



# **TID, SEE and Radiation Induced Failures in Advanced Flash Memories**

**D.N. Nguyen and L.Z. Scheick  
Jet Propulsion Laboratory  
California Institute of Technology**

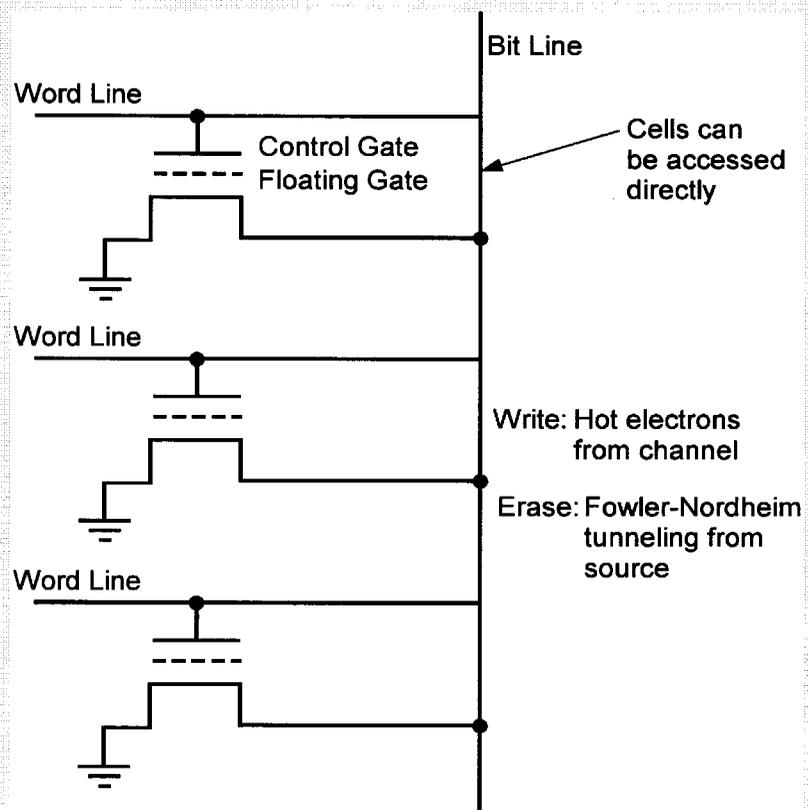


# Outline

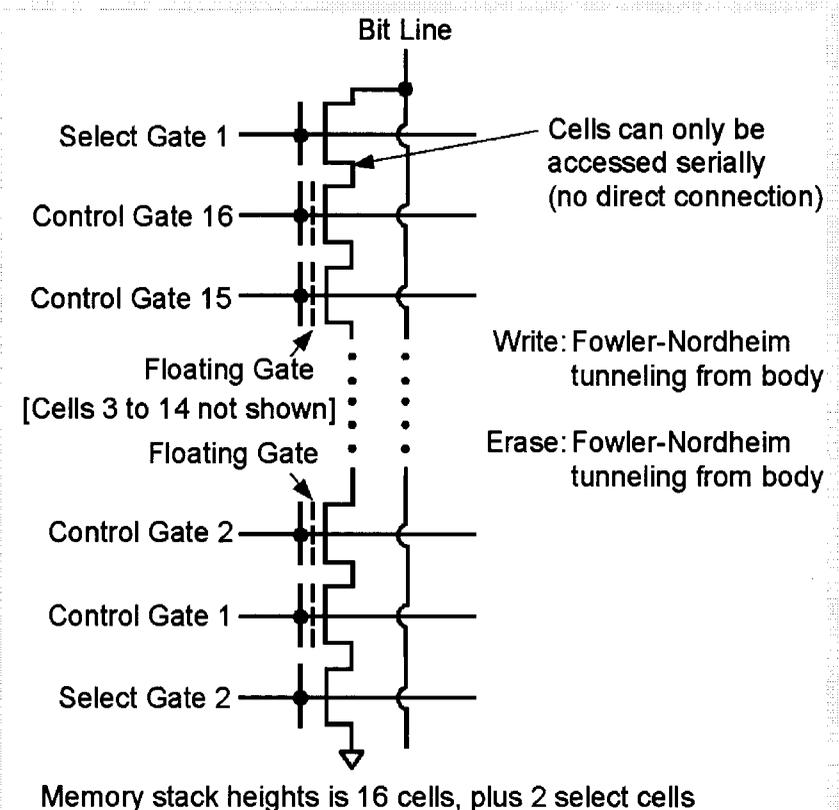
- **Non-Volatile Memory (NVM) types**
- **Test Set-Up**
- **Radiation Induced Failures**
- **SEE Test Data**
- **TID Test Results**
- **Conclusions**



