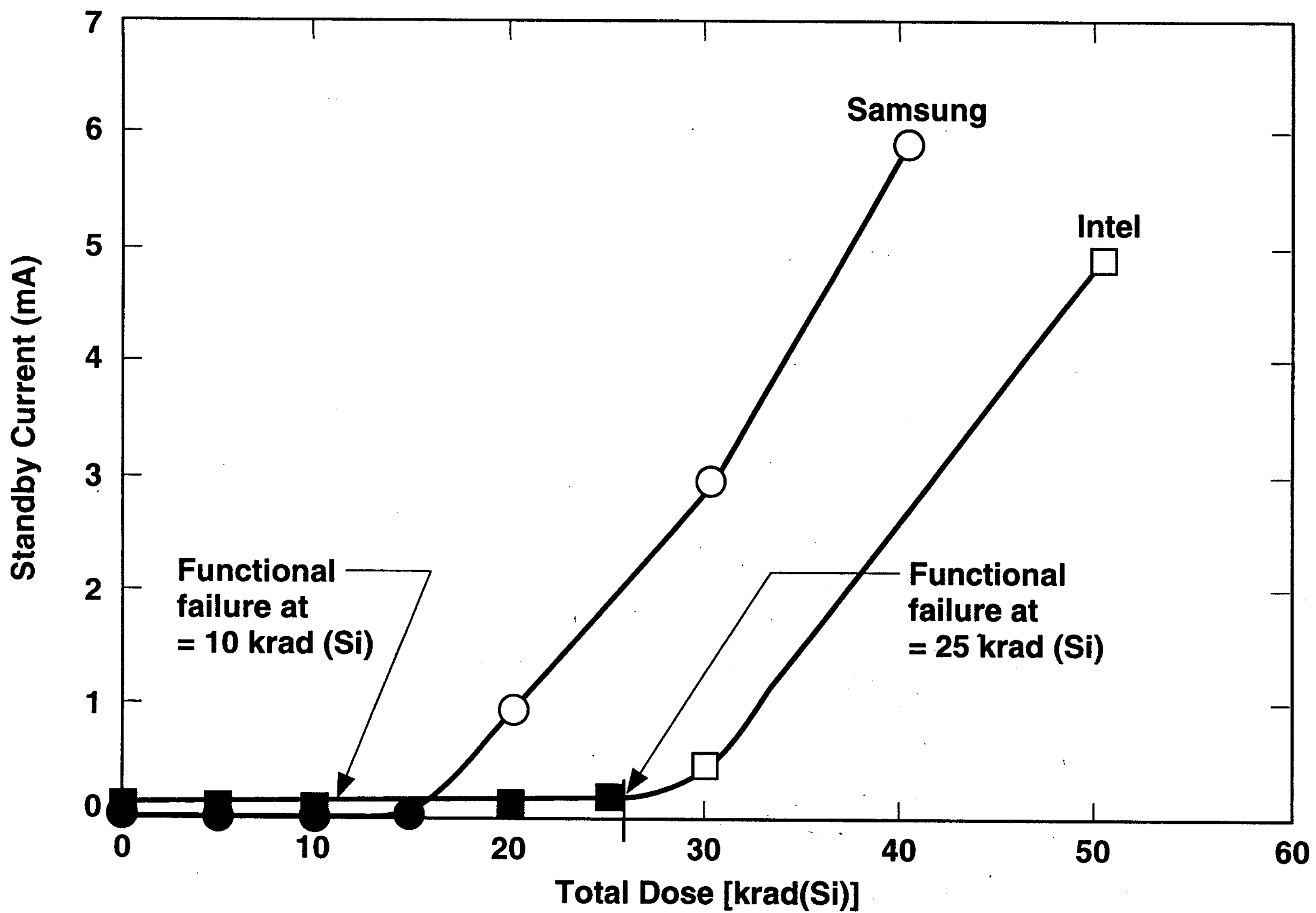


(b) Programming mode (hot electrons)


No Charge Pump
V_p = 12V
No Charge Pump Activated
V_p = 5V
Intel NOR Structure (several power supply options)
Samsung NAND Structure 5V Supply (charge pump always used)
0 10 20 30 40 50 60 70 80 90 100 110 120
Total Dose [krad(Si)]

