TID, SEE and Radiation Induced Failures in Advanced Flash Memories

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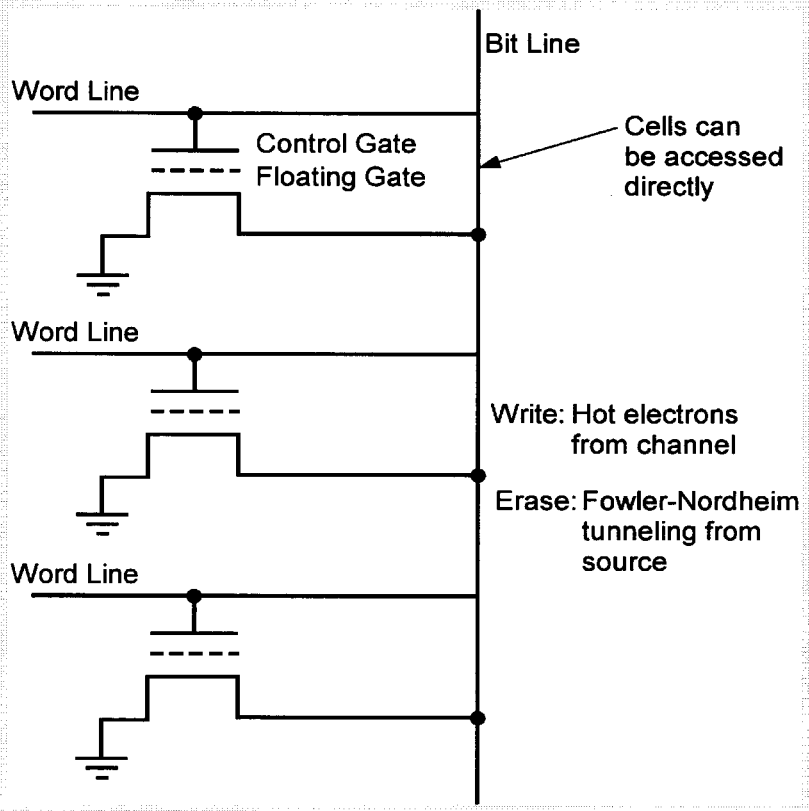
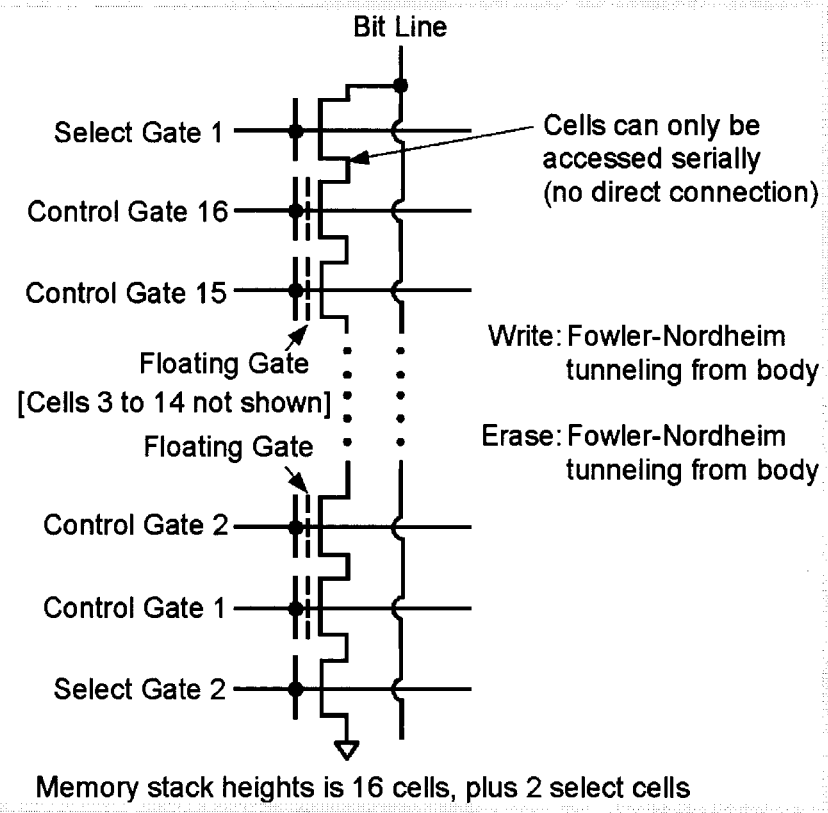
Outline

- Non-Volatile Memory (NVM) types
- Test Set-Up
- Radiation Induced Failures
- SEE Test Data
- TID Test Results
- Conclusions