# Flash Memory Types



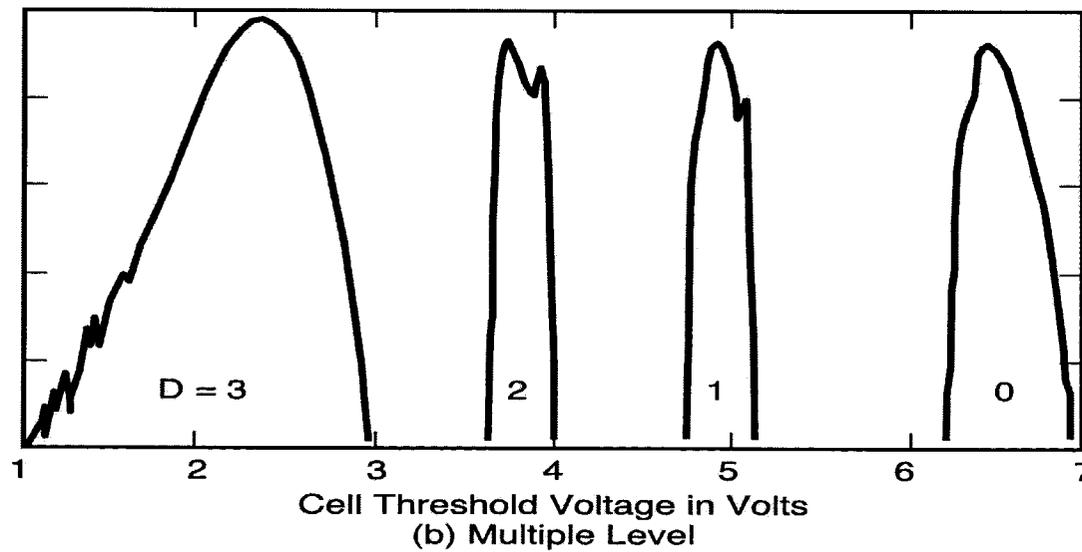
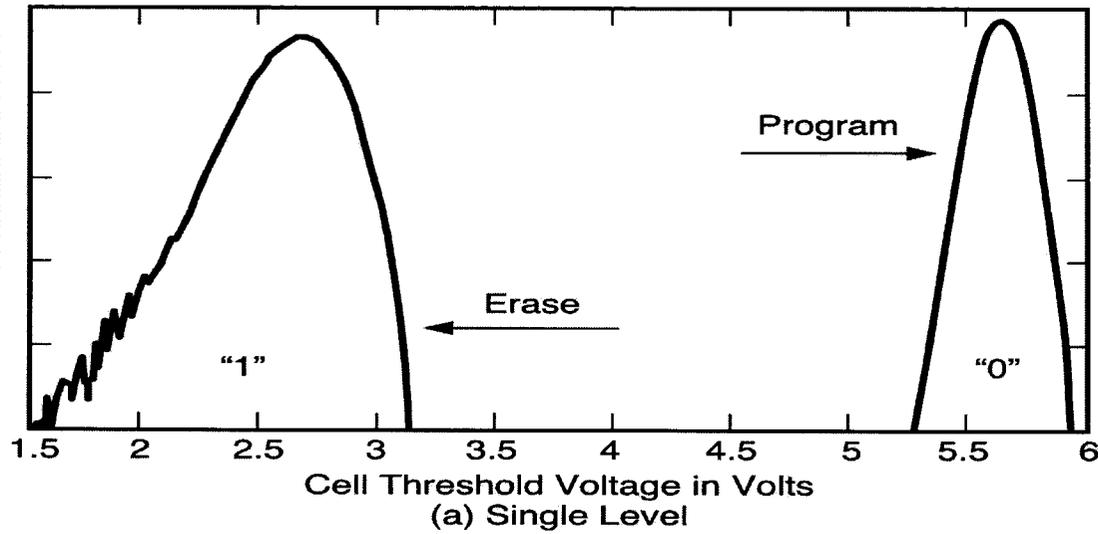
## ● NOR (Intel)



