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


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- 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

IBM 5AM npn SiGe HBT

Microbeam data allows position correlation

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

Peak current magnitude

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

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


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

**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

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

20Ne LET
3.6 (MeV·cm²)/mg

131Xe LET
60 (MeV·cm²)/mg

9.3 MeV/u

Position correlation made possible with microbeam data
Maximum observed transients for each ion at each facility

JYFL vs. GANIL transients

Track structure

Recombination

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