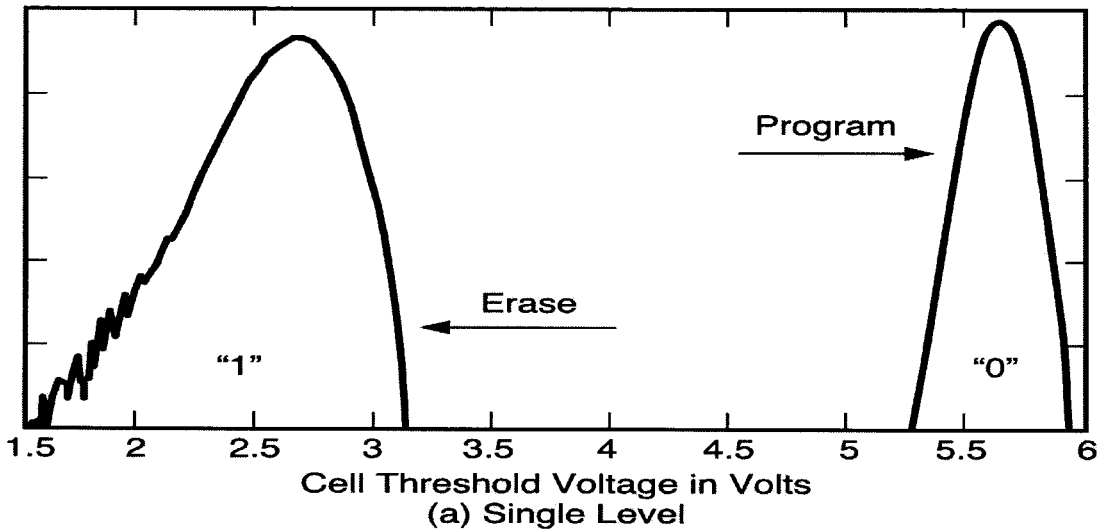
Flash Memory Types

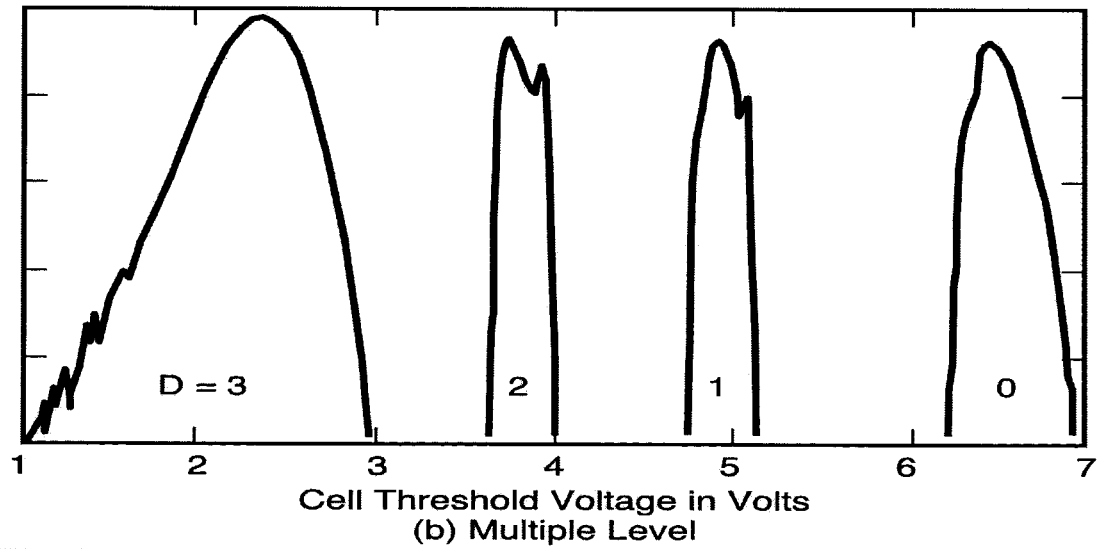




- **NOR (Intel)**
- **NAND (Toshiba)**

Cell Threshold Voltage





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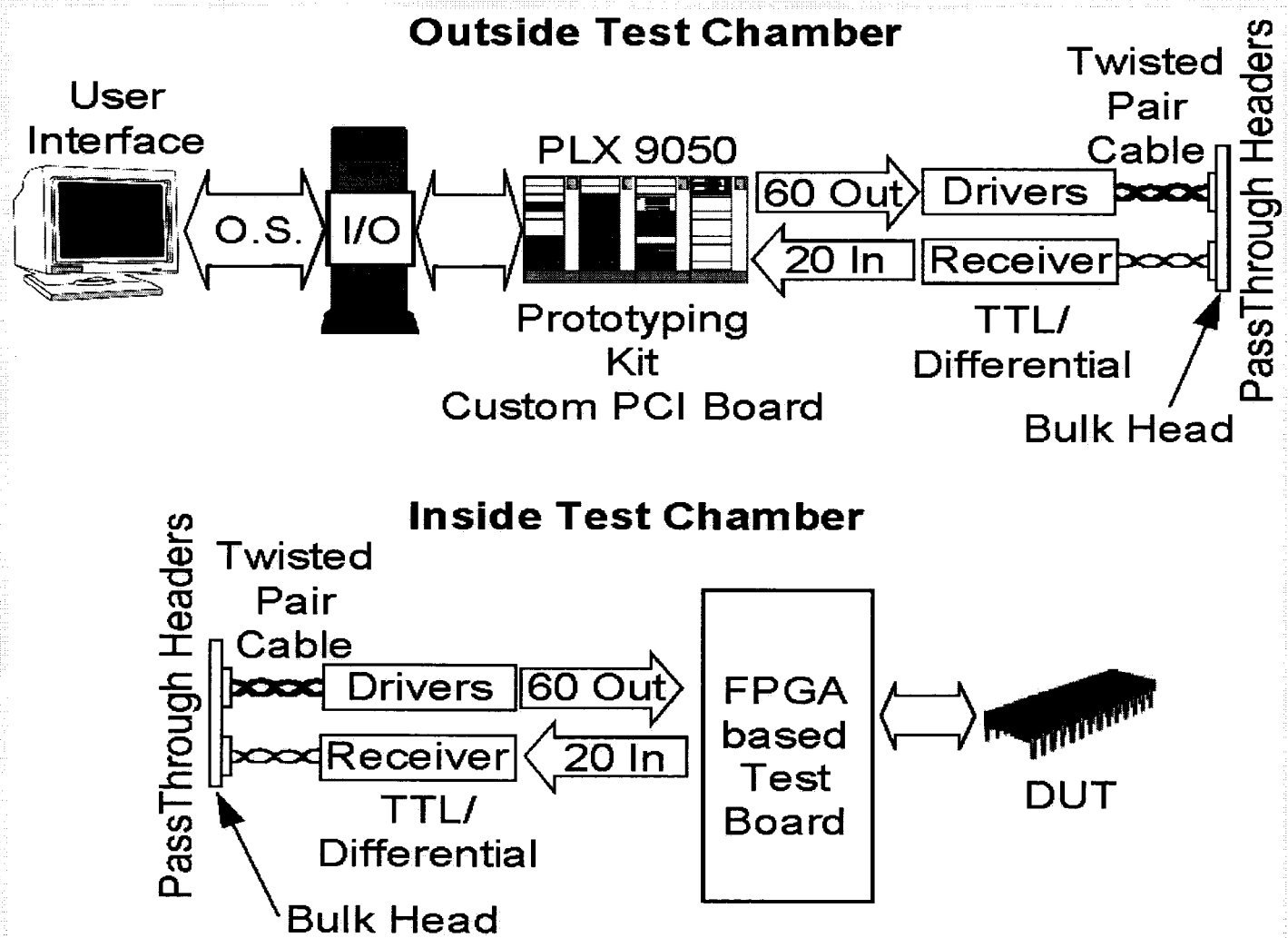
Test Set-up



