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XXXIII Cycle

High power diodes lifetime study and modeling during electrical overstress and advanced reliability

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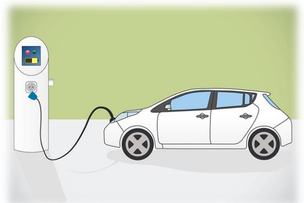
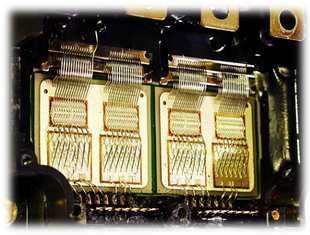
Research context and motivation

- With the **always increasing** diffusion of modern **electronic appliances** and electronic based systems, the request for **efficient** and **reliable power** conversion **circuits** has become nowadays a key requirement both industries and final users.
- In terms of **reliability**, one of the most demanding and challenging fields is the **Automotive Industry**, which as a matter of fact has a great **driving impact** on both application development and new standards definition. A few examples are the recent reviews of the **AEC-Q101** international standard for discrete power semiconductor devices or the **MBN LV 324** standard for power module testing. Moreover, **current** test **standards** and **methodologies** are **always evolving**, and sometimes **new standards are born** following from special customer requests.

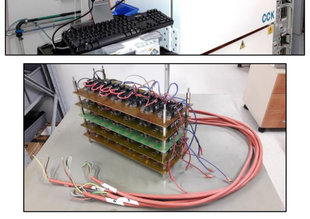




- In this work, several testing methodologies for power diodes have been customized to investigate reliability limits beyond current standards, in order to highlight the presence of new failure modes and suggest design upgrades leading to enhanced diode reliability performances. These tests are the **High Voltage Temperature Humidity Bias (HV-THB)** test, **on-wafer V_F** (forward voltage drop) **measurement** for high-current rated diodes and a test for **cosmic ray induced failures** of Power Devices.
- Research work has been carried on in collaboration with **Vishay Semiconductors Italiana S.P.A.**

Addressed research questions/problems

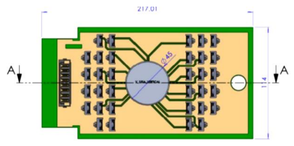
- **HV-THB and Cosmic Ray Test**: **implement** an **automated continuous monitoring** test setup, **including PSU control**. The system supports **high reverse bias testing** (up to 1200V) of power diodes in MTP module packages, for extended reliability and failure mode evaluation.



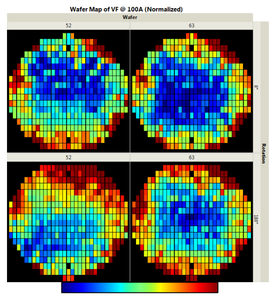
HV-H3TRB Engineering Test Setup with high humidity/temperature chamber and multiple DUTs PCB

National Instruments PXI acquisition system and LabVIEW™ Interface

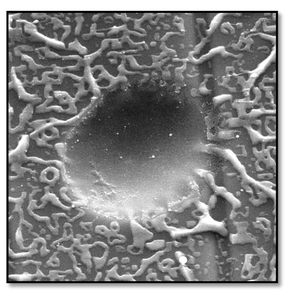
- **High-Current V_F Test**: **perform on-wafer high current measurements without** dice **damage** or wear, by designing a customized probing system for pulsed currents up to 200A.



New Probe Card Designs

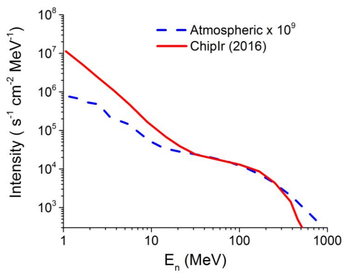


V_F measured at 100A normalized min to max (a.u.)

