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## Static characteristics of 5 kV SiC BJTs and Darlington's

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High voltage low current SiC BJT transistors are interesting devices for applications like active filters, current limiters and active snubbers where high voltage blocking capabilities are required. Few attempts[1]–[3] have proved that such devices can be manufactured and fulfill the requirements in terms of breakdown voltage, beta and reliability. SuperGrid Institute has designed 10 kV - 5A SiC BJTs as a proof of concept with the aim to increase the nominal current rating to 50 A. This devices are intended to operate in the abovementioned applications and also to be employed as a power switch in HVDC converters. This abstract evaluates the static performances of the first run of 10 kV – 5 A BJTs from SuperGrid. The switching performance will be assessed and reported in the full paper.

Four different designs have been manufactured on three 4" SiC wafers. The epitaxial parameters and the peripheral protections are the same as the ones used for the 10 kV PiN diode reported at ECSCRM2018 [4]. Several parameters have been varied in order to test the impact on beta. After the fabrication, devices were tested on wafer and 40 samples have been selected and packaged in ISOPLUS packaging from DeepConcept for further testing purposes. Packaged devices are shown in Fig. 1.

Designs #2 and #3 which have the best betas are compared in figure 3. Design #3 has an average beta of approximately 10 at room temperature which drops at 6 at 150° (Fig. 4). Four devices with very similar characteristics have been selected and packaged into two paralleled BJTs and four others in Darlington configuration. As shown in Fig. 5 and Fig. 6, both these configurations have achieved to double the current rating without deteriorating the static performance and give promising results. Future monolithic Darlington designs can be used to further increase the current amplification and achieve higher current density. Such a configuration could also infer an improved thermal stability of the current amplification. Fig. 7 compares the output characteristics of designs #2 and #3. Both these devices seem to handle well linear operation. The blocking capability has to be improved to reach 10 kV rating as avalanche occurs just above 5 kV.

A specific driver will be designed and used to test the switching performance of the presented devices for the final paper. This work could yield devices that can compete against SiC MOSFETs for higher voltages than 10 kV.

- [1] R. Singh, S. Jeliaskov, B. Grummel, and S. Sundaresan, "Switching and robustness analysis of 10 kV SiC BJTs," in *WiPDA 2015 - 3rd IEEE Workshop on Wide Bandgap Power Devices and Applications*, 2015, pp. 406–409.
- [2] H. Miyake, T. Okuda, H. Niwa, T. Kimoto, and J. Suda, "21-kV SiC BJTs with space-modulated junction termination extension," *IEEE Electron Device Lett.*, vol. 33, no. 11, pp. 1598–1600, 2012.
- [3] Q. Zhang, R. Callanan, *et al*, "10 kV, 10 A bipolar junction transistors and Darlington transistors on 4H-SiC," *Trans Tech Publ.*, 2010.
- [4] B. Asllani *et al.*, "Advanced Electrical characterisation of high voltage 4H-SiC PiN diodes," *Mater. Sci. Forum*, 2019.

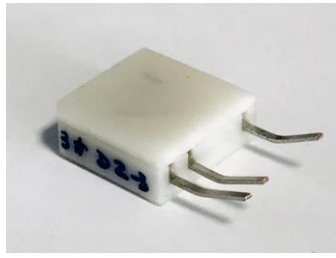


Fig. 1. Isoplus packaging from DeepConcept

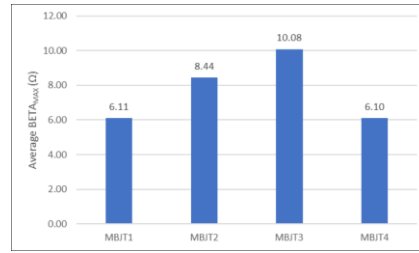


Fig. 2. Average Betas of the four different designs measured on wafer.

