Certification of Electronics with Heavy Ions for Deep Space

Radiation Technologies Event at JSC
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Deep Space Certification
Galactic Cosmic Radiation (GCR)

GCR inside material

Differential Flux ($\#$/cm$^2$ (MeV/n) day)

Energy (MeV/n)

conventional

VDBP

dE/dx ionization

Nuclear Reaction
Process for Ionizing Radiation Analysis of Electronic Parts

This is what we are after!
Problems with Traditional Radiation Testing
Low Energy Heavy Ions (Energy ~15-40 MeV/n) 
(i.e., TAMU and LBNL)

Requires that parts have to have packaging removed (de-lidding)
  • Extra parts required for purchase (~50% survive de-lidding process)

De-lidding/test board setup process may impact schedule

Limited ability to test circuit/system (only piece-part)

Typically takes ~8 hours/part-type to characterize (at ~$1100/hr)

Trends in part technology preclude the use of low energy heavy ions

*depends on packaging style
Modern Parts Example: Altera Hardcopy IV ASIC

- Too much bulk silicon for the low energy beam to penetrate

ASIC 40 nm technology – high priority part for Orion Flight Computer
  - Expensive part (several $100k)
    - For Orion Lunar mission, need to qualify part to LET >= 75 MeV-cm²/mg
    - Attempted to remove ~750 microns of Si, but couldn’t without damaging part
    - At conventional heavy ion facility, max LET achievable was 18 MeV-cm²/mg
    - Part successfully characterized using high energy testing at NSRL

Variable Depth Bragg Peak (VDBP) Characterization and Screening
1) Tandem (2-20 MeV/n) or EBIS/LINAC (200 MeV)
2) Booster: 20 MeV/n – 2 GeV/n (NSRL gets beam from here)
3) AGS: 2 GeV/n – 28 GeV/n
4) RHIC: 20 GeV/n – 200 GeV/n
NSRL 20cm x 20cm Beam Intensity
(can go as high as 60cm x 60cm)

- ~100<Flux< 1e6 (or higher) particles/cm2/spill (spill every 4-5 seconds)
- Beam spot as low as ~ 1cm x 1cm for piece part testing
- Large beam spot can be used for system level testing
Traditional Test

Cyclotron

Provides ions with specific damage level

Delidded Electronic Part

radiation

# Errors

Damage

Energy deposited (damage) in the sensitive volume causes errors. More damage = more errors/failure

Degrader Wheel Placed Here

In the medical industry, cancer therapy is used to focus ionizing radiation beams on tumors. They place the Bragg Peak on the tumor which deposits energy in the tumor thus destroying it.

VDBP Test

(C. Foster, P. O’Neill – NASA JSC)

Beam

Degrader System at NSRL

NASA Space Radiation Laboratory at Brookhaven spent ~$50k to develop degrader system for VDBP
Exposure Set Up

Known: Ion Species (Gold, Iron, Carbon, etc.)
Energy of Ions from Booster Synchrotron, $E_B +/- \Delta E_B$

Need to know: Energy of Ions at DUT, $E_D +/- \Delta E_D$
By associating the maximum error cross section with the maximum LET.
VDBP – Total Ionizing Dose Example
Everywhere in this part was exposed to LET $\geq 52$
VDBP Validation
VDBP Validation (Single Event Upset)

FreeScale SRAM
High energy Heavy Ion Data - NSRL - October, 2010

Results of the VDBP measurements of the latch up cross-sections versus LET(Si) for the Analog Devices Inc. Vertical error bars are for counting statistics only. Horizontal error bars indicate the estimated uncertainty in assignment of the LET(Si) values.

Summary

• NASA/JSC has developed testing and modeling techniques to use high energy heavy ions to qualify parts for space missions.

• Our test and modelling experience can be used to help solve analogous problems in the medical and oil and gas industry.

• The JSC/EV5 radiation team can provide expertise in the following areas:
  - Radiation Testing
    - Proton testing
    - Low Heavy Ion Testing
    - High Energy Heavy Ion Testing
      - VDBP and Screening
  - Radiation Modeling
    - Radiation Environments
    - Beam/Source modeling
    - Radiation Transport through materials
      - Monte Carlo (i.e., FLUKA and MCNP6)