Test Conditions

- **Single Event Upset (SEU):** *Erase, Write, Read*
- **Single Event Latch-up (SEL):** *Read*
- **Ions used:** *Ne, Ar, Cu, and Kr*
- **Total Ionization Dose (TID):** *biased condition*
- **Source used (in TID) :** Cobalt-60
- **Dose rate (in TID) :** *25 rad(Si) per second*

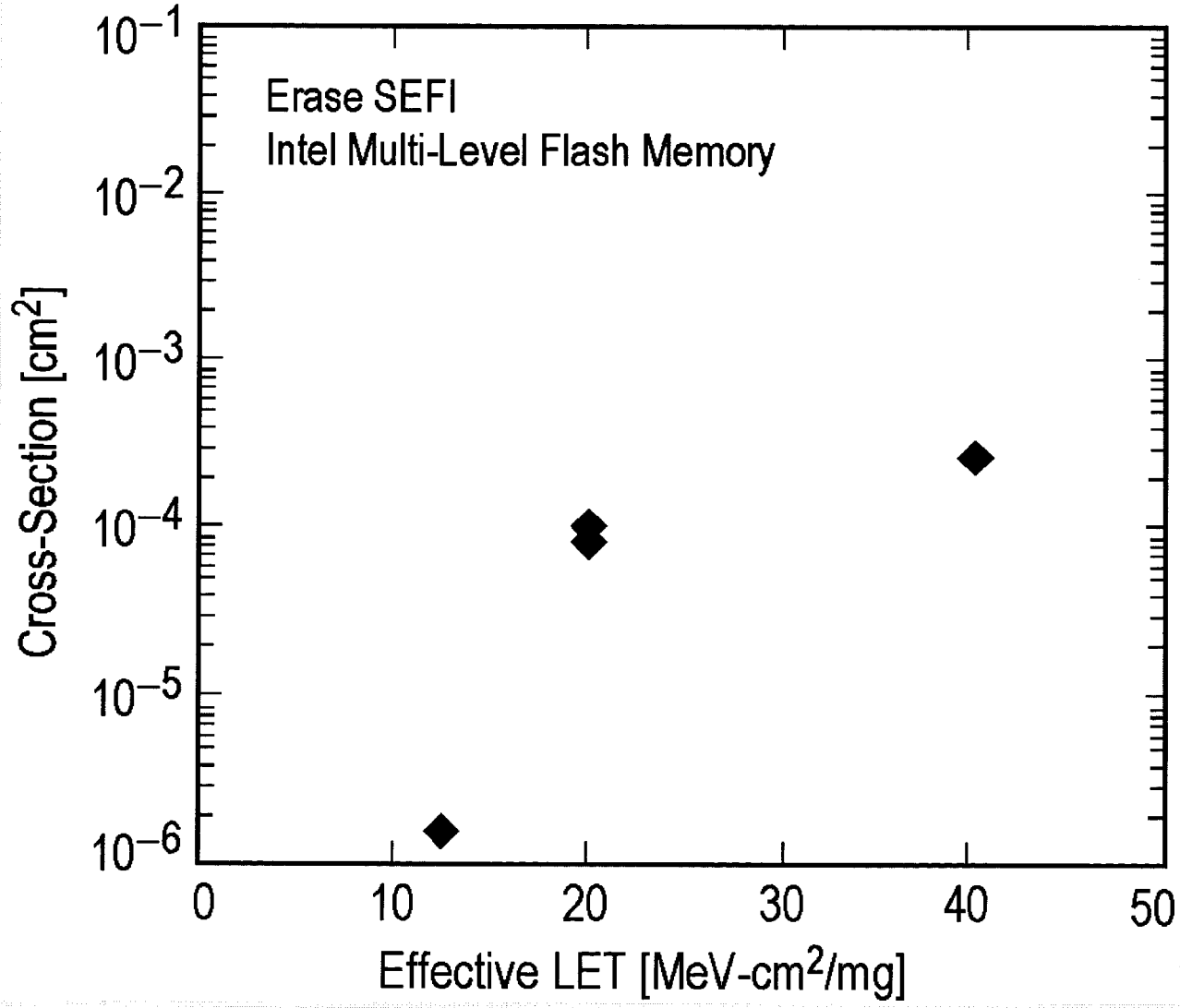
Intel StrataFlash (D/C 0238) 28F256K3
Toshiba (D/C 0240) TC58100FT

[redacted]

