Experiment Proposal

Experiment number GP2024033

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Experiment title	Characterisation of the degree of damage by neutron induced single-event burnout failure in SiC MOSFET by means of X-Ray tomography		
MRF Instrument	**XRD TOMOGRAPHY**	**Days requested:** 3	
Access Route	Direct Access	**Previous GP Number:** GP2023044	
Science Areas	Energy, Engineering, ICT, Materials, Physics	**DOI:** -	
Sponsored Grant	None	**Sponsor:** -	
Grant Title	-	**Grant Number:** -	
Start Date	-	**Finish Date:** -	
Similar Submission?	-		
Industrial Links	StMicroelectronics		

Non-Technical Abstract

We propose to perform materials-to-circuits characterisation of SiC MOSFETs devices, already irradiated with fast neutron on the ChipIR beamline, by means of X-Ray tomography, operating at the IPCB-CNR Unit of IM@IT. Our aim is to access the degree of damage by neutron induced SEBs failure on SiC occurred after the ChipIr neutron irradiation by means of XCT data and compare these results with SEM and profilometry images of the damage already collected in previous experiment GP2023045. All the physical quantities inferred in this study have a direct impact on the understating of the mechanisms trigger SEBs in SiC power MOSFETs.

Publications

Pintacuda et al., Prototyping and characterization of radiation hardened SiC MOS structures, 2019 European Space Power Conference (ESPC).

F. Principato et al., Sensors 20 (2020), 3021; F. Principato et al., Sensors 21 (2021), 5627

AJ Allen, MT Hutchings, CG Windsor, C Andreani, Neutron diffraction methods for the study of residual stress fields, Advances in Physics, 34, 445-473 (1985)

ISIS neutron and muon source **E-platform:** No

Instruments	**Days Requested:**
Access Route	**Previous RB Number:**
Science Areas	**DOI:**
Sponsored Grant	**Sponsor:**
Grant Title	**Grant Number:**
Start Date	**Finish Date:**
Similar Submission?	
Industrial Links	

Sample record sheet

Principal contact Dr Triestino Minniti, University of Rome Tor Vergata, ITALY
MRF Instrument **XRD TOMOGRAPHY** **Days Requested:** 3
Special requirements:

SAMPLE

Material	SiC	-	-
Formula	SiC	-	-
Forms	Solid		
Volume	0.004 cc		
Weight	12.84 mg		
Container or substrate	-	-	-
Storage Requirements	-	-	-

SAMPLE ENVIROMENT

Temperature Range	293 - K	-	-
Pressure Range	- mbar	-	-
Magnetic field range	- T	-	-
Standard equipment	None	-	-
Special equipment	-	-	-

SAFETY

Prep lab needed	Yes	-	-
Sample Prep Hazards	-	-	-
Special equip. reqs	-	-	-
Sensitivity to air	No	-	-
Sensitivity to vapour	No	-	-
Experiment Hazards	-	-	-
Equipment Hazards	-	-	-
Biological hazards	-	-	-
Radioactive Hazards	-	-	-
Additional Hazards	-	-	-
Additional Details	-	-	-
Sample will be	Disposed by IS	-	-

Characterisation of the degree of damage by neutron induced single-event burnout failure in SiC MOSFET by means of X-Ray tomography

1. Background and Context

Silicon carbide (SiC) is a IV–IV compound material with unique physical and chemical properties. The strong chemical bonding between Si and C atoms gives this material very high hardness, chemical inertness, and high thermal conductivity [1]. As a semiconductor, SiC exhibits a wide bandgap, high critical electric field strength, and high saturation drift velocity. Wide-bandgap semiconductors promise high tolerance to extreme environments, such as ionizing radiation, energetic particles, high and low temperatures. Both n- and p-type control across a wide doping range is relatively easy in SiC; this makes SiC exceptional among wide bandgap semiconductors. The ability of SiC to form silicon dioxide (SiO_2) as a native oxide is an important advantage for device fabrication. Because of these properties, SiC is a promising semiconductor for high-power and high-temperature electronics [2-4] both in space and at ground level. In comparison to silicon, SiC is a superior material thanks to its higher breakdown field and thermal conductivity. For terrestrial applications, power semiconductor devices like SiC metal–oxide–semiconductor field-effect transistor (SiC MOSFET) or insulated-gate bipolar transistors (IGBTs) [5] suffer of single-event burnout (SEB) failure when irradiated by high-energy neutrons [6] which constitute the 97% of the total [7] flux of high-energy particles impinging on such device at sea level. Experiments of neutron-induced SEBs in SiC MOSFET at high-voltage have shown the formation of cracks at the device surface as shown in Figure 1. In this Figure profilometry and scanning electron microscopy (SEM) of the SEB (GP2023045) for the SiC diode with ID n. 40 have clearly revealed the damage of the component with dimensions of the order of tens micrometres which preferentially developed in the direction of the crystallographic plane of the SiC crystal.

