Demonstrate of a Low On-resistance 6.5kV PiN Diode Fabricated on a SiC Substrate with p+ epitaxial layer

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Silicon carbide (SiC) is an attractive semiconductor material with a wide band gap of 3.3 eV, to be suitably used in high-power electronic devices. In general, compared to Si power devices, SiC power devices have advantages of excellent dynamic characteristics, high switching speed and low energy losses. These days, SiC Schottky barrier diodes (SBDs) with voltage ratings of 600 V all the way to 3.3 kV are commercially available. However, for ultra-high voltage (over 3.3 kV) applications, SiC bipolar devices, such as PiN diode, are more suitable due to the low resistance of the thick blocking layer.

In this study, we fabricated low on-resistance 6.5 kV SiC PiN diodes and analyzed the forward and reverse characteristics of these devices at both room temperature and 125 °C. Two different 4H-SiC substrates with and without p+ epitaxial layer (p+ epilayer) were used. The p-n junction of the substrate without p+ epilayer was formed by aluminum ion implantation (p+ I. I.). Both of the substrates had a 64-μm-thick N-doped (1×10^{15} cm^{-3}) n-type drift layer. The active area formed on each chip was 0.22 mm^2. The breakdown voltage was over 8 kV, which conformed to our calculation result (Fig. 1). In forward characteristics, as shown in Fig. 2, the on-resistance was lower at a higher temperature and with p+ epilayer. Furthermore, the on-resistances of the chips with p+ epilayer were lower than the unipolar limit (28.7 mΩ・cm^2, resistance of drift layer calculated at RT) when the current density over 129 A/cm^2 (Fig. 3). For 100 A (455 A/cm^2), the on-resistance was only 10 mΩ・cm^2, almost 35% of the unipolar limit. We noticed that the PiN diode formed by p+ i.i. showed high on-resistance. It can be deduced crystal defects at p-n junction generated by p+ i.i which can reduce the lifetime of minority carriers and thus reduce a conductivity modulation.

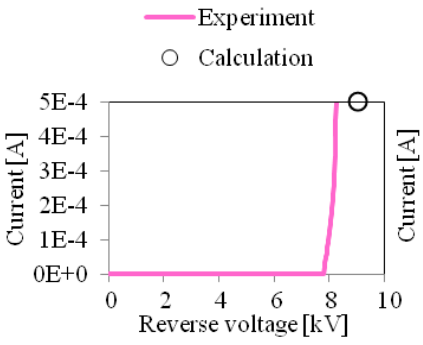

Fig. 1 Reverse characteristics of the fabricated SiC PiN diode.

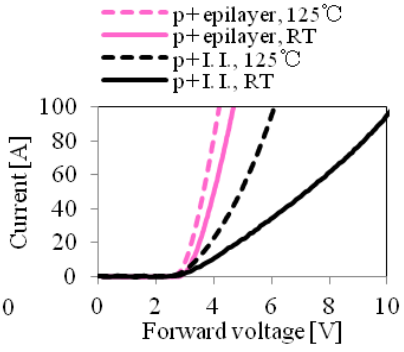

Fig. 2 Forward characteristics of the samples formed by fabricated p+ epilayer and p+ I. I..

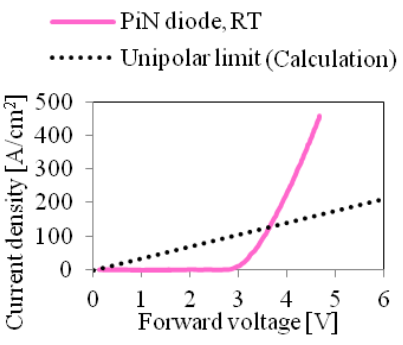

Fig. 3 Current density as a function of forward voltage.