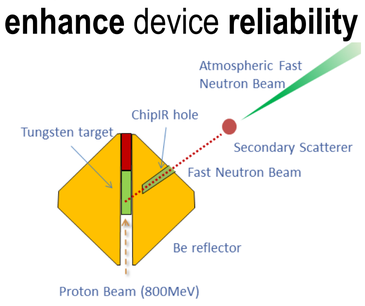


Example of fusion defect due to high-current damage

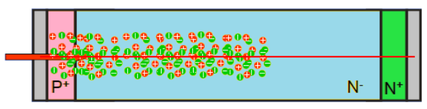
- **Cosmic Ray Sensitivity**: **study cosmic radiation** induced **failure modes** of power electronic devices in order to **enhance** device **reliability**



Neutron Source Energy Spectrum



Neutron Source Structure



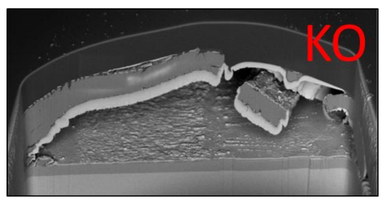
Schematic of a Single Electron Burnout (SEB) in a typical PiN power diode structure

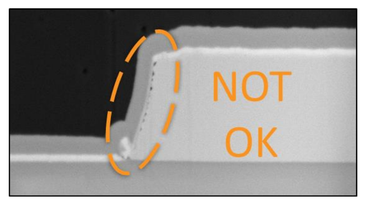
Submitted and published works

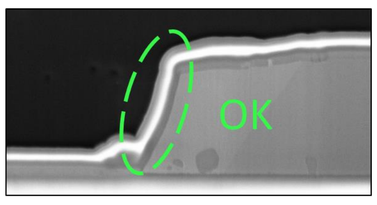
Cimmino, Busca et al. "High Voltage Temperature Humidity Bias Test (THB) customized system and methodologies for reliability assessment of power semiconductor devices." Microelectronics Reliability, (Accepted - Being Printed, 25 Cr.)

Novel contributions

- **HV-THB**: capability to identify and study the "**bubble**" **failure mode**, electrical and reliability performance **degradation** due to **moisture penetration**, and **suggested SiN layer** to **improve HV-THB performances**



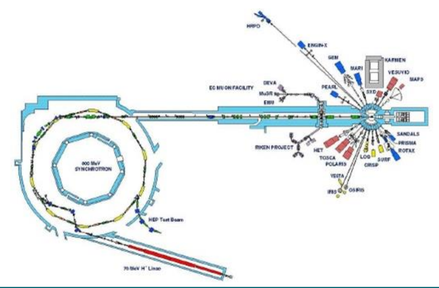




- **High-current V_F test**: capability to perform V_F measurements without damaging the dice, avoiding possible customer returns, failure on the field, and reliability issues.

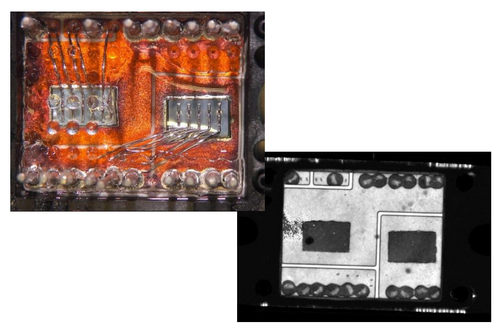
- Performed **JEP151** JEDEC **experimental test** for the **Measurement** of **Terrestrial Cosmic Ray Induced Destructive Effects** in Power Semiconductor Devices as a **first part** of an **extended study** on the failure mode and its **effects on** device **reliability**. The test was carried on at **ChipIR** station of the **ISIS Neutron** and **Muon source** in **Oxfordshire**.

