Effects of the laser beam size on the Optical Beam Induced Current (OBIC) for the study of Wide Band Gap (WBG) Semi-Conductor Devices

Camille Sonneville, Dominique Planson, Luong Viêt Phung, Besar Asllani, Pascal Bevilacqua

Effects of the laser beam size on the Optical Beam Induced Current (OBIC) for the study of Wide Band Gap (WBG) Semi-Conductor Devices

Authors: Camille Sonneville[1], Dominique Planson[1a], Luong Viêt Phung[1],
Besar Asllani[1], Pascal Bevilacqua[1]

[a]dominique.planson@insa-lyon.fr
[1] Univ Lyon, INSA Lyon, Univ. Claude Bernard Lyon 1, Ecole Centrale Lyon, CNRS, Ampère, F-69621, France

Abstract :

Introduction :

UV Laser is used to generate electron-hole pairs into Wide Band-Gap (WBG) semiconductors (SiC, GaN or Ga_2O_3). In the space charge region, the electric field drives the collected carriers and a current, so-called Optical Beam induced Current (OBIC), can be measured. The induced current is then directly related to the electrical field in the device. The OBIC, is a non-destructive technique, which has been previously successfully used to characterize High Voltage (HV) SiC devices [1, 2, 3, 4]. In order to fully benefit of the advantages provided by WBG semiconductors materials and to avoid premature breakdown of the high voltage devices, it is mandatory to have efficient peripheral protections such as a MESA, a JTE and JTE rings…The OBIC characterization can help the technology computer-aided design (TCAD) and the device process to optimize the efficiency of the periphery protection by analyzing the electric field distribution in the structure and especially at the junction periphery. In this talk, we will present an in-house testbench called micro-OBIC which will allow us to characterize HV PiN diodes with a micro-meter spatial resolution.

Experimental:

A spectra physics laser emitting UV at 349 nm is used to generate electron-hole pairs into WBG semiconductors. In order to reduce the laser beam spot size, we developed a testbench represented in figure 1.

The laser beam intensity is first controlled by a set of neutral density filter, before passing through a beam expander. Finally, the laser spot is focused by a long-distance Thorlabs microscope objective. The final spot size is around 1-2 μm. The high voltage device under test (DUT) is fixed on a X,Y,Z motorized stage. The motorized stage, controlled by a homemade Labview program, allows us to move the DUT under the laser beam focus point. Induced current is then measured with a Keithley 237 High-Voltage Source-Measure Unit (SMU). The DUT can be reverse biased by applying voltage thanks to the SMU. The testbench allows us to realize a spatial mapping of OBIC signal on a plane (X, Y) or only on X or Y lines with a 1-2 μm spatial resolution and is named micro-OBIC.

Results and discussion:

Experimental micro-OBIC scans were performed on high voltage PiN diode (10 kV class). The high voltage PiN diodes were fabricated on a 4H-SiC wafer using a 110 µm thick epilayer with a doping concentration of 7×10^{14} cm^{-3}. These diodes are protected by a MESA, a JTE of 400 μm length and have whether (diode 2) or not 8 JTE rings (diode 1), as shown in Figure 2.
OBIC measurements with a former OBIC testbench and a 100 - 80 μm laser spot, were performed on these diodes at 0V. These measurements have already been published in [4]. With the new micro-OBIC testbench, x-line scans were performed on the same diodes at 0V. The spatial resolution is now around 1-2 µm with this new set-up. 800 μm length scans were realized with the two devices.

