Heavy Ion Microbeam- and Broadbeam-Induced Current Transients in SiGe HBTs


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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy’s National Nuclear Security Administration under Contract DE-AC04-94AL85000.

Acknowledgement

- NASA Electronic Parts and Packaging program
- NASA Radiation Hardened Electronics for Space Environments project
- DTRA Radiation Hardened Microelectronics program under IACRO #08-4343I to NASA
- AFOSR MURI program and AFOSR DURIP award
- SiGe teams at the Georgia Electronic Design Center and IBM
- Naval Research Laboratory
- CEA/DIF (Arpajon, France)

- Sandia National Laboratories (SNL)
- Department of Physics at the University of Jyväskylä, Finland (JYFL)
- Grand Accélérateur National d’Ions Lourds, France (GANIL)
Heavy ion transient overview

- IBM 5AM SiGe HBT is device-under-test
- High-speed measurement setup
- Low-impedance current transient measurements
  - SNL, JYFL, GANIL
- Microbeam to broadbeam position inference
- Improvement to state-of-the-art

Bias conditions of interest

All biases based on device isolation

3-D TCAD from DUT GDSII
IBM 5AM npn SiGe HBT

Bias conditions chosen to represent “circuit-like” experiments
Typical experimental setup

Different than broadbeam

36 MeV $^{16}$O dE/dx profile [SRIM-2008]

Sandia National Laboratories’ Microbeam Chamber

SNL Van de Graaff Microbeam

Transient Capture
Device under test and microbeam irradiation

Active junction area
Microbeam rastering concept

Base → Emitter → Collector

7-8 µm

Deep Trench Isolation

N⁺ subcollector collector-substrate junction

p-type substrate: $1 \times 10^{15}$ cm$^{-3}$

IBM 5AM npn SiGe HBT

Microbeam data allows position correlation
36 MeV $^{16}$O SNL microbeam: Case 1

Peak current magnitude

Base

Collector

Active base-collector junction area

- $V_{\text{sub}} = -4$ V; all other terminals grounded
- Base terminal images base-collector junction
- Collector terminal images base-collector junction and subcollector

Imaging provides information about position and current
36 MeV $^{16}$O SNL microbeam: Case 2 vs. 3

Peak current magnitude

Collector vs. Collector

$V_C = +3$ V (Case 2)
$V_{sub} = -3$ V (Case 3)

- Same result was observed in two-photon pulsed laser testing


Difference in peak current results from non-zero $V_{CB}$
Heavy ion broadbeam transients

- Data collection at JYFL and GANIL
- 9.3 MeV/u cocktail including $^{20}$Ne, $^{40}$Ar, $^{82}$Kr, and $^{131}$Xe and 45.5 MeV/u $^{136}$Xe

IBM 5AM npn SiGe HBT

University of Jyväskylä
K-130 Cyclotron

No position correlation with broadbeam irradiation
JYFL vs. SNL: LET scaling

A $^{20}\text{Ne}$ and $^{16}\text{O}$ transients are similar – related by LET
JYFL: LET extremes

Position correlation made possible with microbeam data

- \( ^{20}\text{Ne} \text{ LET} \): 3.6 (MeV·cm\(^2\))/mg
- \( ^{131}\text{Xe} \text{ LET} \): 60 (MeV·cm\(^2\))/mg

9.3 MeV/u

11 MeV/u
Maximum observed transients for each ion at each facility

JYFL vs. GANIL transients

Similar LET values produce different transient responses.
Conclusions

- Microbeam (SNL) transients reveal position-dependent heavy ion response
  - Unique response for different device regions
  - Unique response for different bias schemes
  - Similarities to TPA pulsed-laser data

- Broadbeam transients (JYFL and GANIL) provide realistic heavy ion response
  - Feedback using microbeam data
  - Overcome issues of LET and ion range with microbeam
  - **Angled $^{40}$Ar data in full paper

- Data sets yield first-order results, suitable for TCAD calibration feedback