Outline - Recent Work at JPL under MSREP

Advanced Flash Memories
  • Includes multi-level flash technology
  • Latchup

64-Mb DRAMs

Displacement Damage in Linear Integrated Circuits

Optoelectronics
  • Upset in Optocouplers
  • Proton Damage in Light-Emitting Diodes

Hybrid Devices: Power Converters
Total Dose Degradation of Intel 64-Mb StrataFlash

![Graph showing device evaluation in "READ" mode, with points indicating biased and unbiased irradiation, and error rates.](graph.png)
Summary of Results for Advanced Flash Memories

Two Technologies
- Intel (NOR Technology with 3 Charge States)
- Samsung (NAND Technology)

Total Dose Degradation
- Different for READ and ERASE/WRITE/READ Modes
- Charge Pump Is Probable Cause of ERASE/WRITE Failure
- Newer Devices Similar to Older Flash Devices [8 - 15 krad(Si)]

Single-Event Upset Is Complex
- Devices Subdivided at Page Level
- Internal Controller, Buffers Easily Upset

Paper at 1999 NSREC
64-Mb DRAMs

High Interest at JPL because of Solid-State Recorders

Evaluated Devices from Three Manufacturers

- Parts Require Re-Packaging for SEE Testing
  - Lead frame extends over chip
  - Costly process
- Upset Cross Section Similar to Older DRAMs
  - Very low threshold (LET ~ 2 MeV-cm²/mg)
  - No Latchup
- Multiple-Bit Upset far More Important for Advanced Devices
  - Severe issue for SSR applications
  - Limits effectiveness of EDAC
  - Upsets in decoding, sense amps also important

Analysis of MBU in Progress
Displacement Damage in Linear Integrated Circuits

Protons Produce Displacement Damage as well as Ionization
- Affects linear devices with lateral and substrate pnp transistors
- Net effect is superposition of ionization and displacement damage

Several Device Technologies Affected
- Op-amps
- Voltage regulators
- Some hardened technologies that use pnp transistors

Paper at 1999 NSREC
Example: Proton Degradation of a Hardened Op-Amp
Upset in Optocouplers from Protons

Cross Section Increases at Extreme Angles
• First identified by GSFC (1997)
• Moderate increase at high proton energies
• Mechanism uncertain

New Results Show Large Increase at Less Acute Angles
• Cross Section Increases by 100 at Low Energies
• Verifies Direct Ionization Mechanism in Photodiode
• Occurs because of Large Photodiode Area, High Sensitivity

Paper at 1999 NSREC
Effect of Proton Irradiation at Various Angles

![Graph showing the effect of proton irradiation at various angles.](image-url)

- **Micropac 6N134 Optocoupler**
  - Lid removed
- **Load** = 1 mA

**Axes:**
- **Y-axis:** Cross Section (cm²)
  - $10^{-4}$
  - $10^{-5}$
  - $10^{-6}$
  - $10^{-7}$
- **X-axis:** Proton Beam Angle (degrees)
  - 0° to 90°

**Lines:**
- 20 MeV
- 30 MeV
- 50 MeV
Proton Damage in Optocouplers and LEDs

![Graph showing the normalized CTR vs. total dose for Cobalt-60 gamma rays, 200 MeV protons, and different models of 4N49. The CTR is measured at $I_F = mA$.](image)
Work in Progress

Proton Testing of Several LED Technologies

- GaAs and AlGaAs LEDs Used in Optocouplers
- Other LED Technologies
  - Shorter wavelengths
  - Double-heterojunction devices

Development of Characterization Methods and Models

- I-V characterization and wavelength
- Injection-enhanced annealing

Papers at 1999 NSREC and RADECS99
Hybrid Power Converters

Several Important Issues

- Proton Degradation of Internal Optocouplers
  - Manufacturers changed optocoupler types
  - Illustrates problem of configuration control
- Dropouts from Single-Event Transients

Variability in Part Types and Suppliers Cause Major Problems

- Radiation Testing Limited to Small Samples Sizes
- Testing Must Consider SEE and Displacement Damage
Effect of Protons on MDI Power Converter

![Graph showing the effect of proton fluence on output voltage for different loads. The graph plots output voltage (V) against proton fluence (p/cm²) for 63 MeV protons. There are curves for 10%, 25%, 50%, and 75% load, with each curve showing a rise in output voltage as proton fluence increases.]
Summary

MSREP Is a Multi-Faceted Program

- Radiation Effects in New Technologies
- Development of Testing and Hardness Assurance Methods
- Continual Evaluation of Space and Laboratory Test Data
- Support to NASA Projects
  - Documents on new effects and technologies
  - Support for small projects
  - RADATA data base

Other Work in Progress

- Device Scaling and New Phenomena
- Radiation Effects in Microprocessors
- Latchup Testing and Latchup Mitigation
- Revised Radiation Design Approaches