## ● NAND (Toshiba)

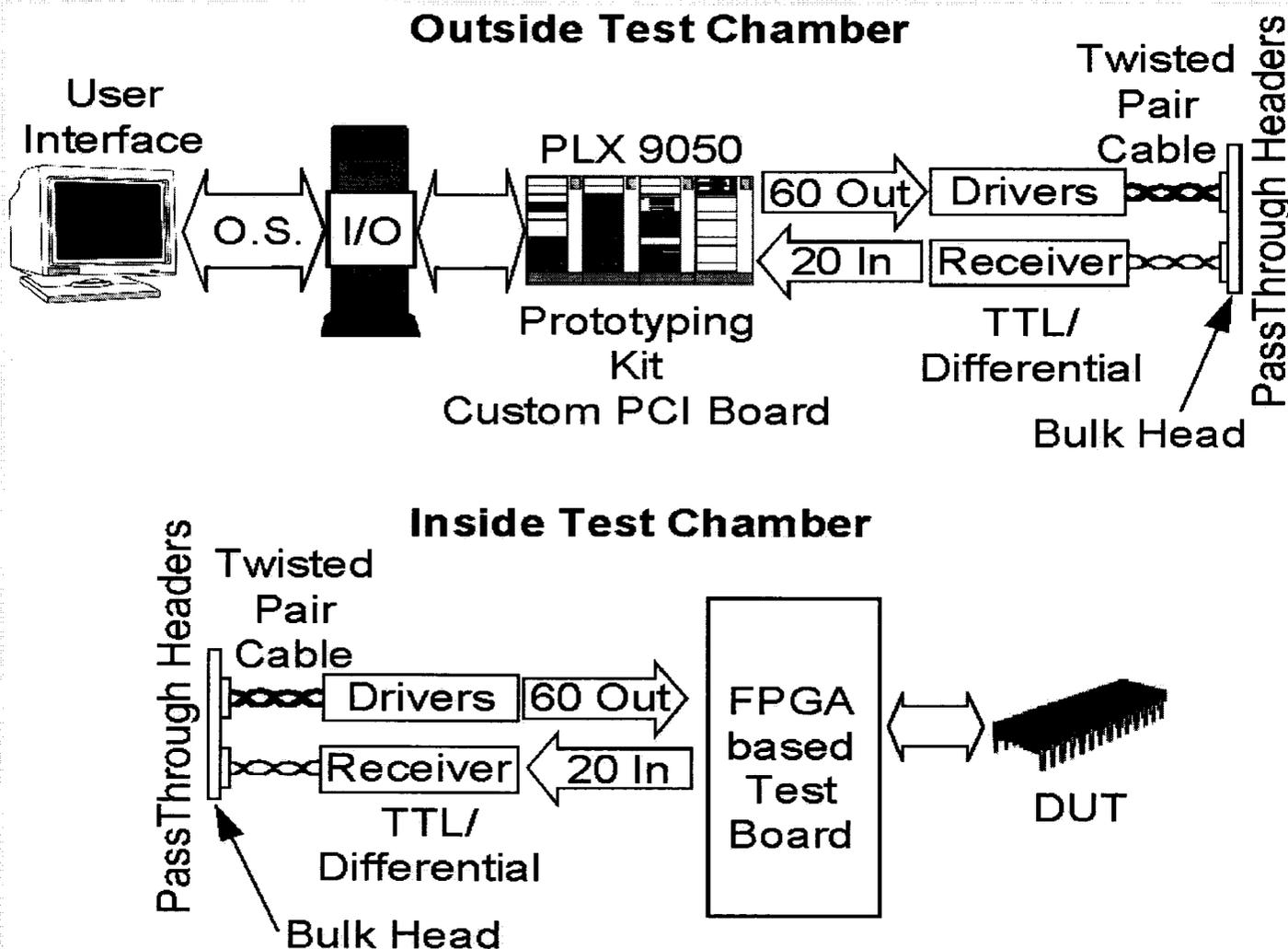


# Cell Threshold Voltage





# 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

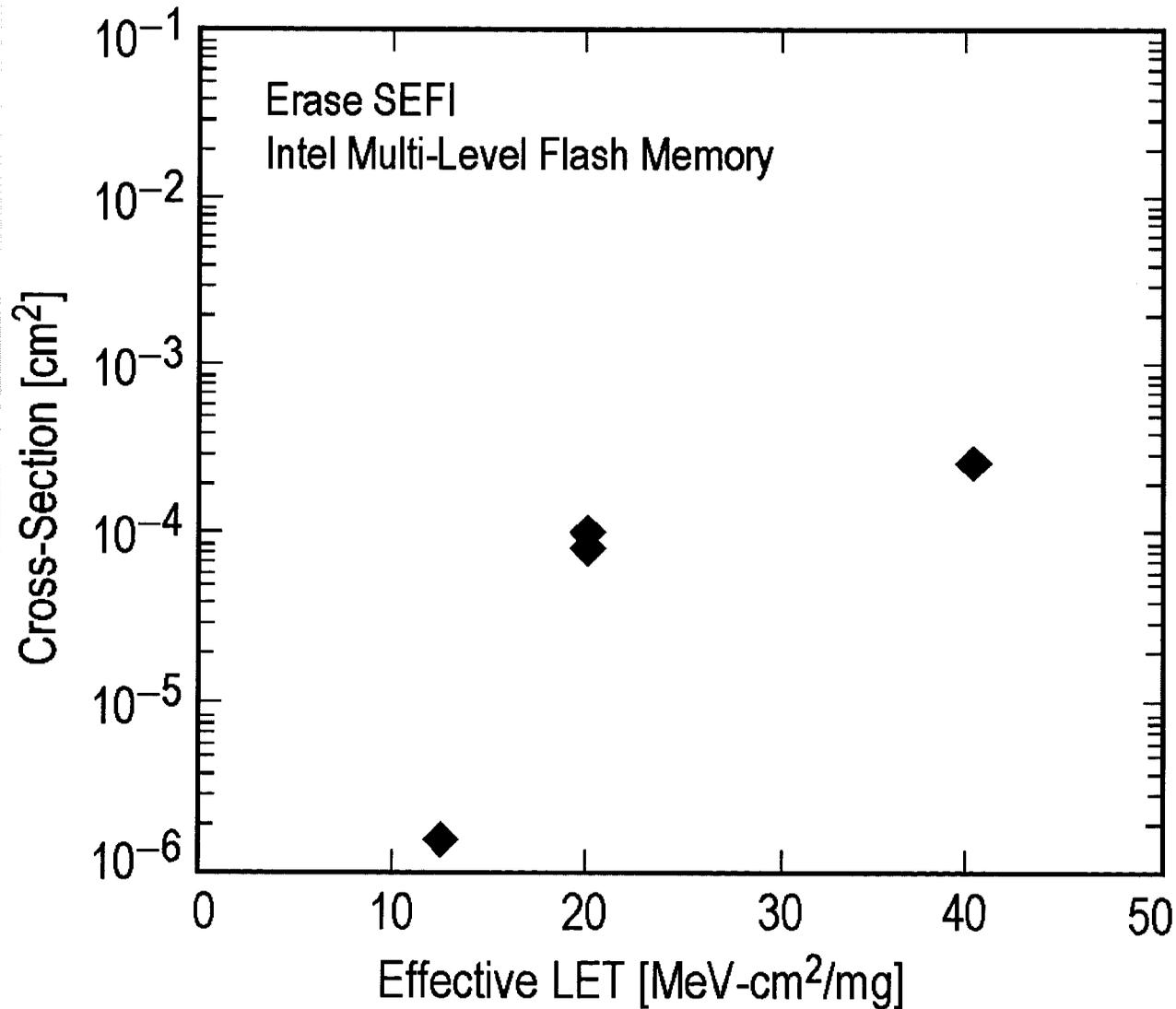