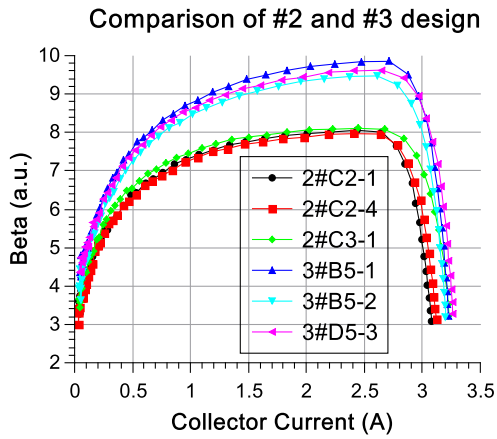


Fig. 3. Comparison of Betas for the best designs as a function of the collector current

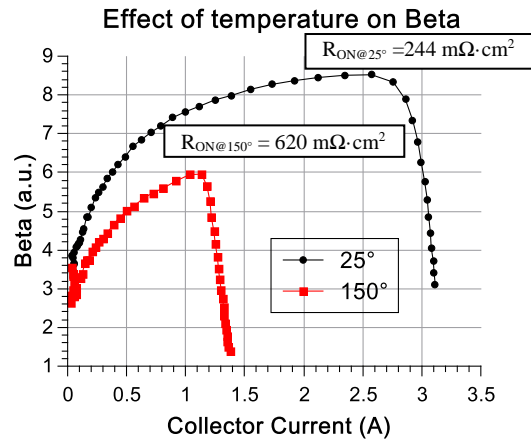


Fig. 4. Effect of temperature on Beta of #3 design.

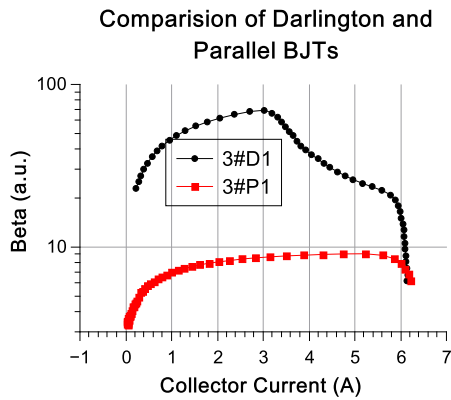


Fig. 5. Comparison of betas of Paralleled and Darlington BJTs.

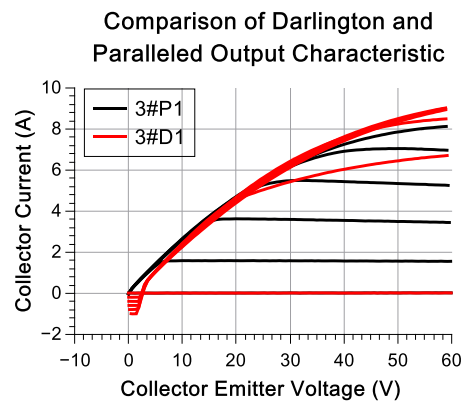


Fig. 6. Comparison of output characteristics of Paralleled and Darlington BJTs.

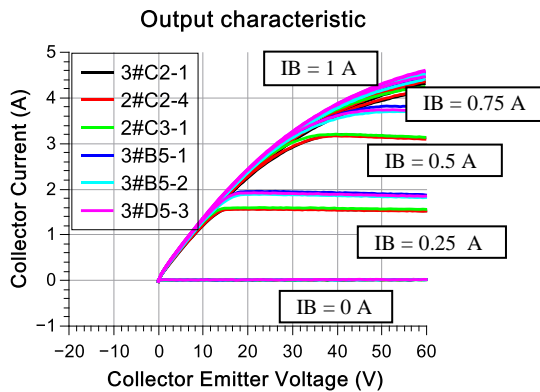


Fig. 7. Output characteristics of the all of the measured single BJTs.

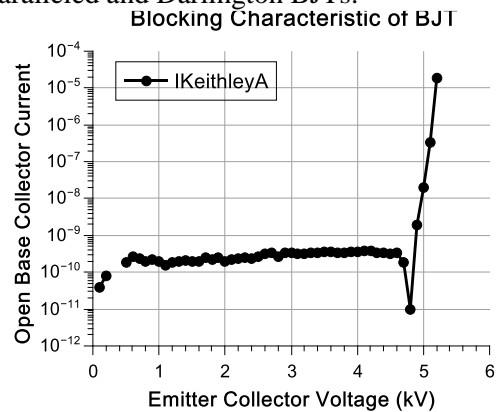


Fig. 8. Blocking capability of BJTs.