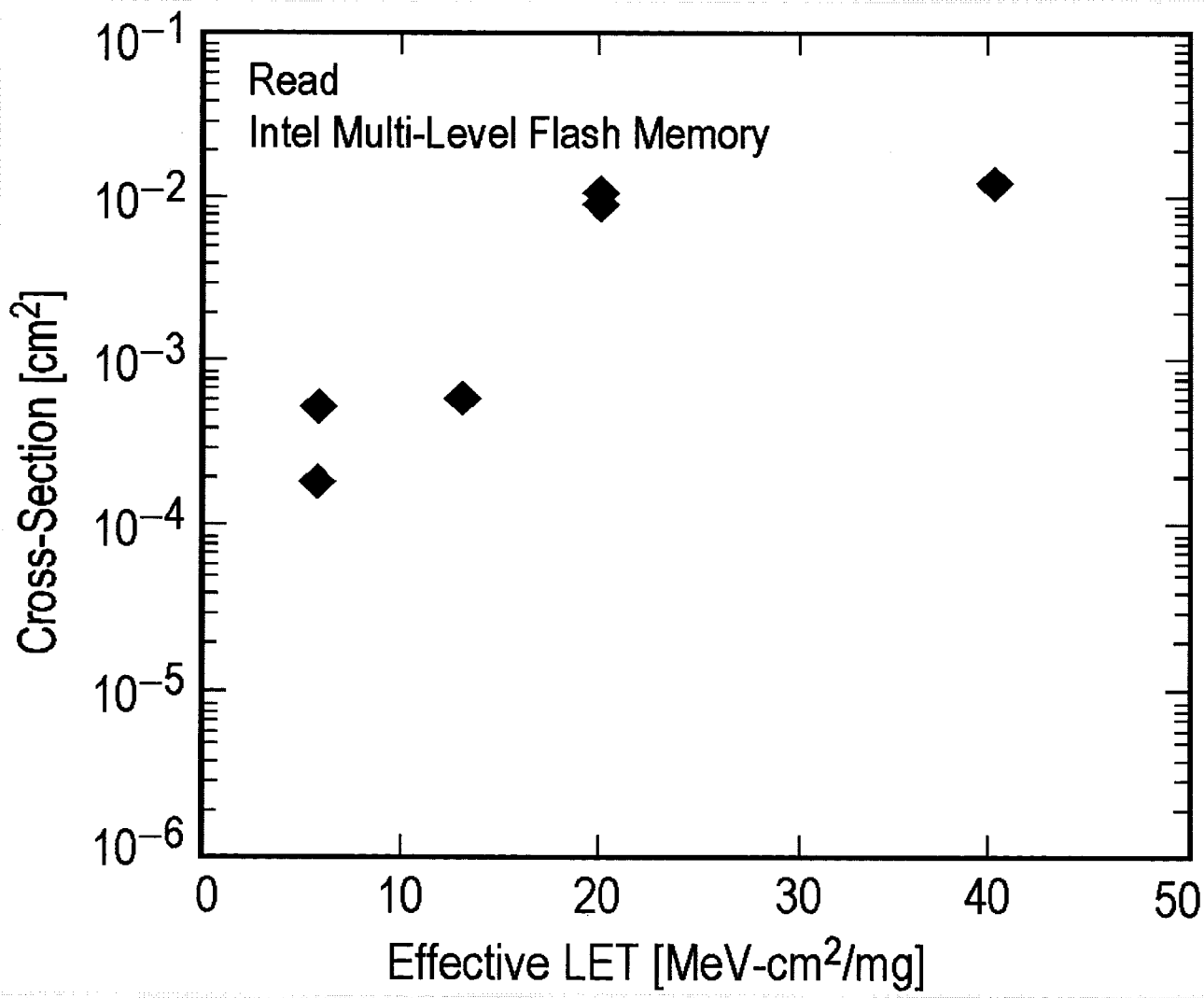
Radiation Induced Failures

Errors	Description	Signature
Single Event Functional Interrupt (SEFI)	Interrupt intended operations and/or locked into unexpected endless loops	Operations lock up. Reset mostly with power cycling.
Read	Read errors during irradiation.	Two errors per address in case of multi-level cells
Erase	Unsuccessful removal of electrons or long elapsed erase time.	Many passes prior to erase successfully
Write	Wrong data written to devices, or no access to the entire block.	Elapsed write time varies grossly from blocks to blocks
Stuck read	Errors remained in subsequent post-irradiation verifications. Initial data came back after several weeks.	No prediction

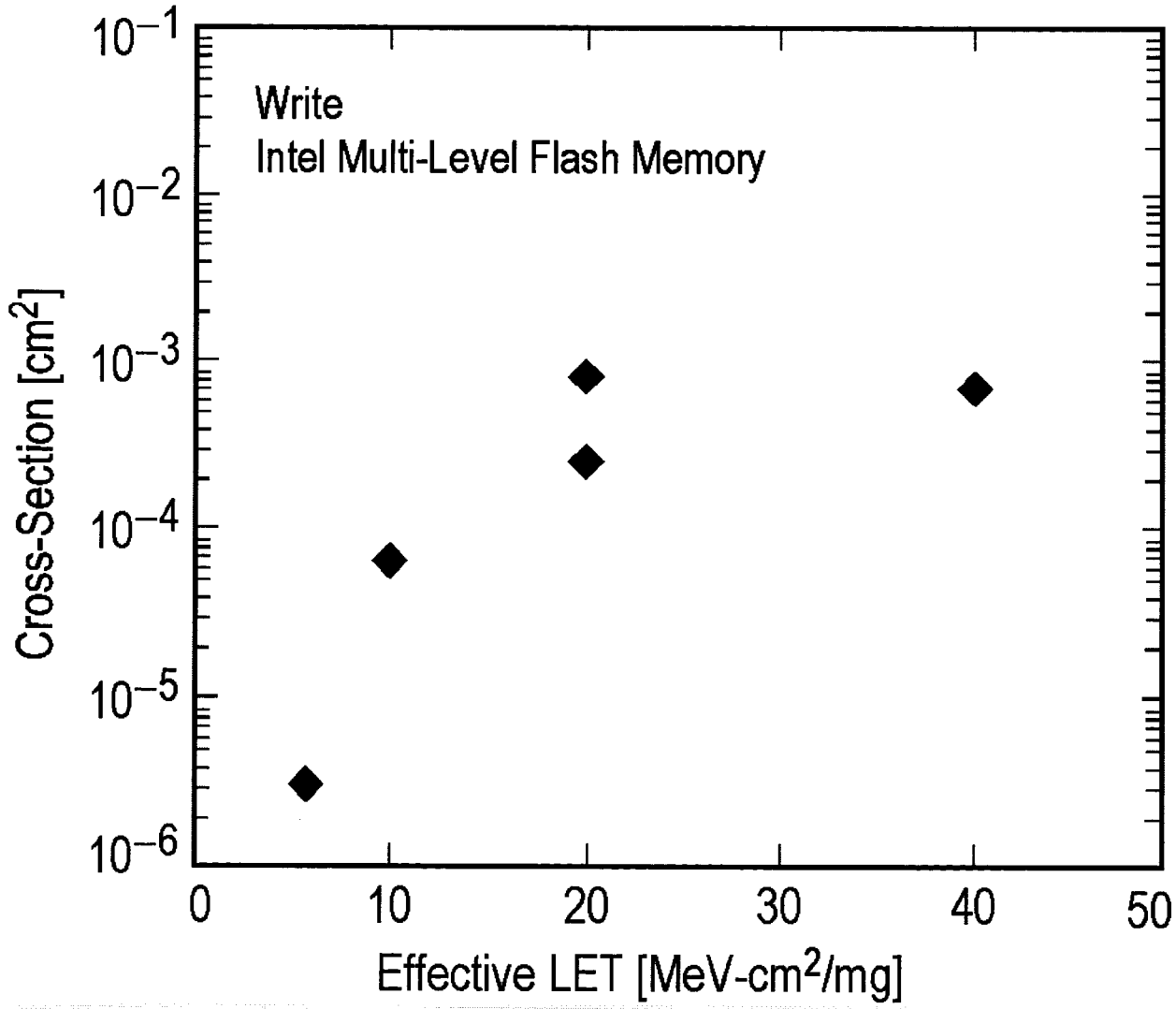
SEFI (Erase mode - Intel)