# Radiation Induced Failures

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

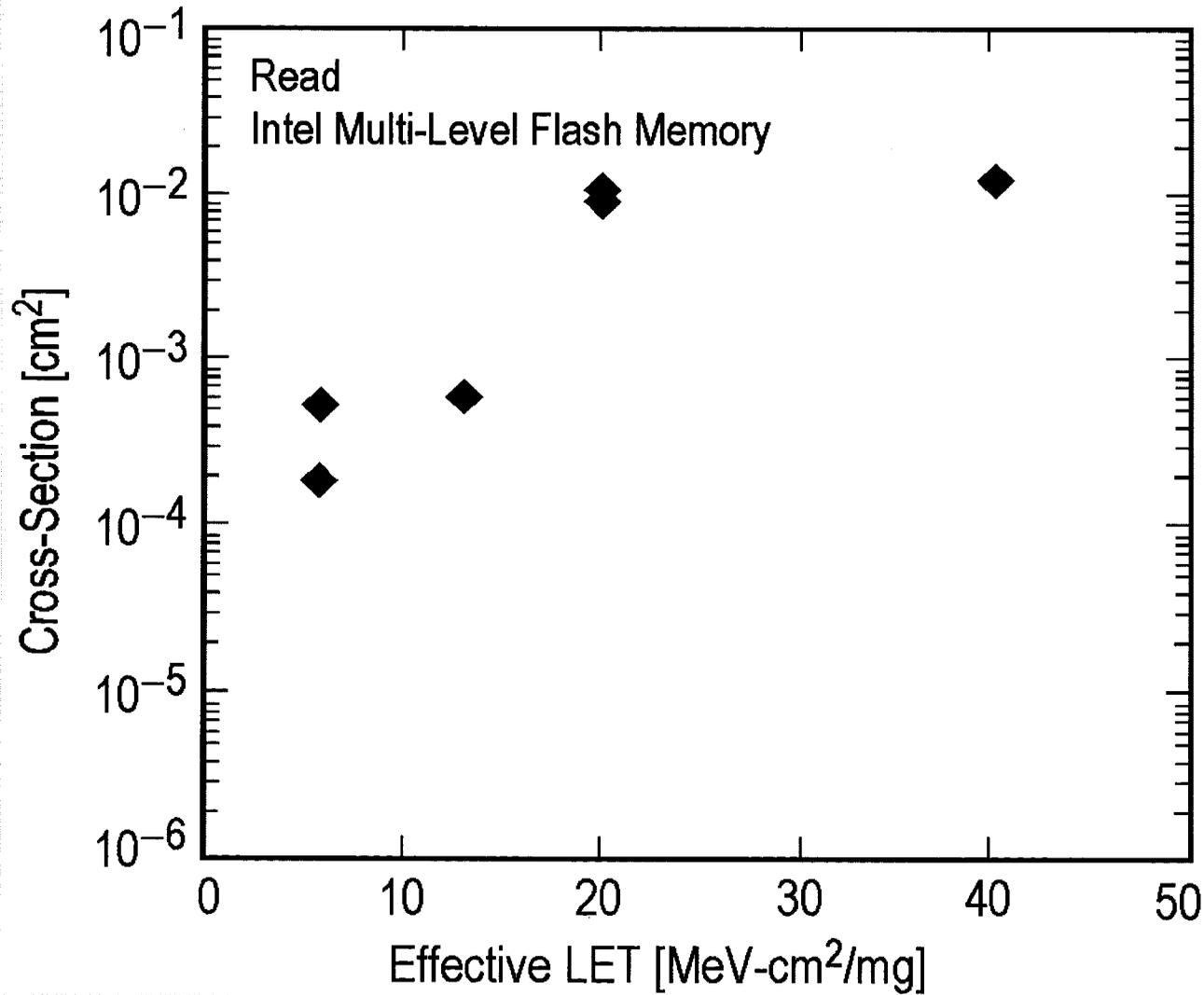


# SEFI (Erase mode - Intel)