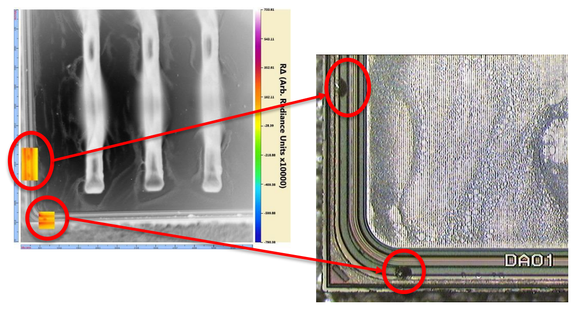
Science & Technology Facilities Council
ISIS Neutron and Muon Source



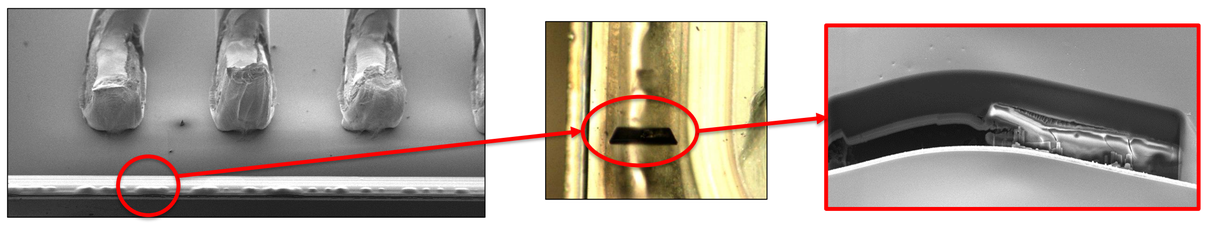
Adopted methodologies

- **Failure analysis** methods by **chemical/physical decapsulation**, **C-SAM, Hot-spot Photoemission**, **cross section**, **profilometer** measurements and **optical inspection**



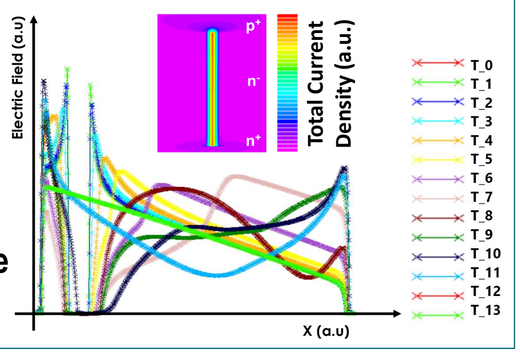


- **Layer analysis** by **FIB** cross section, **SEM** imaging and **EDX**



Future work

- **Extend** the **Study** of **Cosmic Radiation Effects** on Diode **Reliability**. The **experimental work** performed at the ISIS facility will be **complemented** by **Single Electron Burnout (SEB) physical** and **electrical CAD simulation** in order to **link** the **experimental evidence** with the **physical structure** of the selected power diode samples.



List of attended classes

- 01NUWKI – Chimica-fisica dei materiali per le nanotecnologie (*Planned*, 7 cfu, 44 cr.)
- 02LWHRV – Communication (13/9/2018, 1 cfu, 6,67 cr.)
- 01QCRKG – Elementi di fisica dello stato solido per l'ingegneria (11/9/2018, 6 cfu, 50 cr.)
- 08IXTIU – Project management (13/09/2018, 1 cfu, 6,67 cr.)
- 01RISRV – Public speaking (15/02/2018, 1 cfu, 6,67 cr.)
- 01QORRV – Writing Scientific Papers in English (27/06/2018, 3 cfu, 20 cr.)
- 01SYBRV – Research Integrity (26/8/2019, 1 cfu, 6,67 cr.)
- 01QCYRP – Tecniche avanzate per la misura della qualità (20/6/2019, 5 cfu, 41.67 cr.)
- 01SWPRV – Time management (20/6/2019, 0.4 cfu, 2.67 cr.)
- 01MQLKI – X-ray diffraction by materials (11/7/2019, 5 cfu, 41.67 cr.)
- EXTERNAL – FMEA (Failure Mode Effect Analysis) (31/05/2018, 16 cr.)
- EXTERNAL – ECPE Workshop - Reliability Engineering (24/10/2018, 14 cr.)
- EXTERNAL – Corso base di Tecnologia del Vuoto (08/07/2019, 6 cr.)

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