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Visualization of P⁺ JTE embedded rings used for peripheral protection of high voltage Schottky diodes by the Optical Beam Induced Current (OBIC) technique

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When applying a focused UV laser beam into a biased Silicon Carbide device, electron-hole pairs can be generated. Within 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 directly related to the electrical field in the device. **The OBIC is a non-destructive characterization technique, which has been previously used to characterize High Voltage (HV) Si and SiC devices [1,2,3].**

In order to take full advantage of the benefits offered by SiC and to avoid premature breakdown (previous to avalanche) of high voltage devices, it is mandatory to have efficient edge termination such as JTE, or rings assisted JTE [4]. The OBIC characterization can support the technology computer-aided design (TCAD) and the device processing to properly optimize the efficiency of the edge protection by analyzing the electric field distribution in the structure, especially at the junction periphery. **In this work, our new OBIC test-bench with a micro-meter spatial resolution allowed to characterize the periphery of SiC 1.2kV JBS diodes with a high resolution and compare the results with the electric field distribution calculated from TCAD simulations.**

A laser emitting UV at 349 nm is used to generate electron-hole pairs into the SiC. In order to reduce the laser beam spot size, a new testbench where the laser spot is focused by a microscope objective have been developed [5]. The diode is fixed on a X,Y,Z motorized stage and it can be moved under the laser beam focus point. Induced current in the reverse biased the DUT is then measured with a Source-Measure Unit (SMU).

1D micro-OBIC scans were performed on two sets of JBS diodes fabricated at CNM on a 4H-SiC wafer using a 12 μm thick epilayer with a doping concentration of $8 \times 10^{14} \text{ cm}^{-3}$. The two diodes (A and B) are protected by two different lengths of JTE with 3 rings implanted inside as shown in Fig. 1-left. Diode A has a JTE length of 200 μm, and diode B has a JTE length of 100 μm. Rings have 3μm width and are separated 4.5/5/5.5μm. For efficient measurement, selected diodes must exhibit a very small reverse leakage current as shown in Fig. 1-right. Up to now, OBIC spatial resolution was not high enough to observe the rings inside the JTE.

Figure 2 exhibits the OBIC current for different voltages (100V and 300V) for both diode A and B. The impact of the implanted rings in the JTE on the OBIC signal can be now clearly seen (zone A) as well as the JTE length (zone B). The current intensity increases sharply with the applied reverse voltage. In zone C, the OBIC signal decreases slowly probably due to the interface charges between passivation oxide and the SiC. The impact of the channel stopper (zone D) is also observed as the OBIC signal is nearly zero.

TCAD simulation using SynopsysTM [6] have been performed. First the diode structure was defined as shown in Fig. 3-Left. Fig. 3-Right shows the electric field distribution along the x-axis under a reverse voltage of 200V. The impact of the implanted rings is clearly observed in zone A. The JTE length (for diode A and B) is clearly seen in zone B. However, with this electric simulation the electric field remains constant throughout the JTE, and do not show a slow decrease like in the OBIC measurement in Fig. 2 This is probably due to the interface charges which have not been taken into account in the TCAD. The same observation can be made in the C-zone between the edge of the JTE and the channel stopper. Additional simulation results with interface charges will be added in the final paper.

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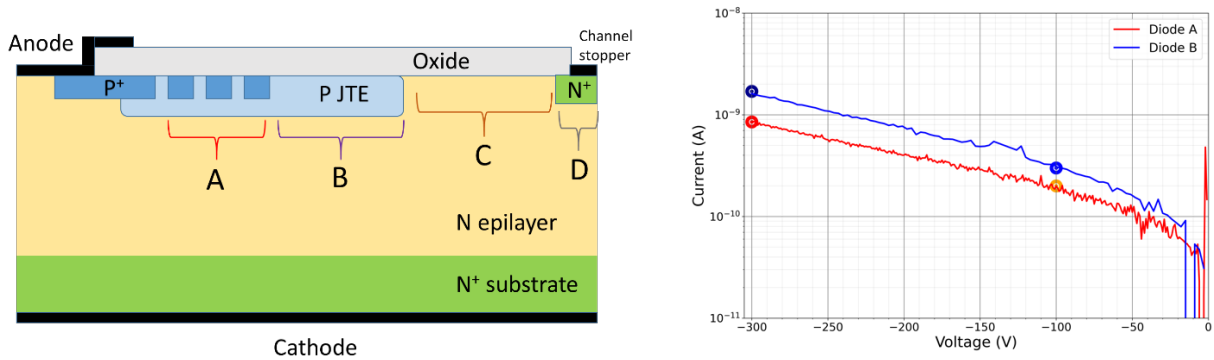


