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Electrical characterization of HV (10 kV) Power 4H-SiC Bipolar Junction Transistor

Pierre Brosselard¹⁾, Brenda Fosso-Sob¹⁾, Dominique Planson¹⁾, Pascal Bevilacqua¹⁾, Camille Sonnevill¹⁾, Mihai Lazar²⁾, Bertrand Vergne³⁾, Sigo Scharnholz³⁾ and Hervé Morel¹⁾

pierre.brosselard@insa-lyon.fr

- 1) INSA Lyon, Université Claude Bernard Lyon 1, Ecole Centrale Lyon, CNRS, Ampère, UMR-5005, F-69621, France
- 2) Light, Nanomaterials, Nanotechnologies, L2n, UMR CNRS7076, Université de Technologie de Troyes, 10004, Troyes, France
- 3) ISL, French–German Research Institute of Saint Louis, 5 rue Général Cassagnou, 68301 Saint Louis, France

SiC-BJTs with their superior characteristics, including low on-state resistance and their elevated breakdown voltage is very suitable for high-voltage and high-temperature applications with a greater efficiency in sectors [1]-[2]. However, temperature can change the conductivity of the semiconductor material thus affecting its performance [3]-[4]. In this paper static and dynamic electrical characterization are carried out on 4H-SiC BJTs at Ampere Lab. The BJT were fabricated on a 4H-SiC wafer with an epilayer layer of 120 μm thick and doping concentration of $8 \times 10^{14} \text{ cm}^{-3}$ (Fig.1). A maximum breakdown voltage of 11 kV was obtained in vacuum conditions with a high voltage source [5].

Fig.2 shows three distinct configurations of BJTs with their respective finger length and active area, incorporated to optimize the electrical parameters. Two different finger lengths were implemented (420 μm and 640 μm) both with active area of 15.6 mm^2 and 2.12 mm^2 for large and small devices respectively as describes in Table 1.

The large and small BJTs exhibit a similar on-state resistance per unit area as seen in Fig.3, and are both seen to have approximately 55 A.cm^{-2} for collector current density with the same base-current density (3.3 A.cm^{-2} to 3.2 A.cm^{-2}) corresponding to different base current (0.5 A and 70 mA respectively). We can deduce that the active area has no strong impact on its electrical characteristics regarding the current density.

From Fig. 4, we can observe a very similar current gain, β , between the large and small BJTs (420 μm finger length, 15.6 mm^2 and 420 μm finger length, 2.12 mm^2). A similar behavior is observed between the large BJTs (640 μm and 420 μm finger lengths, both 15.6 mm^2). However large BJTs with same finger length of 420 μm , 15.6 mm^2 exhibit a significant difference in current gain but localize at a different position on the wafer. That can be due to very small variation in the fabrication process and inherent material properties (as doping level and thickness) across the wafer. Therefore, β is similar with different finger lengths probably due to the low effect of the depolarization along the finger length.

The current gain of the large BJTs tends to increase with decrease in temperature as a result of a decrease in the recombination rate of charge carriers due to lower thermal energy as seen in Fig.5. This implies that a smaller base current is required to control a given collector current, thus effectively increasing its amplification capacity.

In the final paper, we will present results for the switching characteristics of the BJT using a double source test bench.

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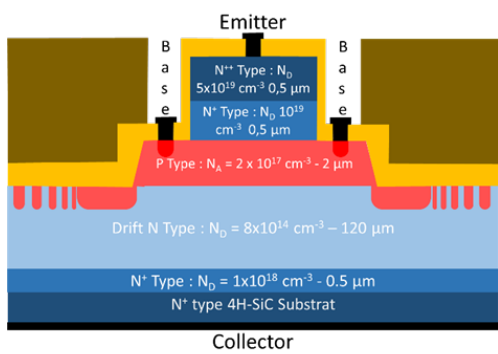


Fig.1 Cross-section of the studied 4H-SiC 10 kV BJT

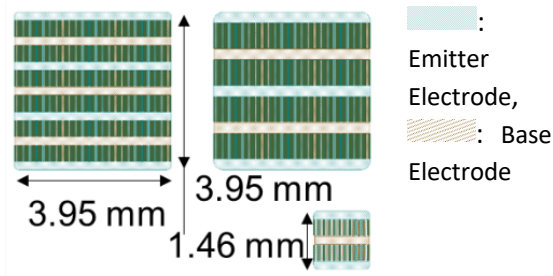


Fig. 2 Picture of 3 selected BJT with finger length of 640 μm and 420 μm

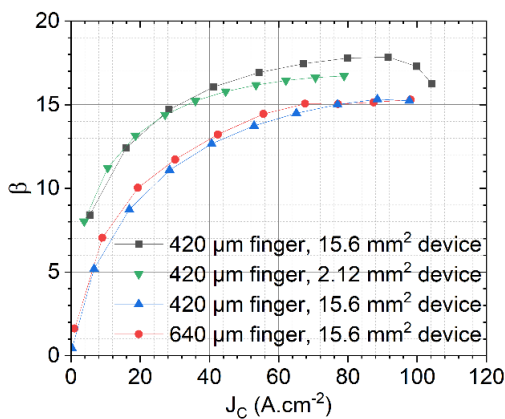


Fig. 4 Extracted β for 4 different BJTs (finger length and area) at 25°C

Finger Length (μm)	Die area (mm^2)
420	2.12
420	15.6
640	15.6

Table 1: Summary of the different BJT configurations, square dies

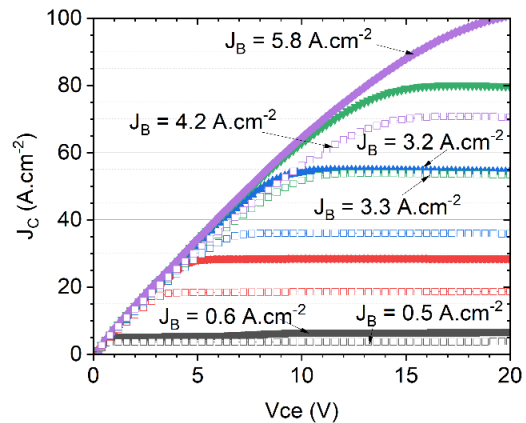


Fig. 3 J_c (V_{CE}) for different J_B at 25°C for a small (open symbol) and large (closed symbol) BJT, finger length of 420 μm

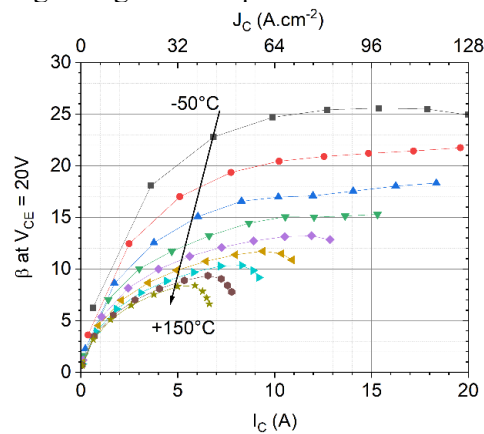


Fig. 5 Extracted β for the large BJT (finger length 420 μm, from square symbol on Fig. 4) for a temperature range of -50°C to 150°C