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


1. NASA Goddard Space Flight Center, Code 561, Greenbelt, MD 20771 USA
2. Department of Electrical Engineering and Computer Science, Vanderbilt University, Nashville, TN 37235 USA
3. Naval Research Laboratory, Washington, DC 20375 USA
4. Sandia National Laboratories, Albuquerque, NM 87185-1083 USA
5. CEA, DAM, DIF, F-91297 Arpajon, France
6. School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA 30332 USA
7. IBM SRDC, 2070 Rte 52 MS 32A, Hopewell Junction, NY 12533
8. CFD Research Corporation, Huntsville, AL 35805 USA
9. NASA Consultant, Brookneal, VA 24528 USA

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  - 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

Case 1
-4 V

Case 2
+3 V

Case 3
-3 V

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

Different than broadbeam

36 MeV $^{16}$O dE/dx profile
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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

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

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

Active base-collector junction area

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

Peak current magnitude

Collector

$V_C = +3 \text{ V (Case 2)}$

$V_{\text{sub}} = -3 \text{ V (Case 3)}$

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


Difference in peak current results from non-zero $V_{\text{CB}}$
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

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

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

Position correlation made possible with microbeam data

9.3 MeV/u

$^{20}\text{Ne LET} \quad 3.6 \ (\text{MeV} \cdot \text{cm}^2)/\text{mg}$

$^{131}\text{Xe LET} \quad 60 \ (\text{MeV} \cdot \text{cm}^2)/\text{mg}$
Maximum observed transients for each ion at each facility

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 and feedback