Fig. 1. *Left*) cross-section of the periphery protection of the diode (JTE (with implanted rings inside) with channel stopper. 4 zones are defined: A: implanted rings, B: JTE, C: margin and D: channel stopper. *Right*) Reverse currents for both diodes until 300V.

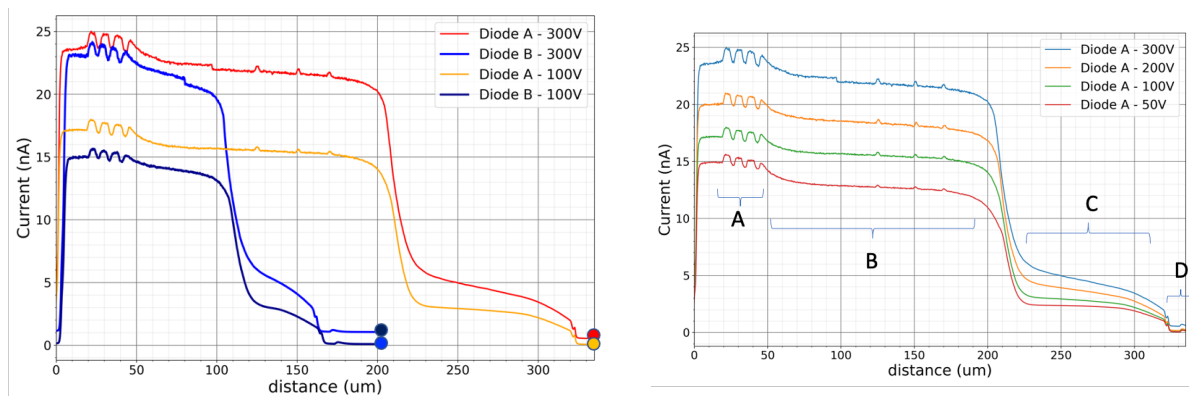


Fig. 2. *Left*) Micro-OBIC 1D-scans under two biasing voltages for diodes A and B. *Right*) Micro-OBIC 1D-scans for several voltages for diodes A including the different termination's zones.

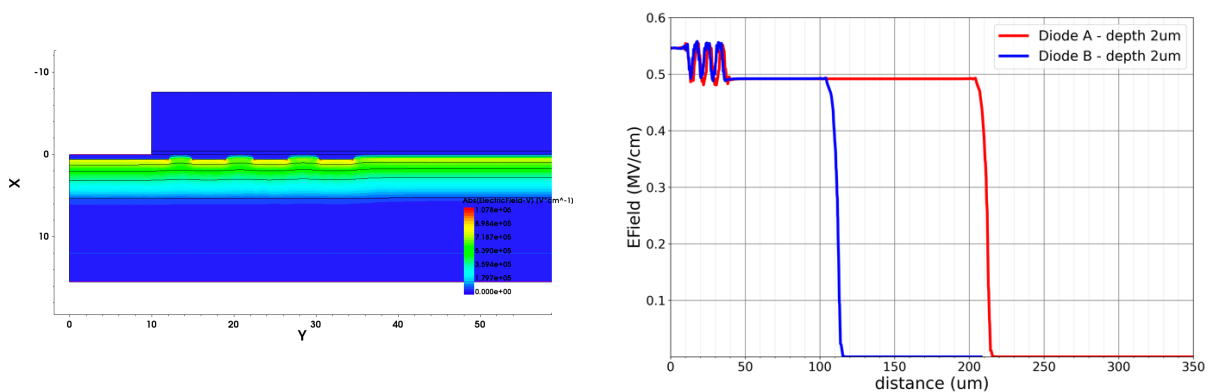


Fig. 3. *Left*) TCAD Electric Field, and potential isolines (step 50V) of the peripheral protection under a reverse voltage of 200 V. *Right*) Electric field distribution along the periphery protection at a given depth of 2 μm .