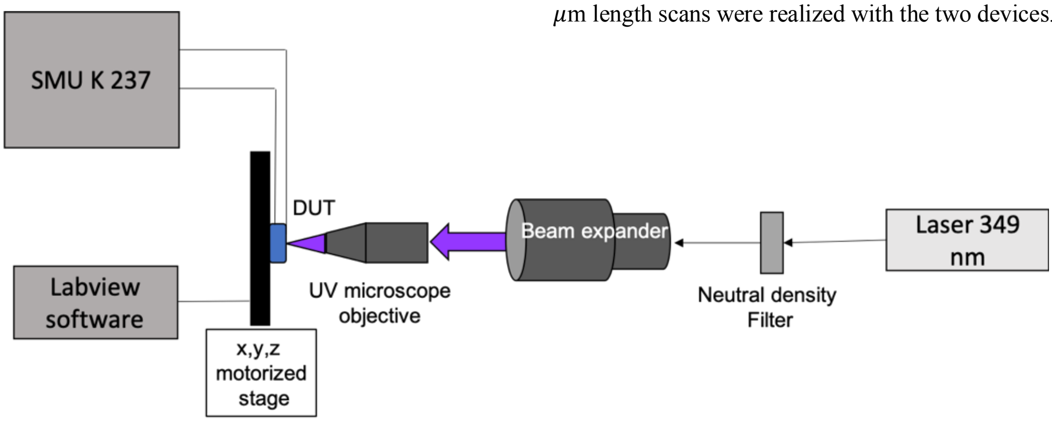


Figure 1. Schematic representation of the micro-OBIC testbench

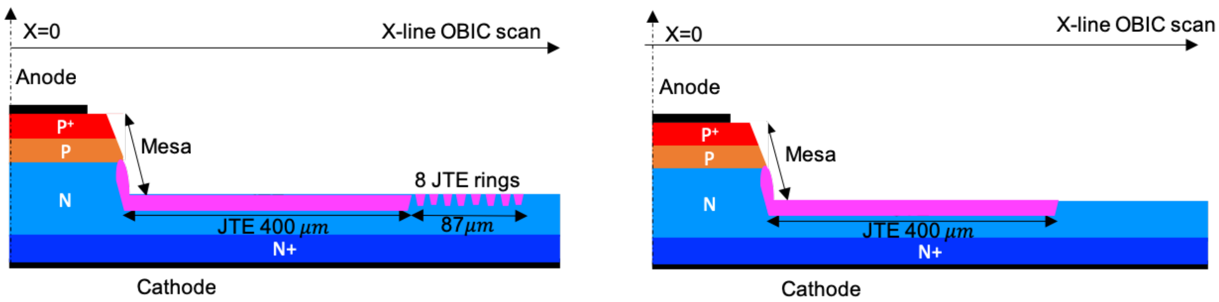
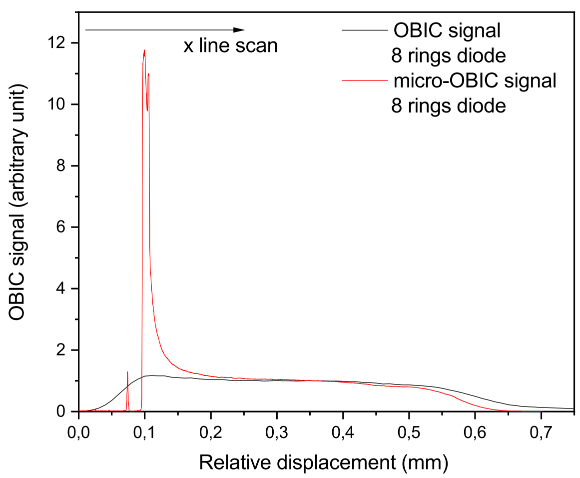


Figure 1. Structure of the 8 JTE rings HV PiN diodes (diode 1) and JTE without ring HV PiN diodes (diode 2). Schema are not in scale.



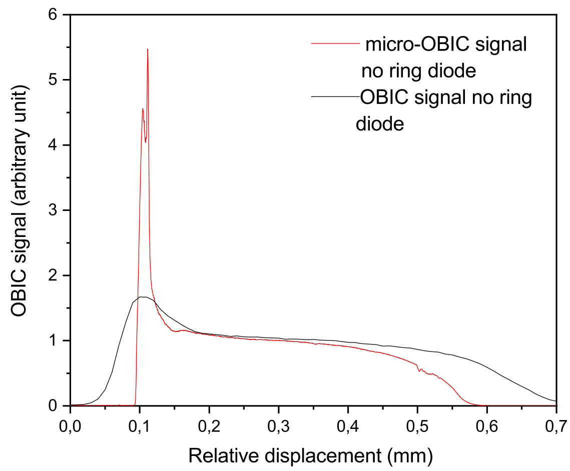


Figure 2a (left): OBIC (black) and micro-OBIC (red) X-line scan performed on the 8 JTE rings diode (diode 1)
Figure 3b (right): OBIC (black) and micro-OBIC (red) X-line scan performed on the no JTE ring diode (diode 2)

Figure 3a shows the comparison of the normalized OBIC (in black) and the normalized micro-OBIC (in red) signal for the diode with 8 JTE rings. Figure 3b shows the comparison of the OBIC (in black) and the micro-OBIC (in red) signal for the diode without JTE rings. Figure 3a and 3b shows an important increase of the relative intensity of the OBIC signal with the micro-OBIC device explained by the increase of the surface power intensity thanks to the laser beam size reduction. Interestingly the use of well-focused laser beam shows the appearance of smaller feature in the MESA region, which were invisible with the previous device because of its low spatial resolution. Moreover, the better spatial resolution of the micro-OBIC testbench at the JTE/JTE rings frontier (diode 1) or at the JTE/n frontier (diode 2), give us interesting information on the structure of the peripheral protection.

Conclusion :

The microscopic spatial resolution of the micro-OBIC testbench, highlights very small features, which were not observable with the previous OBIC testbench. In order to better understand the physical origin of these fine structures observed in the micro-OBIC signal, these experimental results will be compared to OBIC simulations. The finite element simulation suite Sentaurus will be utilized to simulate the diode structure and the micro-OBIC signal induced from a focalized laser beam with the same characteristics (spot diameter, power,…). In a closed future, our micro-OBIC device aims to be adapted to be used in a high voltage vacuum chamber with a temperature control.

Acknowledgements:

The authors want to acknowledge SuperGrid Institute for providing the HV devices.

Bibliography:

[1] R. Stengl, High-voltage planar junctions investigated by the OBIC method (1987), IEEE Transactions on electron devices , vol. ED-34, no. 4, pages 911-919.

[2] H. Hamad, D. Planson, C. Raynaud, P. Bevilacqua, OBIC technique applied to wide bandgap semiconductors from 100 K up to 450 K, (2017), Semicond. Sci. Technol. 32 (5) 054001.

[3] Raynaud, C., Nguyen, D., Dheilly, N. , Tournier, D., Brosselard, P., Lazar, M. and Planson, D. (2009), Optical beam induced current measurements: principles and applications to SiC device characterization. phys. stat. sol. (a), 206: 2273-2283. doi:10.1002/pssa.200825183

[4] D Planson, B Asllani, LV Phung, P Bevilacqua, H Hamad, C Raynaud (2019) , Experimental and simulation results of optical beam induced current technique applied to wide bandgap semiconductors, Materials Science in Semiconductor Processing 94, 116-127