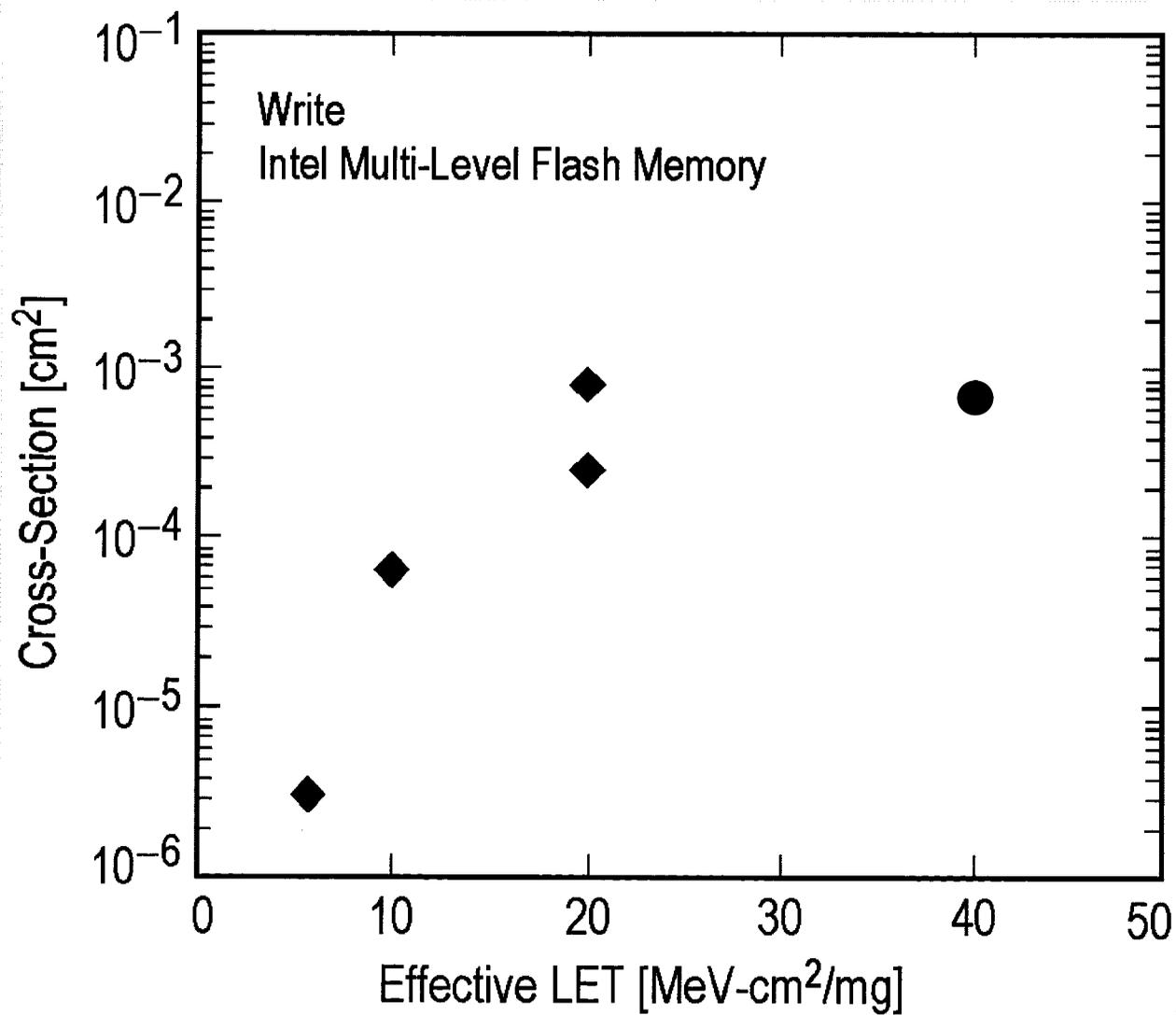


# Read-upsets (Intel)



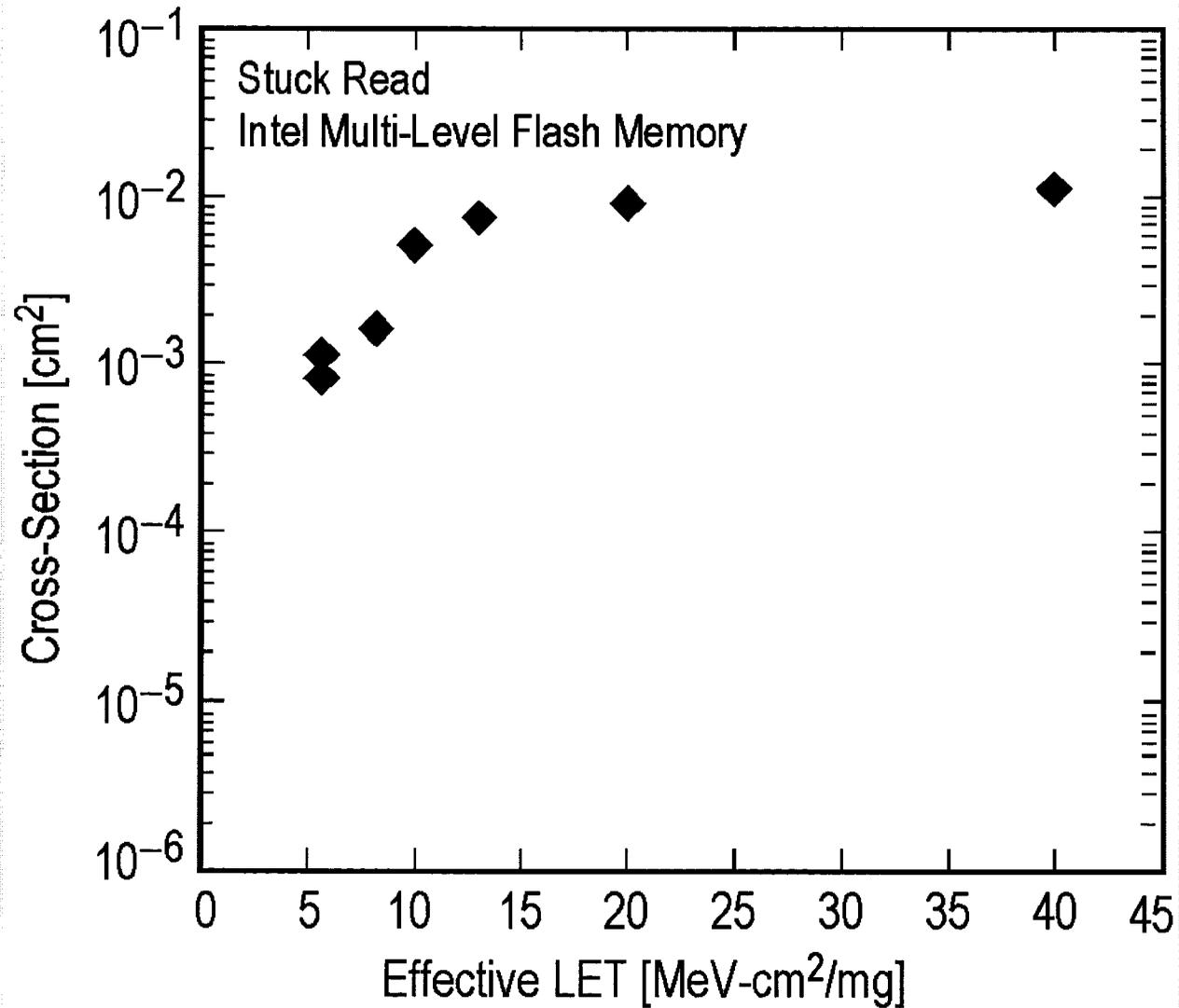


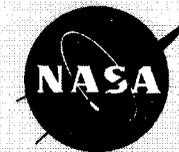
# Write upsets (Intel)