Read-upsets (Intel)



Write upsets (Intel)



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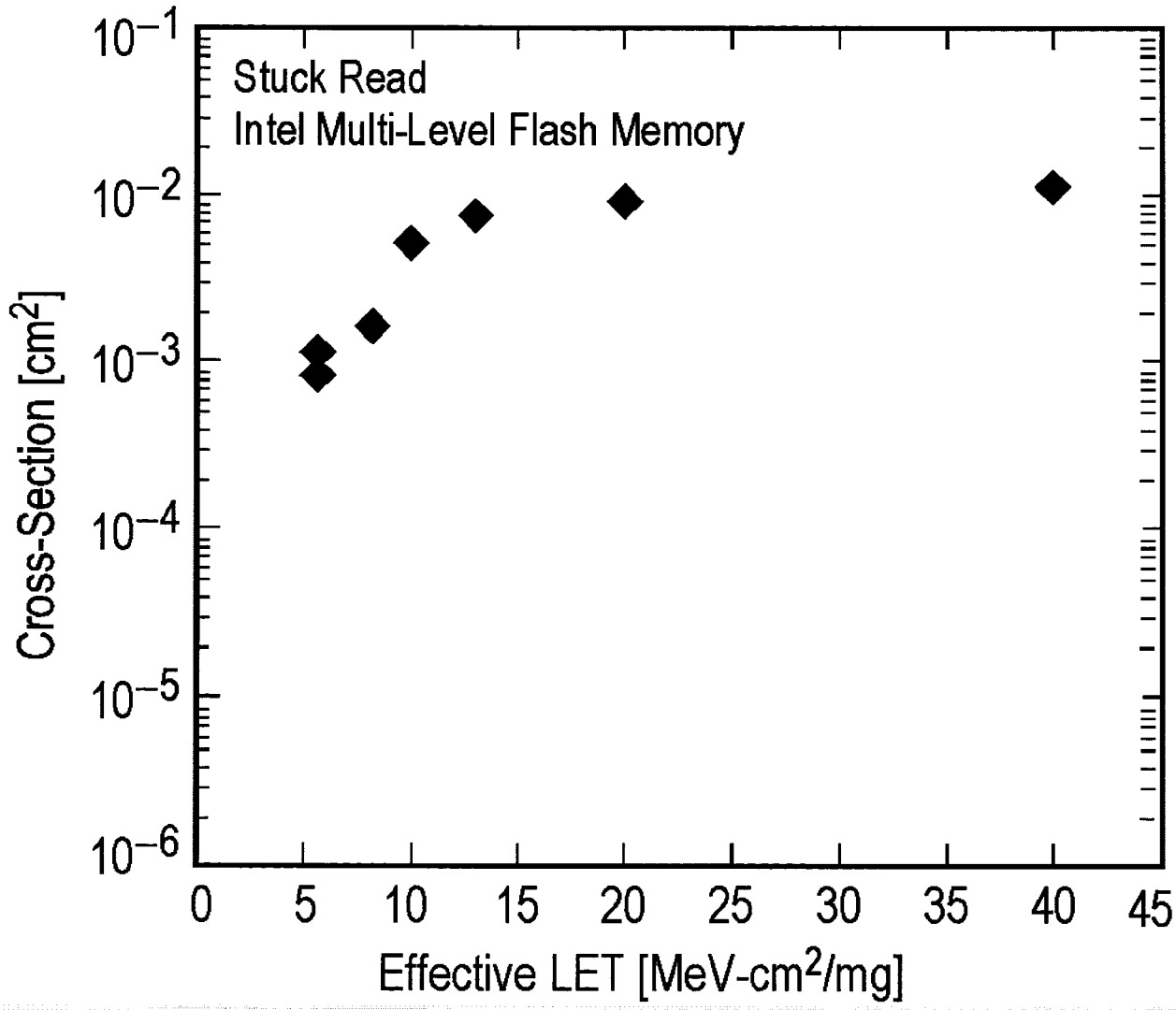
