HIGH-VOLTAGE EPITAXIAL EMITTER BIPOLAR JUNCTION TRANSISTORS IN 4H-SIC

by

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ABSTRACT

Silicon carbide (SiC) power devices are under active development for high-voltage power switching applications because of its wide bandgap, high critical electric field and high thermal conductivity. This research focuses on utilizing these properties to explore high-voltage SiC bipolar junction transistors (BJTs) with superior forward active and blocking performances. 4H-SiC epitaxial emitter BJTs with breakdown voltages up to 6kV with a specific on-resistance as low as 28mΩ.cm^2 have been experimentally demonstrated. This specific on-resistance is lower than that of any previously reported SiC BJT for a comparable blocking voltage.

Analytical equations have been developed to model the forward voltage drop, forced current gain and switching times of the device. The total power dissipated is estimated and used as a figure of merit to evaluate the useful range of device operation. The influence of different material parameters such as lifetime in the collector, base and emitter regions and process induced defects such as recombination at the SiO_2-SiC interface and p+ implantation induced damages is evaluated using numerical simulations. Simulation results indicate that the optimum spacing between the p-contact implantation and emitter side-wall for the best device performance is around 4μm.

1-4kV devices are fabricated using the implanted base process. The 4kV device exhibits a specific on-resistance of 56mΩ.cm^2 (current gain of ~10) which is higher than the unipolar value for the drift layer. This is attributed to the loss of minority carriers in the extrinsic base region due to surface recombination and implantation induced damages.

Novel high-voltage BJTs are fabricated (on the same material as the previous devices) using self-aligned selective and blanket growth of p-type SiC for the base contact. High-voltage BJTs fabricated using the selective growth technique exhibit specific on-resistance values (28mΩ.cm^2) below the unipolar limit but show degradation in the current gain in the active region (~ 4). A storage time of ~0.4μs is observed from the open-base turn-off curves. The blanket growth devices demonstrate higher current gain values (~9) but degradation in specific on-resistance (46mΩ.cm^2). The devices demonstrate up to 6kV forward blocking capability and the enhancement in the blocking

yield is accredited to the incorporation of a p+ guard ring implantation around the JTE trench corner.