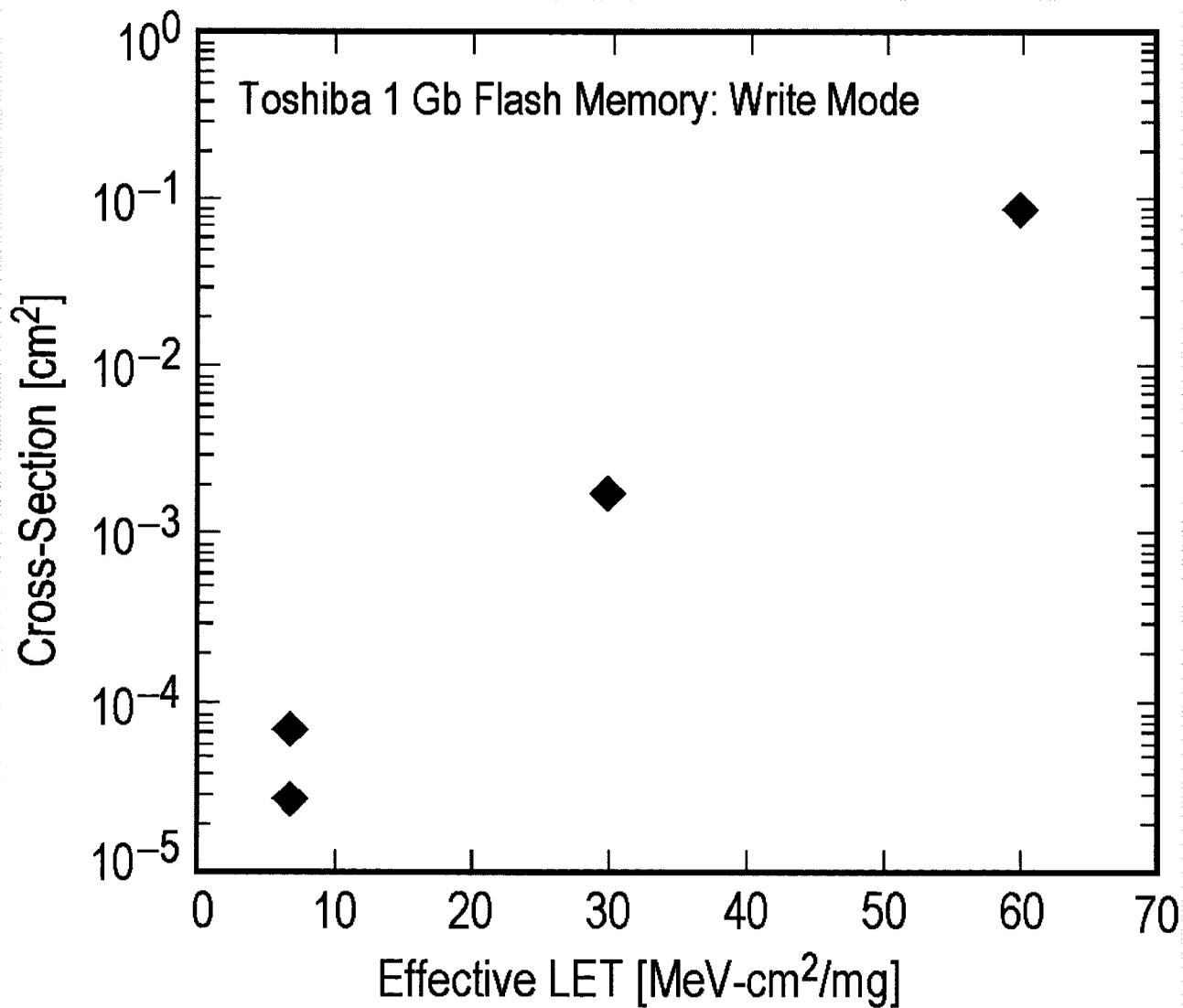


# Stuck-read upsets (Intel)



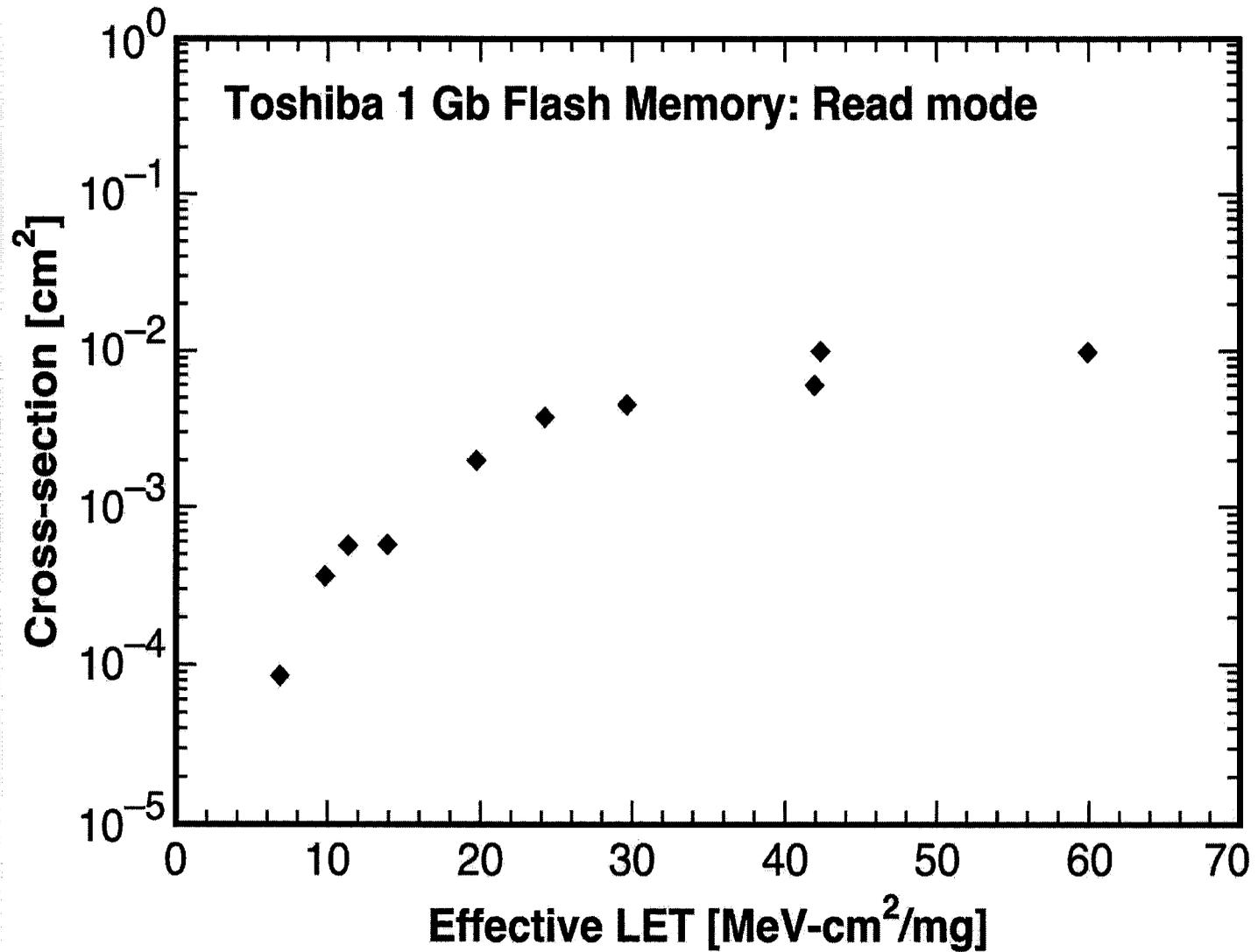