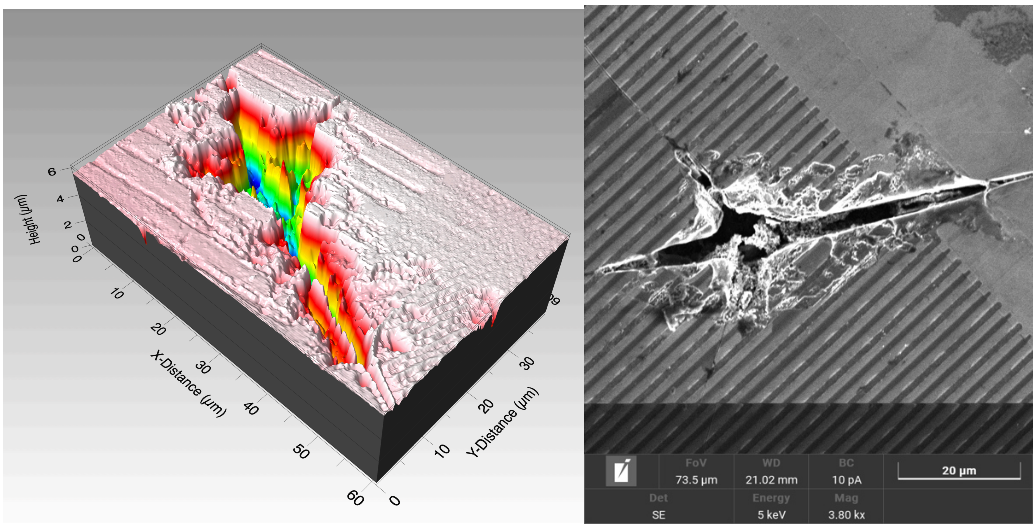

Figure 1: (Left panel) 3D profilometry of SEB damage for SiC diode with ID n.40. (Right panel) Cross-sectional SEM image of SEB damage for the same SiC diode.

We plan to continue non-destructive characterisations of damaged and survived SiC MOSFETs, following the neutron induced SEBs by fast neutron test at the ChipIr beamline, using X-ray computed topography (XCT) to complete measurements already taken by profilometry and SEM experiment. To this aim we requested the use of XRD Tomography (for XCT) available at IM@IT and operating at the IPCB-CNR Unit.

In the present proposal we wish to study the SEBs damage in SIC MOSFETs through a series of XCT scans. The 2D and 3D reconstructions from XCT data will provide non-destructive evaluations of the damage for the semiconductors under investigation. The XCT scans will also provide information on the presence of micro-burning or multiple burning, which are not easily observed with microscope after decapsulation of the package. On the other hand, a comparison of XCT results with independent SEM and profilometry analysis (Figure 1), considered the gold standard procedure for evaluation of damage in semiconductors, we enable us to perform an experimental benchmark.

2. Proposed experiment

We aim to measure a total of n. 2 damaged and n. 2 survived SiC MOSFETs by means of X-ray computed topography for samples which undergo to neutron induced SEBs during a previous test performed at the ChipIr beamline, ISIS neutron and muon source. The 3D reconstruction of SEB damaged SiC MOSFET extract from XCT data will be compared with cross-sectional SEM and profilometry images of the same sample already collected in the experiment GP2023045, like the one shown in Figure 1, and used here to benchmark XCT results.

3. Justification of experimental time requested

The damaged and survived SiC MOSFETs after neutron induced SEBs on ChipIr have dimensions of about 4mm x 5mm and a thickness of about 200 μm. We aim to measure n. 2 damaged and 2 survived SiC MOSFETs using a field of view of 600 μm x 600 μm, pixel size of 0.293 μm, and about 2050 projections to fulfil the Niquist-Shannon sampling theorem. With an exposure time per projection of 7 s, each tomography will last about 4 hours. Hence, after discussion with the instrument scientist, we request 3 days of instrument time including set-up and calibration time.

4. References

[1] Harris, G.L. (1995) Properties of Silicon Carbide, INSPEC.
[2] Davis, R.F., Kelner, G., Shur,M. et al. (1991) Proc. IEEE, 79, 677.
[3] Ivanov, P.A. and Chelnokov, V.E. (1992) Semicond. Sci. Technol., 7, 863.
[4] Morkoç, H., Strite, S., Gao, G.B. et al. (1994), J. Appl. Phys., 76, 1363.
[5] Pintacuda et al., 2019 European Space Power Conference (ESPC).
[6] Principato et al., Sensors 20 (2020), 3021;
[7] J. F. Ziegler, IBM J. Res. Dev. 40, 19 (1996).
[8] Yeong-Jae Yu et al., Cryst. Eng. Comm. 19 (2017), 6731.
[9] AJ Allen, MT Hutchings, CG Windsor, C Andreani, Advances in Physics, 34, 445-473 (1985).