Recent Development of Nitirde Heterojunction Bipolar Transistors

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Nitride heterojunction bipolar transistors (HBTs) have several advantages such as high breakdown voltages, high current densities, and good threshold voltage uniformity, which are preferable for high-power microwave electronic devices. For this application, the first Npn-type AlGaN/GaN HBT [1,2] was reported in 1998 and between then and 2002 several AlGaN/GaN [3,4], GaN/InGaN [5] and AlGaN/InGaN HBTs [6] were developed. However, there were two major issues that had to be addressed for these nitride HBTs. One was low current gains and the other high offset voltages in the common-emitter current-voltage (I-V) characteristics. Both problems were related to etching damage of the base, so the base regrowth technique using p-GaN was applied to AlGaN/GaN HBTs as a solution [1,2]. However, the ohmic characteristics were not greatly improved. In 2003, we applied the extrinsic base regrowth technique using p-InGaN to Npn-type GaN/InGaN HBTs grown on SiC substrates and successfully obtained high current gains as well as low offset voltages in the common-emitter I-V characteristics. In this conference, we will introduce these GaN/InGaN HBT characteristics.

The HBT structure consists of a Si-doped GaN sub-collector, a Si-doped GaN collector, a graded InGaN layer, a Mg-doped InGaN base, and a Si-doped GaN emitter. The p-InGaN extrinsic base layer was selectively regrown on the exposed p-InGaN base and the ohmic characteristics of base were vastly improved [7]. Figure 1 shows typical common-emitter I-V characteristics of our Npn-type GaN/InGaN HBT at room temperature [8]. The device has a 50 μm x 30 μm emitter area and the base current is 5 μm/step. The collector current increases with the base current and the maximum current gain ($\beta = \Delta I_C/\Delta I_B$) reached 2000, which is 100 times as high as our previous GaN/InGaN HBT [5]. The offset voltage is reduced to less than 1 V.

Figure 2 shows the maximum collector current as a function of the emitter size [9]. The emitter size was changed from 1.5x10^{-5} cm^2 to 1.4x10^{-4} cm^2 to investigate the HBT's power density characteristics. The slope of the straight line in Fig. 2 is nearly equal to 1, indicating that the maximum collector current is proportional to the emitter size at least in this emitter-size range. From this slope, the maximum collector current density is calculated to be as high as 6700 A/cm^2, indicating the high current density characteristics of bipolar transistors. The maximum DC power and the corresponding power density are as high as 10.4 W and 230,000 W/cm^2 [8]. These characteristics show that GaN/InGaN HBTs are promising for high-power electronic devices.

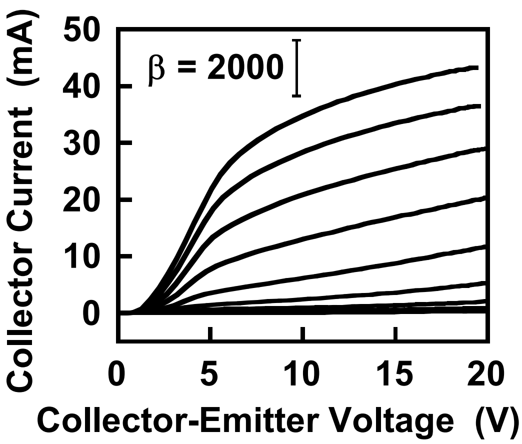

Fig. 1 : Typical common-emitter I-V characteristics of an Npn-type GaN/InGaN HBT on a SiC substrate with an extrinsic regrown base of p-InGaN. The emitter size is 50 μm x 30 μm.

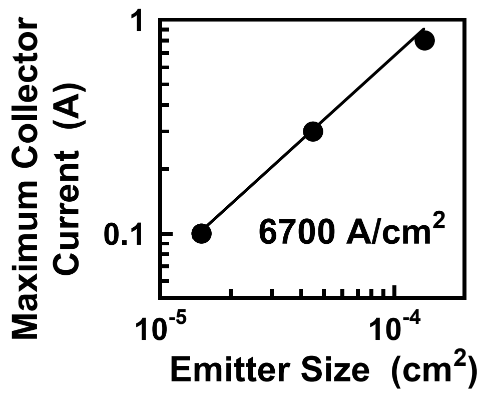

Fig. 2 : Maximum collector current as a function of emitter size.

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