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


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- **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

Bias conditions chosen to represent “circuit-like” experiments

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

Case 1

Case 2

Case 3

www.nasa.gov
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 Chamber

Transient Capture
Device under test and microbeam irradiation

Microbeam rastering concept

Active junction area

Microbeam data allows position correlation

IBM 5AM npn SiGe HBT

N+ subcollector collector-substrate junction

p-type substrate: \(1 \times 10^{15} \text{ cm}^{-3}\)

7-8 µm

Base

Emitter

Collector

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36 MeV $^{16}$O SNL microbeam: Case 1

- $V_{sub} = -4$ 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

Peak Collector Current (mA)

Y Position (um) 0 2 4

X Position (um) 0 2

Collector

Peak Collector Current (mA)

Y Position (um) 0 2 4

X Position (um) 0 2

$V_C = +3$ 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 $^{20}\text{Ne}$, $^{40}\text{Ar}$, $^{82}\text{Kr}$, and $^{131}\text{Xe}$ and 45.5 MeV/u $^{136}\text{Xe}$

**University of Jyväskylä**
**K-130 Cyclotron**

**IBM 5AM npn SiGe HBT**

No position correlation with broadbeam irradiation
Average transients from inside the deep trench isolation

JYFL vs. SNL: LET scaling

\[ \frac{20}{9.3 \text{ MeV/u}} \]

\[ \frac{16}{2.3 \text{ MeV/u}} \]

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

Position correlation made possible with microbeam data

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

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

9.3 MeV/u
JYFL vs. GANIL transients

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