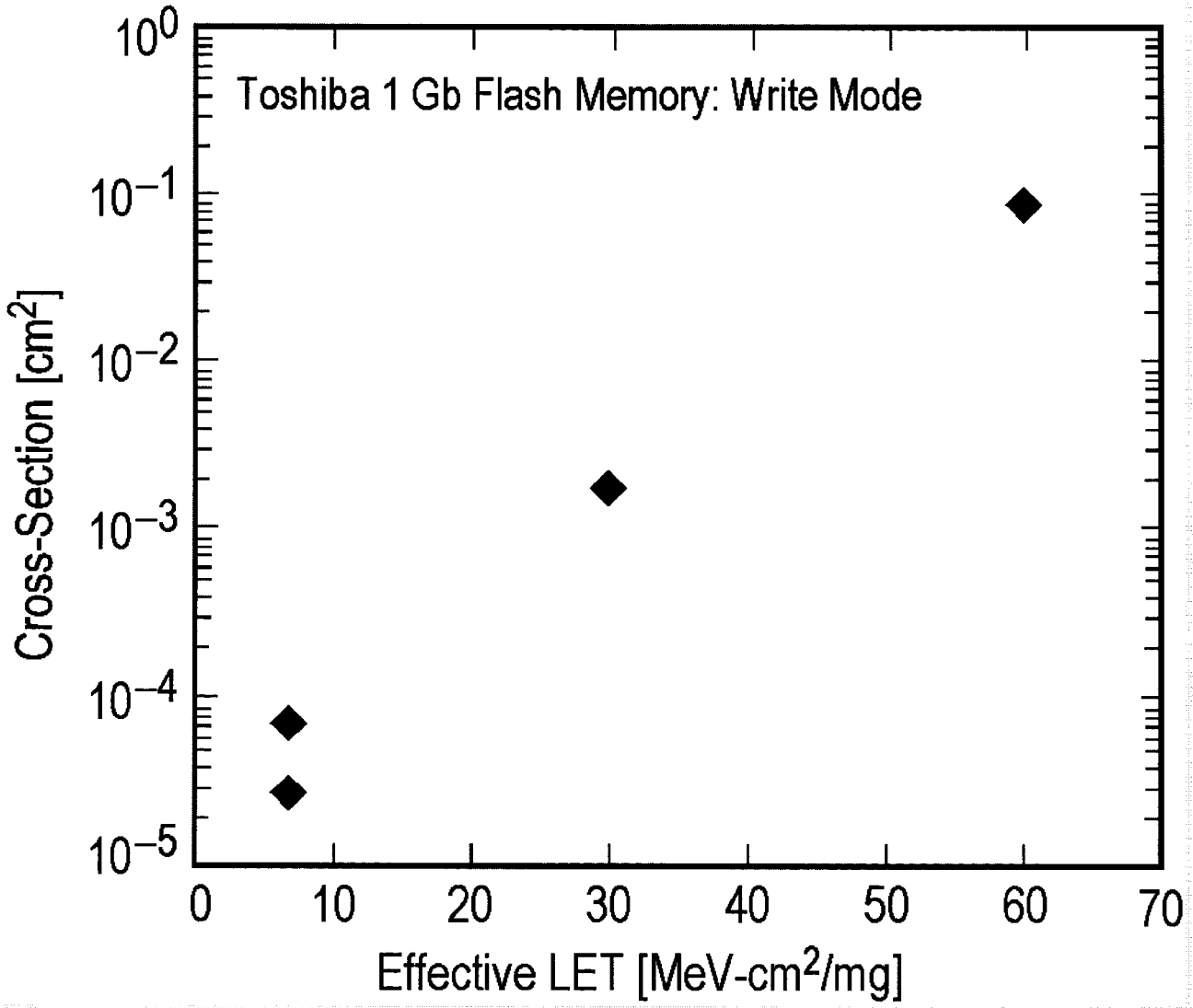
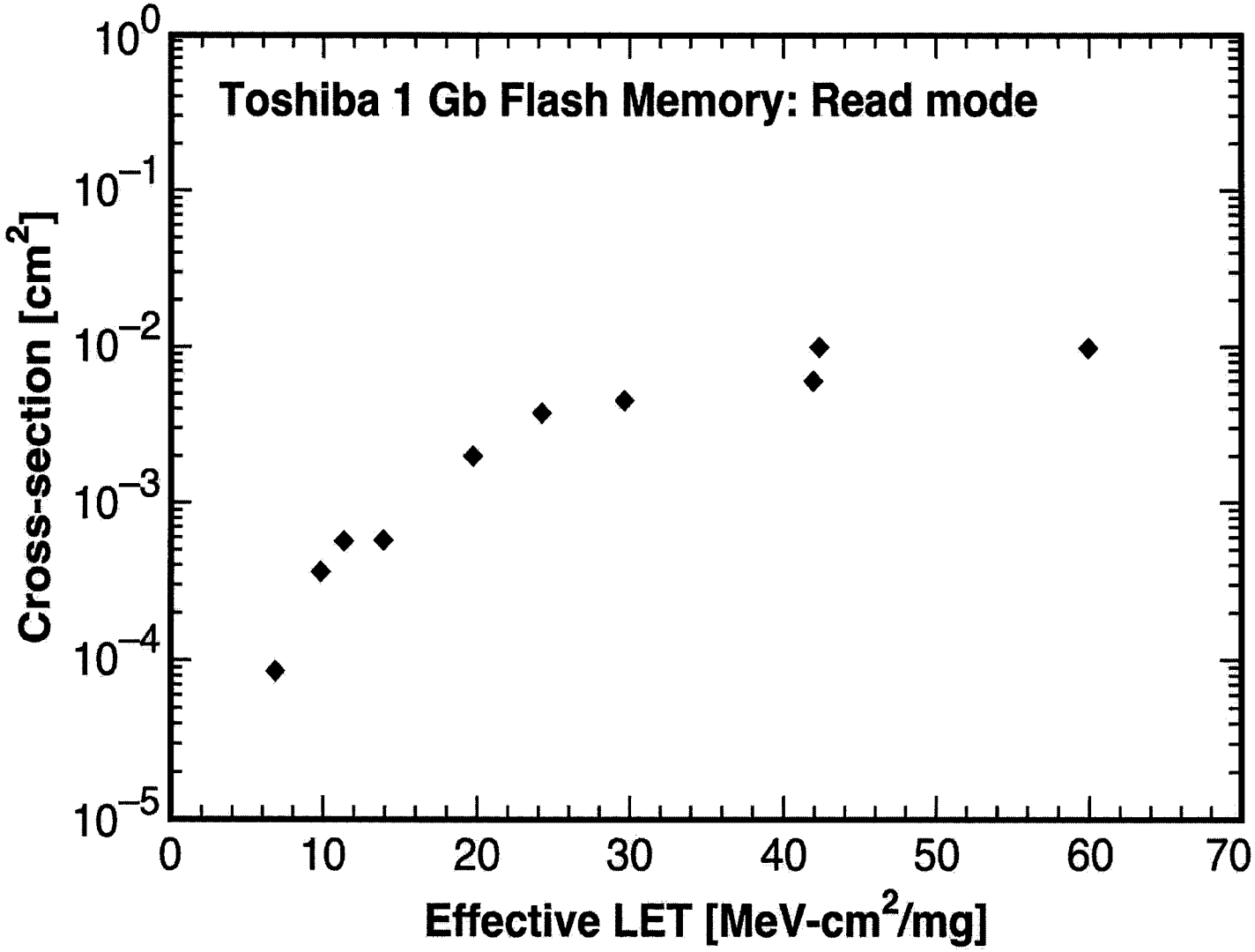
Stuck-read upsets (Intel)



