Single-Event Effects in SiGe Technologies

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Single Event Effects in SiGe HBTs

Key Partners

- University
  - Robert Reed, Robert Weller, Ron Schrimpf, Mike Alles, Jonny Pellish, Enrique Montes (Vanderbilt),
  - John Cressler, and students (Georgia Tech),
  - Guofu Niu and students (Auburn University),
  - Device and circuit modeling, mitigation approaches, basic mechanisms, fabrication support, testing support, access to emerging SiGe technologies (IBM, TI, Jazz, etc…)

- Naval Research Laboratory (NRL)
  - Dale Mc Morrow
  - Laser test support

- Sandia National Laboratory (SNL)
  - Gyorgy Vizkelethy, Paul Dodd
  - Microbeam testing

- NASA Goddard Space Flight Center
  - Paul Marshall, Marty Carts, Ray Ladbury, and Hak Kim
  - Radiation testing, modeling support, mitigation approaches support

- Mayo Foundation’s Special Purposes Processor Development Group
  - Barb Randall, Pam Riggs, Karl Fritz, Steve Currie, Barry Gilbert
  - Circuit design, fabrication support, device packaging, testing support

Funding provided MURI, NEPP, DTRA, RHESE
Outline

• Single-Event Effects Analysis
• Overview of our approach to improve predictive methods
• Basic mechanisms for charge collection in SiGe HBTs
• Implications for ground testing
• Plans
• DURIP award
Classical On-Orbit SEE Performance Predictions

**Space Environment**

![Graph showing space environment flux vs. kinetic energy](https://creme96.nrl.navy.mil/)

**Ground Testing**

![Ground testing setup](https://example.com/image)

**Integral Rectangular Parallelepiped (RPP) model**
(circa 1980)

https://creme96.nrl.navy.mil/

**On-Orbit SEE Rate**
SEE Ground Testing on SiGe HBTs

Other Examples of Breakdown of Existing SEE Models

Protons effects in Optical Links

Proton effects in SOI based memories

Heavy Ion effects CMOS SRAM


MURI Review June 13-14, 2006
Plan for Investigation of Single Event Effects in SiGe HBTs circuits

Understanding of basic mechanisms + Mixed-Mode TCAD

New Predictive Method for On-Orbit Performance
IBM SiGe HBT Technology

Cross Section of IBM’s 0.5 Micron UHV/CVD SiGe HBT

<table>
<thead>
<tr>
<th>Figure of Merit</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
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</thead>
<tbody>
<tr>
<td>$W_E$ ($\mu$m)</td>
<td>0.42</td>
<td>0.18</td>
<td>0.12</td>
</tr>
<tr>
<td>peak $f_T$ (GHz)</td>
<td>50</td>
<td>120</td>
<td>207</td>
</tr>
<tr>
<td>peak $f_{max}$ (GHz)</td>
<td>70</td>
<td>100</td>
<td>285</td>
</tr>
</tbody>
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http://www.03.ibm.com/chips/services/foundry/technologies/roadmap.html
SEMs* of SiGe Technology

7HP

8HP

Jazz-120

National

* Taken at NASA/GSFC
Ion Beam Induced Charge Collection Measurement

- Sandia National Laboratories
- 36 MeV $^{16}\text{O}^{5+}$
  - 26 MeV deposited in Si
- ≈ 600 ions/s = 0.48 fA
- 25.5 μm range in silicon
- Bragg peak @ 7.5 MeV·cm²/mg
- 1.5 μm² spot size; 0.1 μm steps
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- Peak collection occurs for event inside the deep trench isolation (DTI)
- Lower amount of charge collection for events outside the DTI
- Clear delineation of DTI boundary

Collaboration with Georgia Tech
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TCAD Modeling of Charge Collection in SiGe HBT

HBT details provided by John Cressler and Guofu Niu
Ion Event within DTI

Transient disturbance in the junction electrostatic potential induced by a ion event

Collection Collection Mechanisms in SiGe HBTs

$t = 6 \text{ ps}$

0.5 pC deposited

Charge Injection
Collection Collection Mechanisms in SiGe HBTs

Transient disturbance in the junction electrostatic potential induced by carrier diffusion

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SEU Cross Section Measurement of Shift Registers Fabricated in IBM’s 5AM SiGe HBT Technology

Heavy Ion Broadbeam Data

Variation of cross section over angle depends on circuit.
SEU Cross Section Measurement of Shift Registers Fabricated in IBMs 5AMHP SiGe HBT Technology

Variation of cross section over angle depends on circuit.
Charge collection and SEU sensitivity driven by interaction of ion path and deep trench isolation
IBICC Data at Angle

0 Degrees

~15 Degrees
• Larger charge collection events:
  – Classical model would predict 4% reduction in area
  – Data shows 30% reduction in this area
  – Due to truncation of charge collection by DTI

• Small charge collection events:
  – Tends follow classical model more closely
  – Increased charge collection area is due to charge collection by carrier diffusion in the substrate
TCAD Simulation of Angle Response

- Detailed TCAD simulation support these results
  - Montes, et al., NSREC 2006: implication of this for SEU cross section

Experiment
Plan for Investigation of Single Event Effects in SiGe HBTs circuits

Understanding of basic mechanisms

Mixed-Mode TCAD

New Predictive Method for On-Orbit Performance

Next Few Year!
Defense University Research Instrumentation Program

• Proposal awarded 4/15/2006
  – Associated with the MURI
  – Jerry Witt
  – Kitt Reinhardt (New PM)

• Focused on instrumentation needed to perform high-speed single event effects testing
  – Analog up to 26 GHz
  – Digital up to 12.5 Gbps

• Highlights
  – 0.025 to 12.5 Gbps Anritsu BERT
  – Tektronics 13 GHz single shot, 40 Gsps sampling oscilloscope
  – Agilent 0.250 MHz to 31.2 GHz signal generator
  – Development of a novel method of detecting errors in oscillating circuits(< 26 GHz)
  – High-speed probe station