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Edge termination design improvements for 10 kV 4H-SiC bipolar diodes

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Summary: 10 kV class 4H-SiC bipolar diodes have been fabricated. Two different edge terminations (Mesa/JTE or MESA/JTE with JTE rings) with two different junction bend radius have been designed and tested. Measurement results show that the inclusion of JTE rings improve the edge termination efficiency. The measurements indicate also better reverse performances of diodes with large bend radius.

Abstract: SiC is particularly attractive for high voltage devices thanks to its critical electric field which is ten times higher than Si. Many high voltage SiC devices were presented in recent years. SiC bipolar diode is more interesting than SiC Schottky diode for very high voltage and high current applications through the conduction modulation. Until now, the highest blocking voltage of bipolar SiC diodes is 19 kV [1]. Some research groups demonstrated the bipolar diodes with a good compromise between forward performance and breakdown voltage as high as 10 kV [2], 6.5 kV [3], 4.5 kV [4]. The edge termination of these high voltage diodes is typically a combination of MESA/JTE or MESA/multiple-JTE. In this work, we present and compare the diodes protected by a single MESA/JTE (MJ) and a MESA/JTE with JTE rings (MJJR) [5] as shown on Fig. 1, to achieve the blocking voltage of 10 kV.

A 4H-SiC epitaxial wafer from Cree was used to fabricate the diodes. It consists of a stack of $p^{++}(2 \times 10^{19} \text{ cm}^{-3}, 1 \text{ } \mu\text{m})/p^{+}(2 \times 10^{17} \text{ cm}^{-3}, 1 \text{ } \mu\text{m})/n^{-}(2 \times 10^{14} \text{ cm}^{-3}, 120 \text{ } \mu\text{m})$ epilayers grown on heavily-doped n^{+} -type substrate. Diodes have been implemented with different edge terminations in two geometries: round shape with a bend radius of 0.12 mm and square shape with a radius of 0.45 mm. A summary of the different diode structures is presented in the table 1. The number, position and width of the JTE rings are optimized by simulation using SentaurusTM. According to the simulation results, the presence of the JTE rings extends the optimum doses of main JTE and increases the maximum blocking voltage.

Current-voltage (I-V) measurements have been performed on the wafer in a vacuum chamber. As seen in Fig. 2, the best diodes show an abrupt reverse characteristic and a blocking voltage of 10 kV is achieved. A statistics of measurement results is also presented in the table 1. These results show that, for same JTE length, the termination efficiency is improved with JTE rings. In addition, we also see that the diodes with larger bend radius gives better breakdown performances. Fig. 3 reports on the (I-V) characteristic for the forward mode.

In the final paper, the conception, fabrication and characterization of the diodes will be described in detail and the influence of JTE rings and junction bend radius will

be discussed. We will also present the results of 3-D simulations to better understand the influence of junction bend radius on the diode performance.

References

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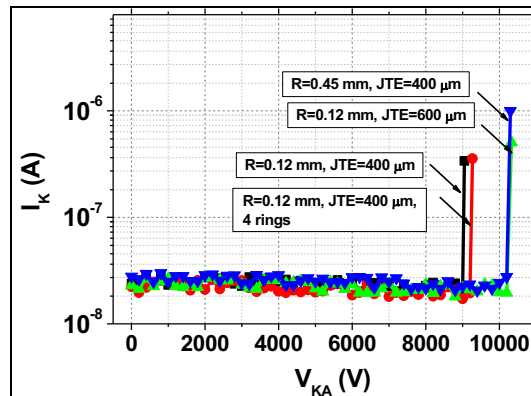
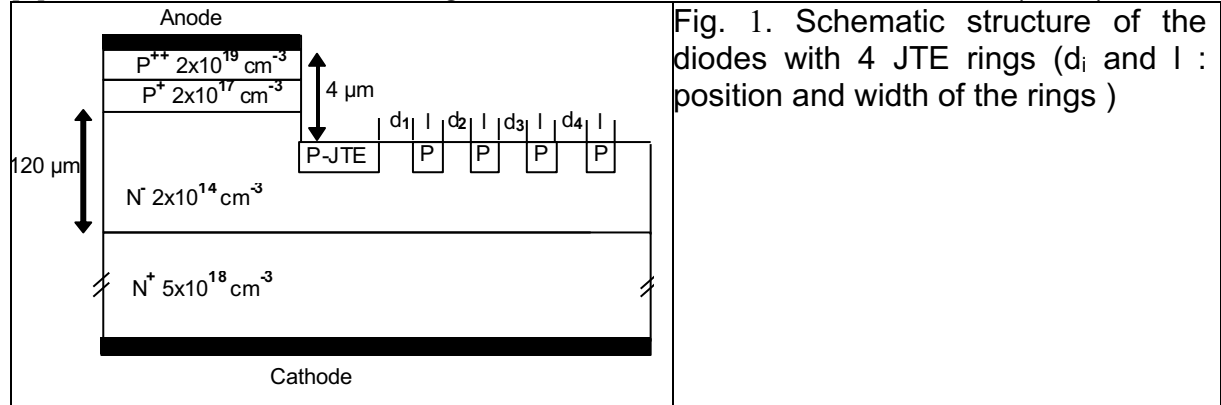


Fig. 2. Reverse I-V characteristics of the best performance diodes.

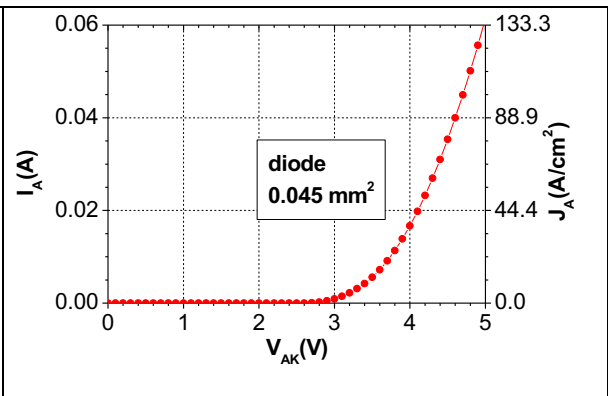


Fig. 3. Forward current-voltage characteristic of the 0.045 mm² diode.

Table 1: Summary of the realized diodes with the experimental breakdown voltage: R - bend radius, S - active area, N – number of tested diodes, A / σ / Max - average / standard deviation / maximum of breakdown voltage.

R (mm)	S (mm ²)	Protection	N	A (V)	σ (V)	Max (V)
0.12	0.045	JTE (600 μ m)	68	7760	2196	10200
0.12	0.045	JTE (400 μ m)	70	5670	2670	9000
0.12	0.045	JTE (400 μ m), 4 rings	71	6190	2657	9400
0.45	3.9	JTE (400 μ m)	67	6192	2820	10200