Observation of Current Gain Collapse in Large-Area HBT with Rectangular Emitter and Etched Base

M.-K. Tsai, S.-W. Tan[*], W.-S. Lour[*] and Y.-J. Yang

Dept. of Electrical Engineering,
National Taiwan University,
1 Sec. 4, Roosevelt Road, Taipei, Taiwan.
[*]Dept. of Electrical Engineering,
National Taiwan-Ocean University,
2, Peining Road, Keelung, Taiwan.

The GaAs-based heterojunction bipolar transistor (HBT) has been used to fabricate high-performance microwave power modules due to its high current density and high breakdown voltage. However, the HBT's performance is limited by its thermal characteristics. The combination of the high current density during the operation and the relatively low thermal conductivity of the GaAs substrate elevates the junction temperature severely, which may lead to the failure of power HBTs [1]. Liu et al. have demonstrated a phenomenon called the current gain collapse, which has been repeatedly observed in multi-finger HBT's [2-3]. Liu proved that the extreme non-uniform thermal distribution (or current distribution) across the finger is responsible for this unwanted phenomenon.

In this paper, however, we observe the current gain collapse in our studied HBT with a rectangular emitter and an etched base. Figure 1 shows the schematic diagram of the fabricated device. The detailed epitaxial parameters and fabrication steps have been published elsewhere [4]. Since there is no etching selectivity between the AlGaAs/GaAs digital-graded superlattice (DGSL) layer and the GaAs base when using $1H_2SO_4{:}1H_2O_2{:}8H_2O$ as the etching solution, it is very likely to etch the base layer with the thickness of 1000Å to about 300~500Å, resulting in an increased resistivity in the base region that leads to significantly undesirable thermal effect.

Figure 2 shows the common emitter characteristics with 20 μA/step base current of the device, measured by Tektronics-577 curve tracer. The same device is then measure by HP-4145B semiconductor analyzer to show the current gain collapse phenomenon when the collector-emitter voltage reaches 3.5 V, as shown in Figure 3. It is interesting to observe the current gain collapse even though the HBT does not have multiple fingers.

In conclusion, we have demonstrated the current gain collapse phenomenon in an HBT with a large-area emitter and an over-etched base. This phenomenon is attributed to non-uniform thermal distribution (or current distribution) when the base is undesirably etched. Furthermore, the detailed analysis and explanation of current gain collapse mechanism will be reported.

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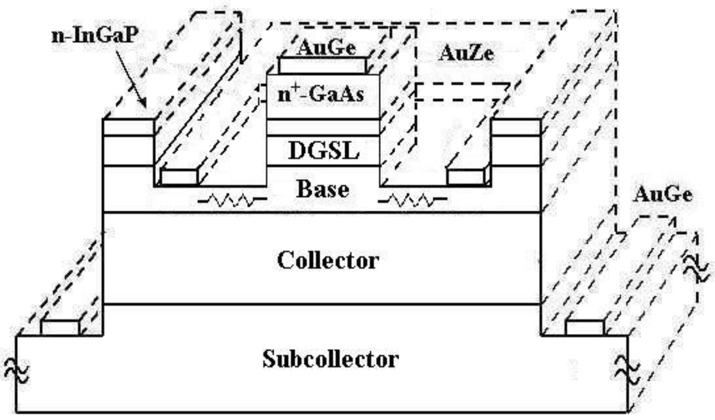

Fig. 1: The schematic diagram of the fabricated device with the base over-etched.

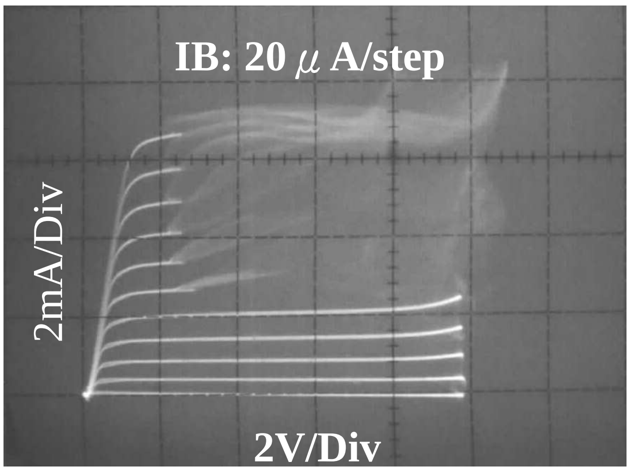

Fig. 2: The common emitter characteristics with 20 μA/step base current measured by Tektronics-577 curve tracer.

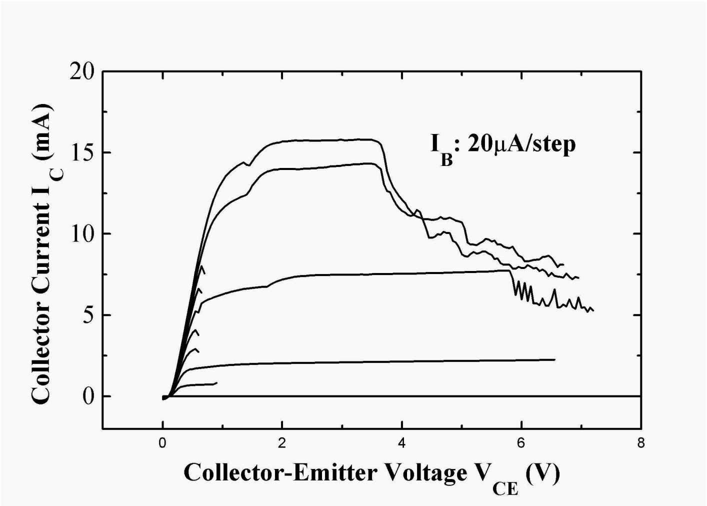

Fig. 3: The common emitter characteristics with 20 μA/step base current measured by HP-4145B.