# Write upsets (Toshiba)



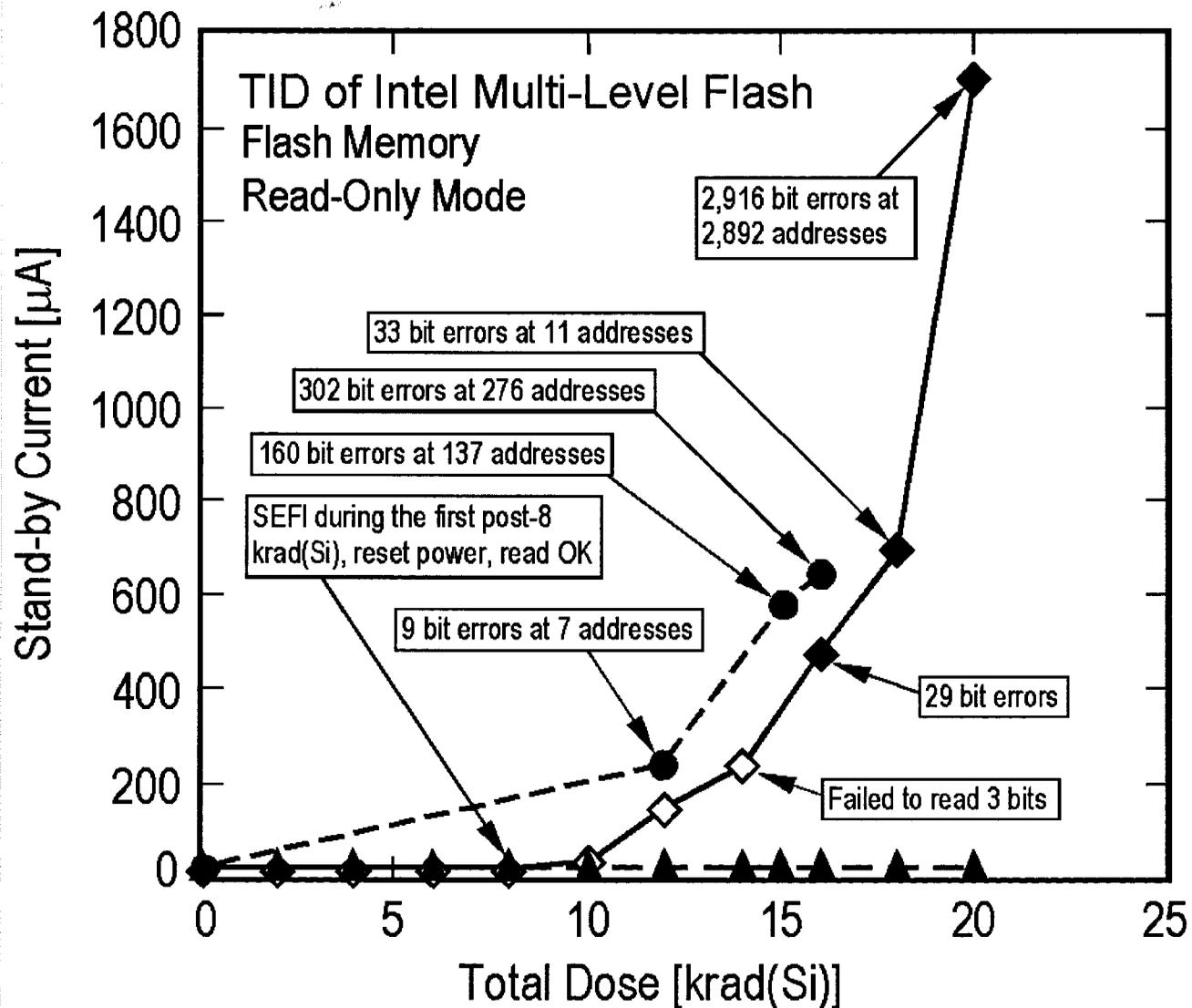


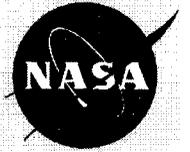
# Read upsets (Toshiba)