Write upsets (Toshiba)



Read upsets (Toshiba)



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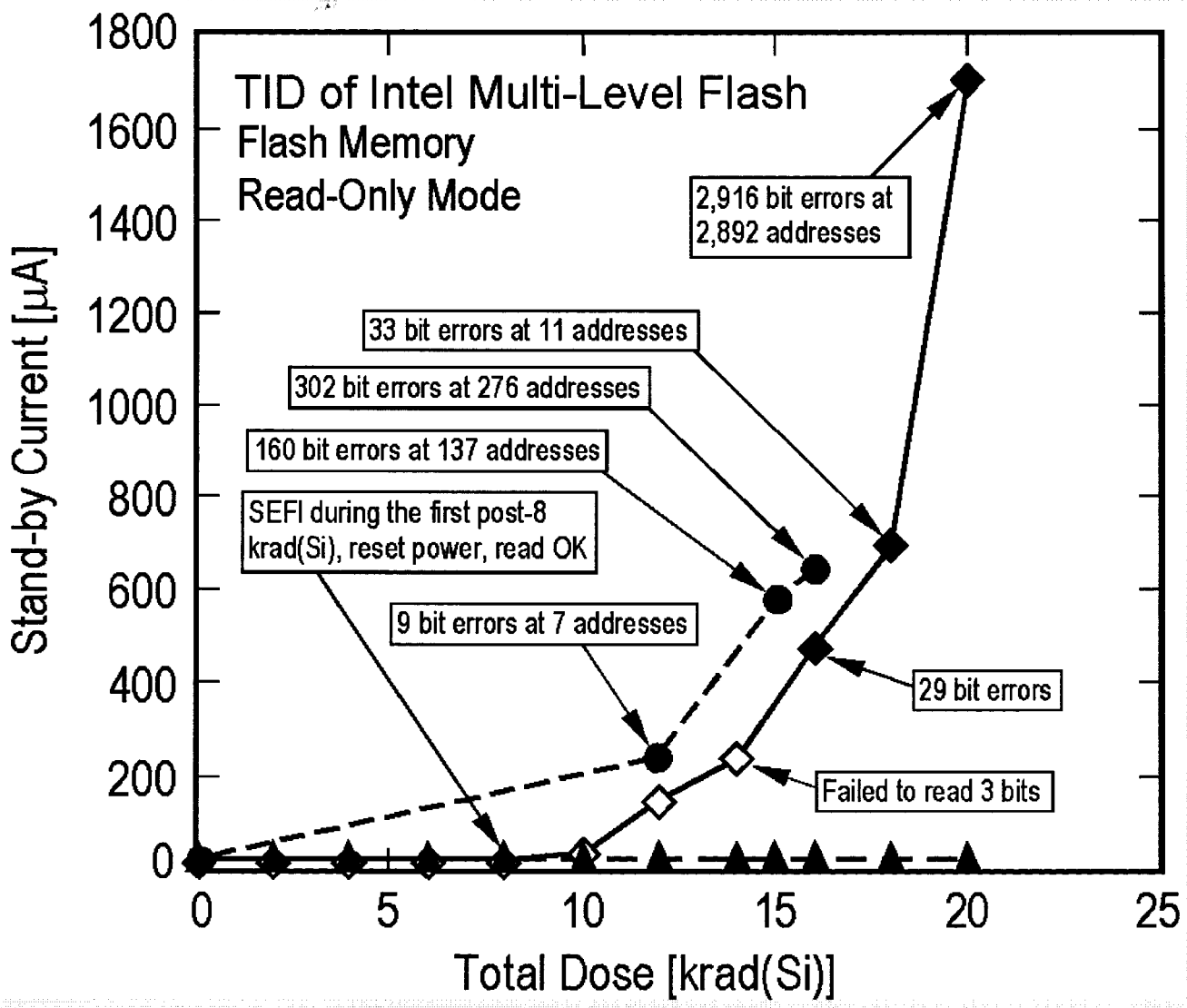
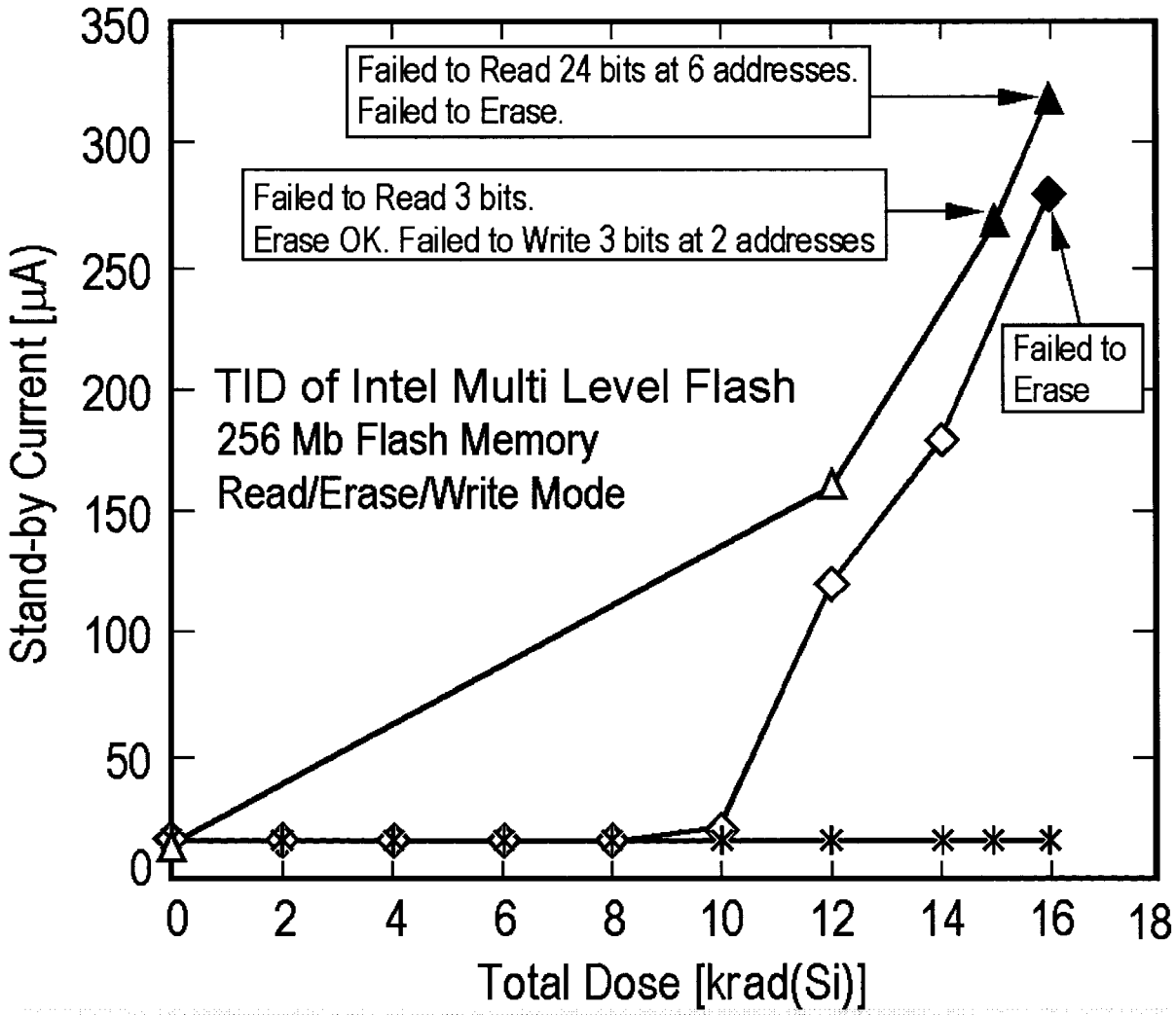
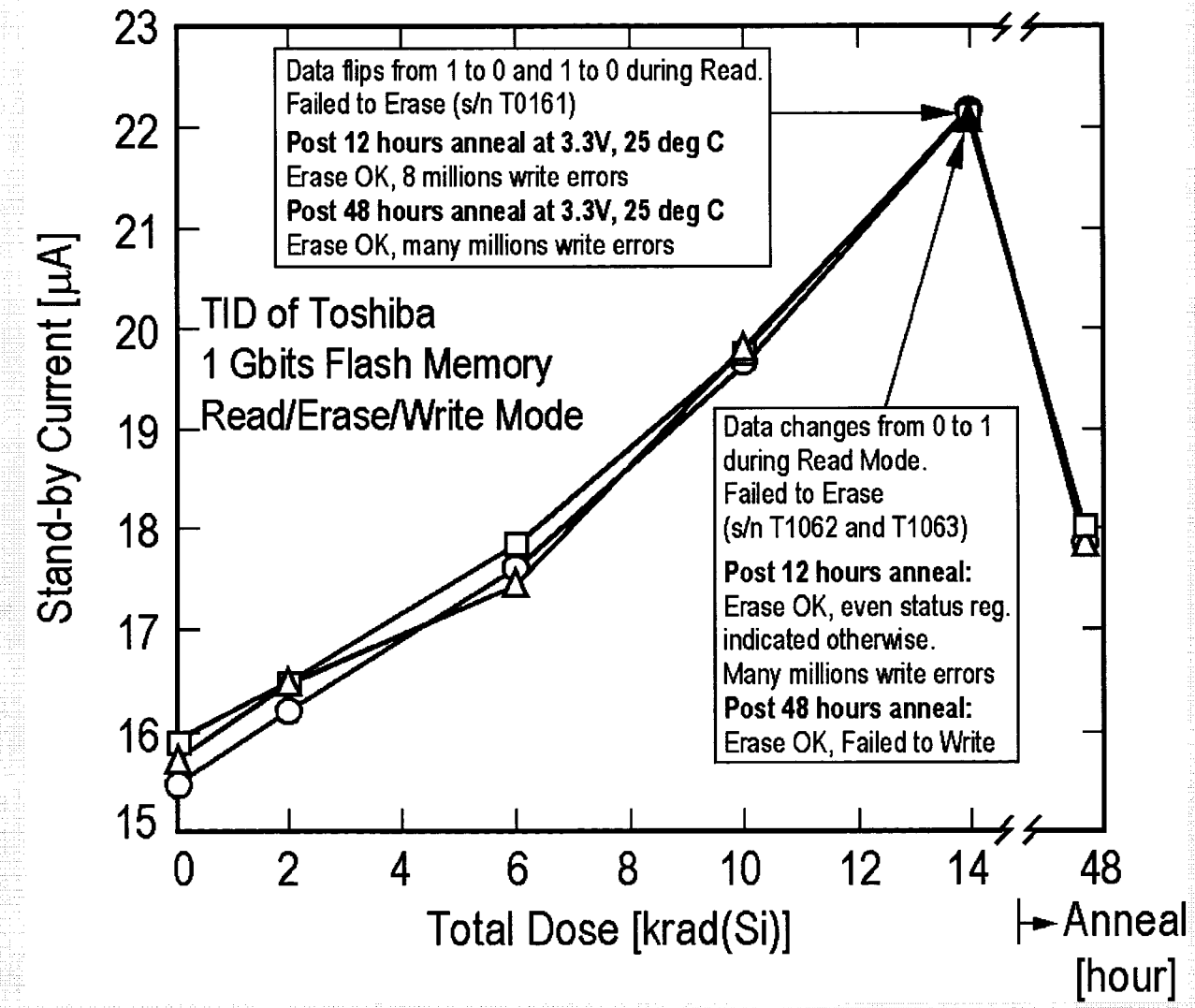
TID results (Intel read mode)



TID results (read/erase/write)



TID results (read/erase/write)



Conclusions

- Intel StrataFlash:
  - **TID ~ 15 krad(Si)**
  - **SEL ~ 10 MeV-cm^2 / mg**
- Toshiba:
  - **TID ~ 15 krad(Si)**
  - **No observed SEL at 25° C (60 MeV-cm^2 / mg)**
- Both are prone to SEFI