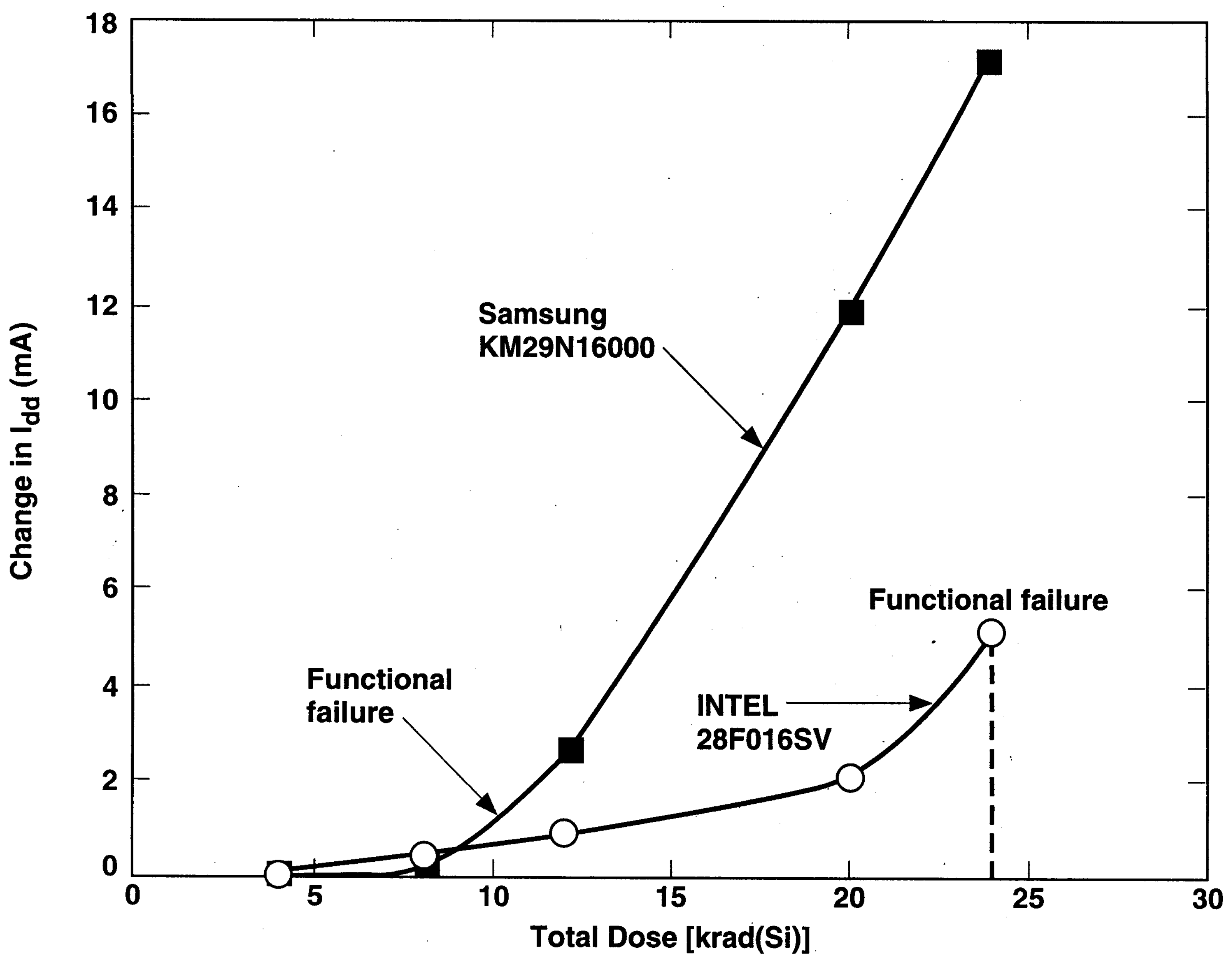


JPL



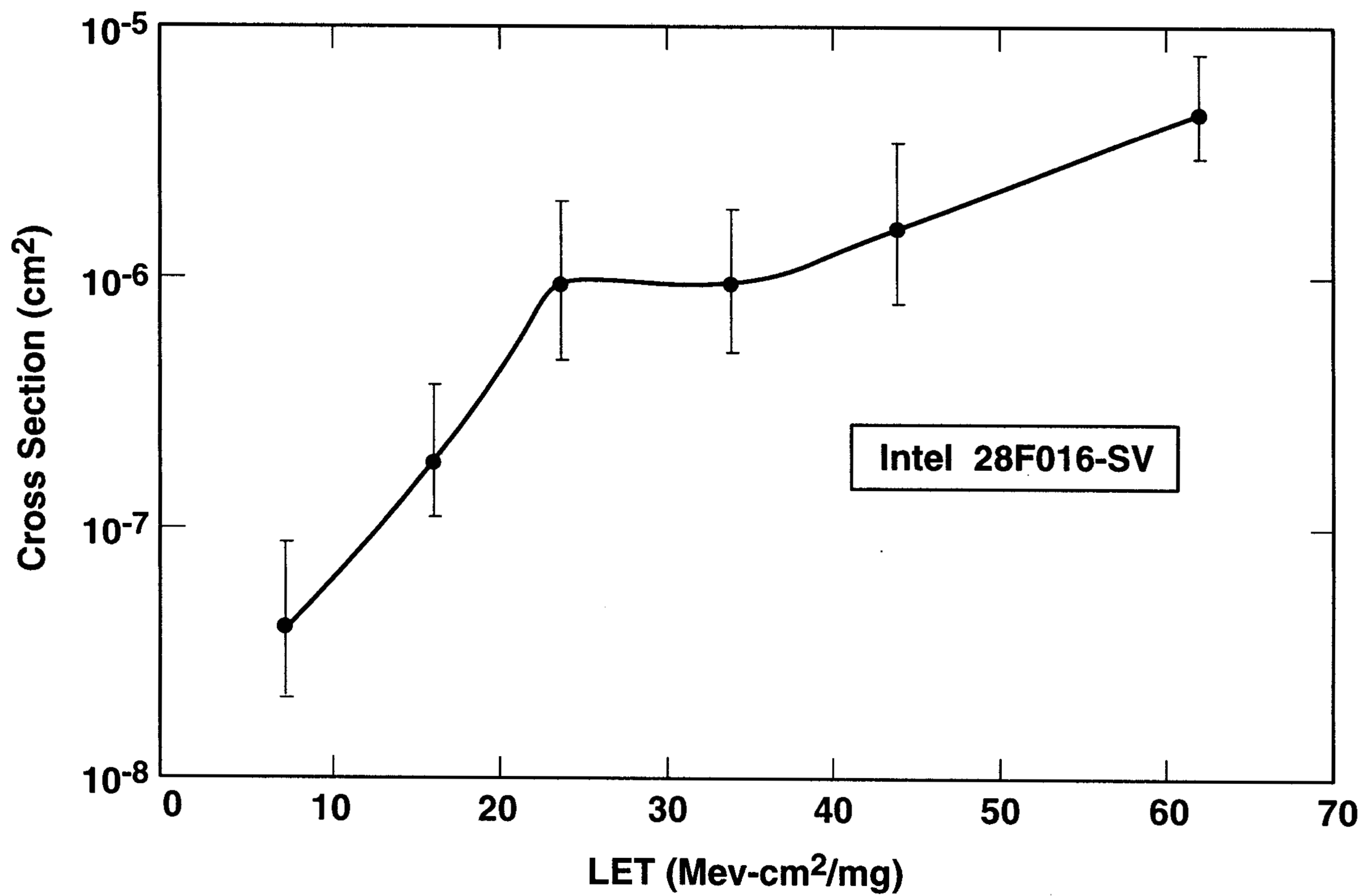
JPL

Samsung3

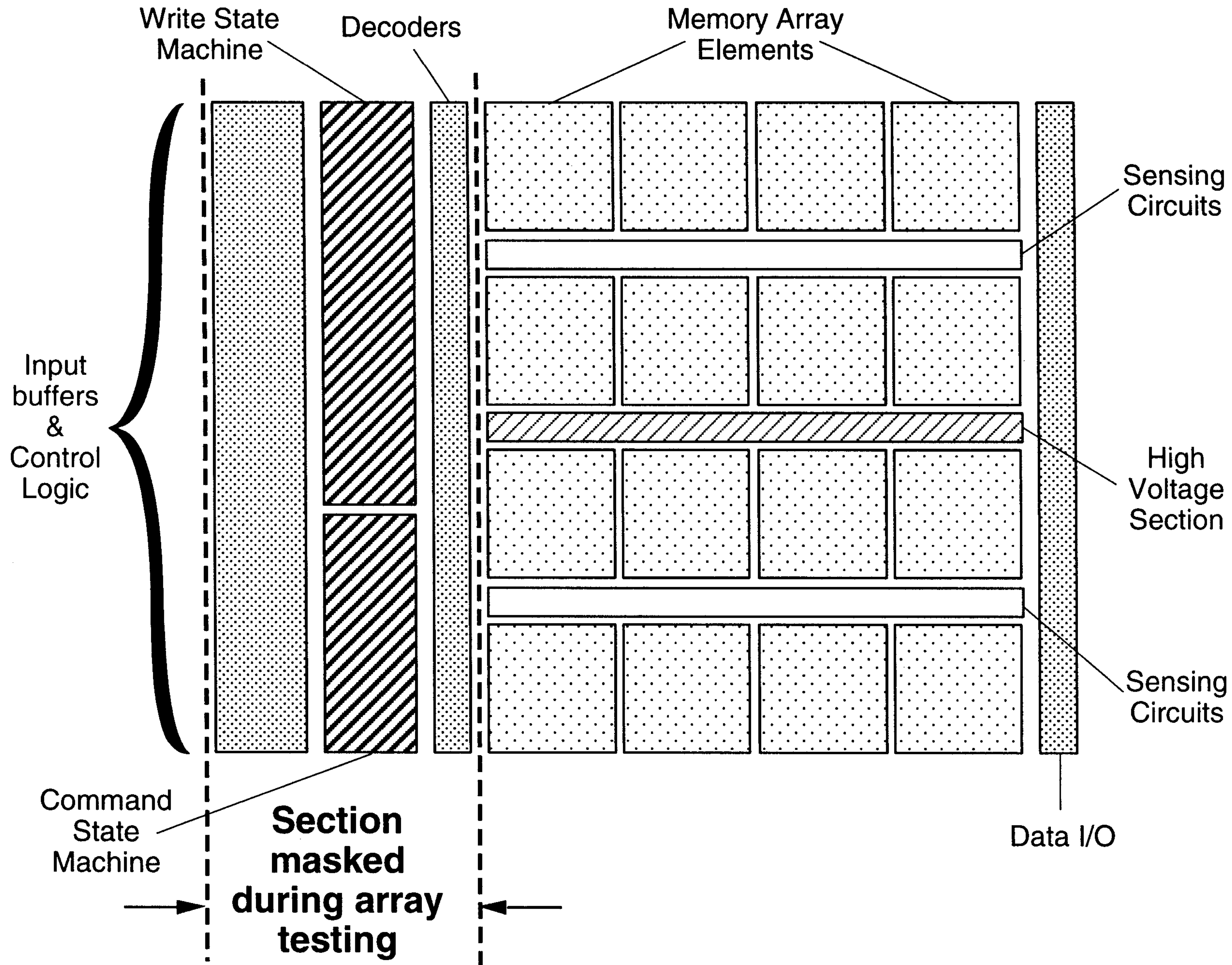


Samsung2

CROSS SECTION FOR COMPLEX FUNCTIONAL UPSET MODES



Chip Micrograph



Sequence of Current Steps During Static-Mode Irradiation of Intel SV Flash Memory

Power Supply Current (mA)

20

10

0

Run 1
Clear lockup

Run 2
Clear lockup

LET = 37 MeV-cm^2/mg

Fluence = 10^6 ions/cm^2 per run

Time

Sequence of Current Steps for 16 Mb Samsung Memory