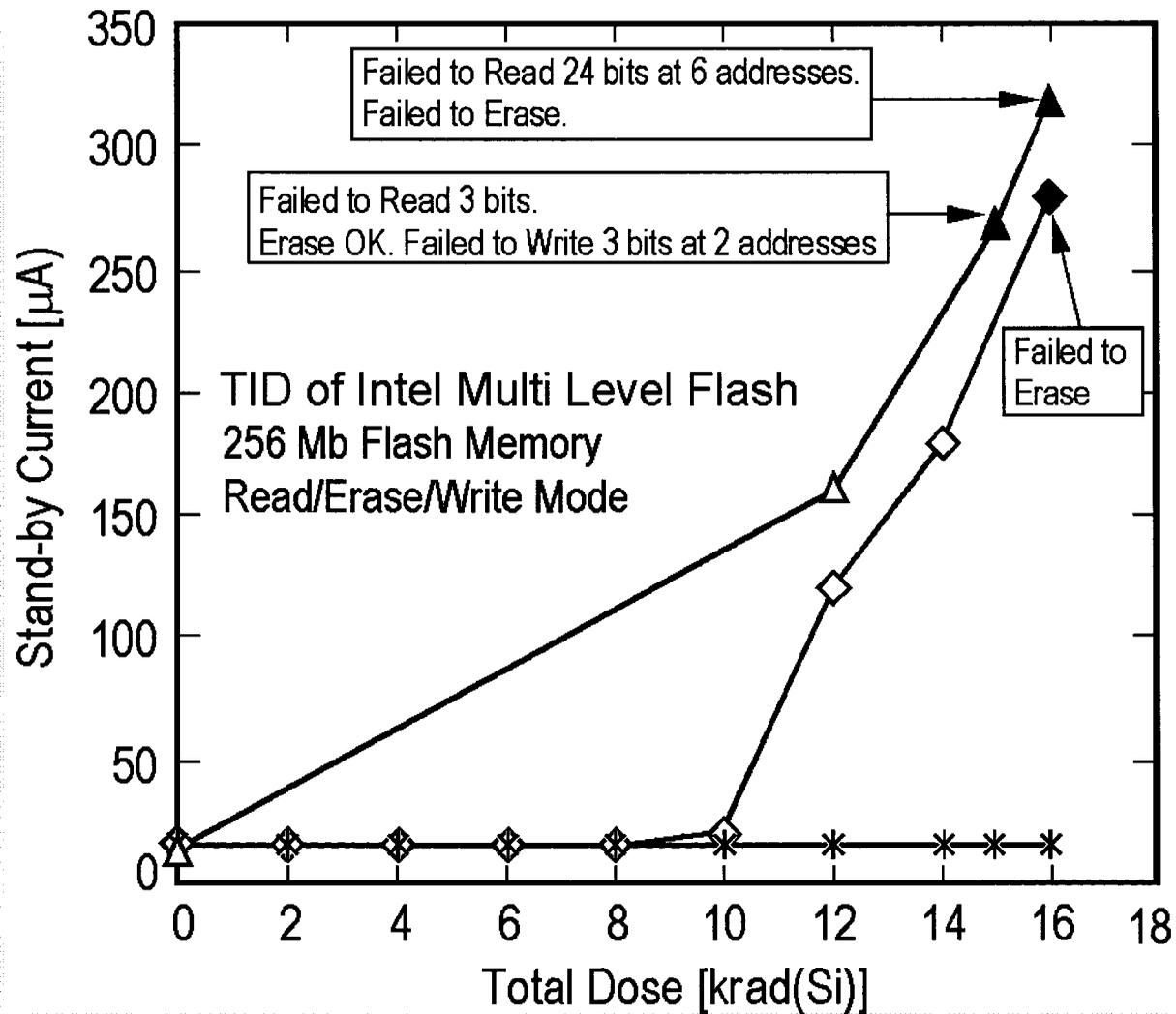


# TID results (Intel read mode)



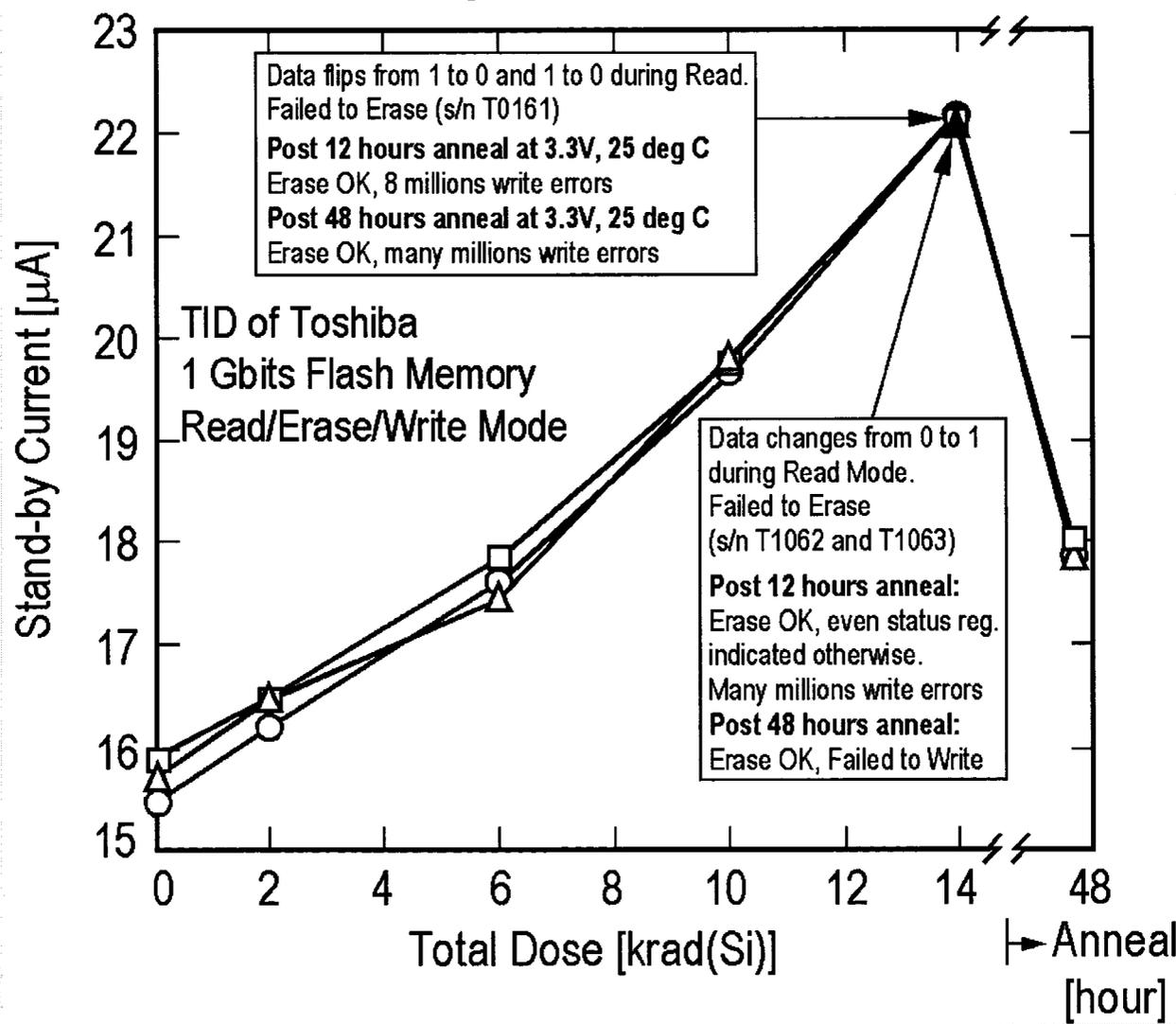


# TID results (read/erase/write)





# TID results (read/erase/write)





# Conclusions

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