OBIC measurements on 1.3 kV 6H-SiC bipolar diodes protected by Junction Lateral Extension

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Introduction - Due to its good electrical properties, mainly a high critical electric field and a large bandgap, silicon carbide has demonstrated potentialities for high power devices. We have designed and realised bipolar diodes to sustain a reverse voltage of about 1.3 kV. We present below the experimental breakdown voltage we achieved, and results of OBIC measurements.

Samples details - 6H-SiC n-type epitaxial layers from Cree Research have been used for this study. With values of thickness of 10 µm, and of doping level $N_D = 10^{15}$ cm^{-3}, the theoretical breakdown voltage is about 1.5 kV. The p^+ emitter has been realised by room temperature (RT) aluminium implantations with energies varying between 25 and 300 keV, with a total dose of 1.75×10^{15} cm^{-2}. To avoid surface premature breakdown, lateral protections have also been realised by RT Al implantations with a total dose of 1.3×10^{13} cm^{-2}. These protections are know as Junction Terminal Extension (JTE). Then samples are annealed in a rf-induction heating furnace at 1700°C during 30 min. [1].On the half of the wafers, an additional ring, named stop-channel, have been realised by a RT nitrogen implantation. Then diodes have been metallized with Ni in backside and Al-Ti in the front side. Different kinds of diodes are available, with varying emitter diameters and JTE lengths. No passivation layers have been deposited after metallisation.

Current-voltage measurements – IV measurements have been performed with a Keithley 237 Source Measurement Unit, or a picoammeter K485. Reverse biases are delivered by a 12.5 kV-100 mA supplier. In forward biases, current densities as high as 220 A cm^{-2} at 5V have been achieved (Figure 1), and about 50% of diodes achieved 150 A cm^{-2}. In reverse biases, several diodes protected with JTE have been able to block up to 1200 V (Figure 2), which is very closed to the theoretical value (given by numerical 2D simulators). The majority of non protected diodes have shown breakdown voltages at bout 500 V. This is significant of the benefit role of JTE. We have used Optical Beam Induced Current (OBIC) measurements in order to study the distribution of equipotential lines at the surface of the samples.

OBIC measurements – Details about this technique have been described elsewhere [2]: a UV beam is focused at the surface of the samples, and therefore generates free carrier, up to a determined depth, which depends of the wavelength. If these carriers are generated in a space charge region, electrons and holes are separated by the electric field and a current is measured. By translating the beam, we can measure the generated current as a function of the position on the wafer. Figure 3 shows the photocurrent measured along a diameter of the diodes, the width of the current peak is relevant of the spreading out of the equipotential, and its value agrees well with the JTE length and it means that JTE are depleted even at very low voltage. The structure has been drawn on the figure for easier comparison. Figure 4 is similar analyses on a diode without JTE. It is clear that on diodes without JTE, the OBIC signal increases very fast at the edge of the emitter, which is due to the high electric field present in this corner region. We can also notice that at 800 V, a peak also appears at the emitter edge for protected diodes. This could mean that the doping level of JTE is close to the optimised value but a little lower.

Numerical simulations of the photocurrent generated by such a UV beam are currently under investigations, to correlate the OBIC signal with the distribution of the electric field. Detailed discussions and comparison with numerical simulations will be done in the full article.

Conclusion – We have fabricated p^+n bipolar diodes, which shows good rectifying properties, high current density in forward bias, and breakdown voltages closed to the theoretical value. OBIC analyses, correlated with numerical simulations, shows that the periphery protection has a good efficiency, and is close to the optimised value.

References –

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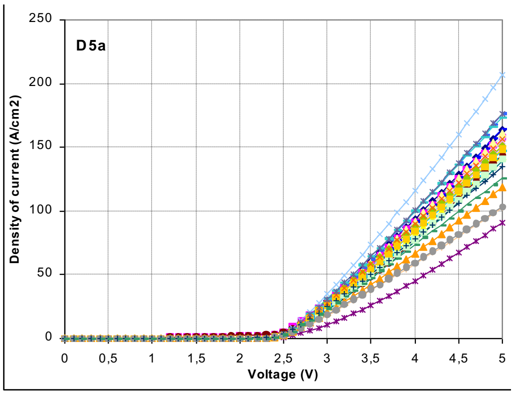


Figure 1 : IV characteristics of some diodes with JTE, in forward bias, measured with a SMU K237.

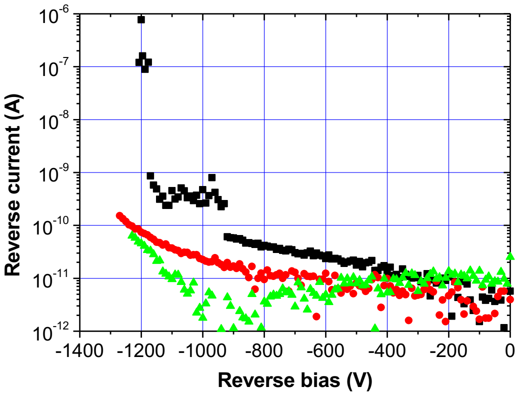
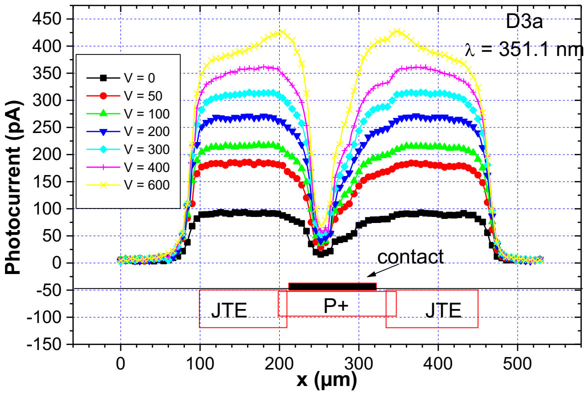


Figure 2 : IV characteristics of 3 diodes with JTE, in reverse bias, measured with a picoammeter K483, by step of 10 V. The lowest significant current is 10^{-11} A. The last datapoints which are drawn are considered as the breakdown voltage (next point is more than 1 μA).



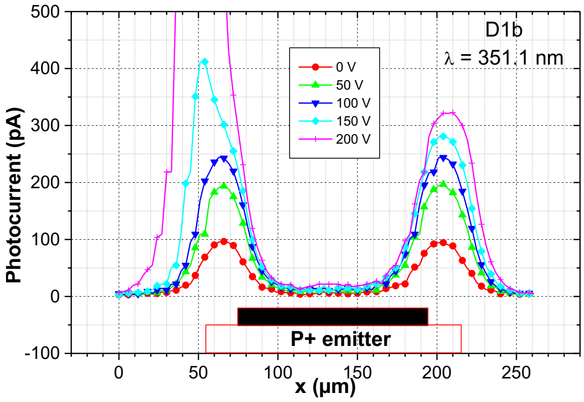


Figure 3 : OBIC measurements performed on a p^+n diode protected by JTE, for increasing reverse voltage. Wavelength is 351.1 nm, which corresponds to a penetration depth of about 11 μm in 6H-SiC.

Figure 4 : OBIC measurements performed on a p^+n diode without JTE, for increasing reverse voltage. Wavelength is 351.1 nm.