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Growth and Characteristics of AlGaN/GaN HBTs

R. D. Dupuis[1)], D. J. H. Lambert, U. Chowdhury, M. M. Wong, T. G. Zhu, and B. S. Shelton,
The University of Texas at Austin, Microelectronics Research Center
10100 Burnet Road, Building 160, PRC/MER 1.606D-R9900, Austin, TX 78758 USA
Phone: (512) 471-0537; FAX: (512) 471-0957; dupuis@mail.utexas.edu

J. J. Huang, D. Caruth, and M. Feng
Microelectronics Laboratory, Department of Electrical and Computer Engineering
University of Illinois at Urbana-Champaign, 208 North Wright Street, Urbana, IL 61801 USA

1. Introduction

Wide-bandgap GaN is a promising material for high-temperature and high-power device applications. Excellent microwave performance of nitride based heterojunction field effect transistors (HFETs) has been reported [1][2][3]. However, the progress of GaN-based HBTs is relatively slow. Several reports have been made of nitride HBTs tested in common-base configurations with DC current gains as high as β=10,000 [4][5][6], and HBTs tested in common-emitter configurations with betas as high as β=100 [7][8][9]. However, these papers have not reported the common-emitter current-voltage (I_C-V_{CE}) curves for device applications except three reports describing a beta equal to 4-10, 2 and 1.5 [10][7][8]. In this work, the common emitter I_C-V_{CE} modulation curves in AlGaN/GaN graded emitter HBTs at low temperature was studied to understand the limiting issues related to the low CE current gain of a GaN HBT. We have measured a common emitter current gain of 27 at 190K and 11 at 295K. The increase in collector current and CE current gain at lower temperature can be attributed to the reduced base recombination current, which is due to the carrier traps associated with defect (dislocation) centers in the base-emitter junction.

2. Fabrication Process

The HBT device fabrication is a two-mesa, two-metalization process. The emitter mesa was first defined by ion cyclotron plasma (ICP) etching. The base metal (Ni/Au) was deposited and the base and collector layers were then etched. Next, Ti/Al/Ti/Au was deposited as the collector metal. Finally, the sample contacts were alloyed.

3. Device Results

Figures 1 (a) and (b) show the common-emitter I_C vs. V_{CE} curves at 295K and 190K, respectively. The input base current I_B ranges from 0 to 15μA in 3μA steps. For the same bias condition, V_{CE} =50V and I_B =15μA, the collector current increases from I_C =169μA at 295K to I_C =411μA at 190K. The corresponding current gain is increased from 11.3 at 295K to 27.5 at 190K. We also observed an increase in the offset voltage when the temperature was decreased (V_{CEoff}=8V at 295K; V_{CEoff}=15V at 190K), since the offset voltage is related to $I_B R_E$, where I_B and R_E are base bulk current and emitter resistance, respectively. The increase in offset voltage is due to the increase of base bulk current and the reduction of the recombination current at low temperature. The 2.4 times increase in current gain from 295K to 190K is mainly attributed to the increase in base bulk current and the reduction of base recombination current. Fig. 1 (a) and (b) indicate a factor of two increase in offset voltage can then be attributed to the 2X increase of base bulk current.

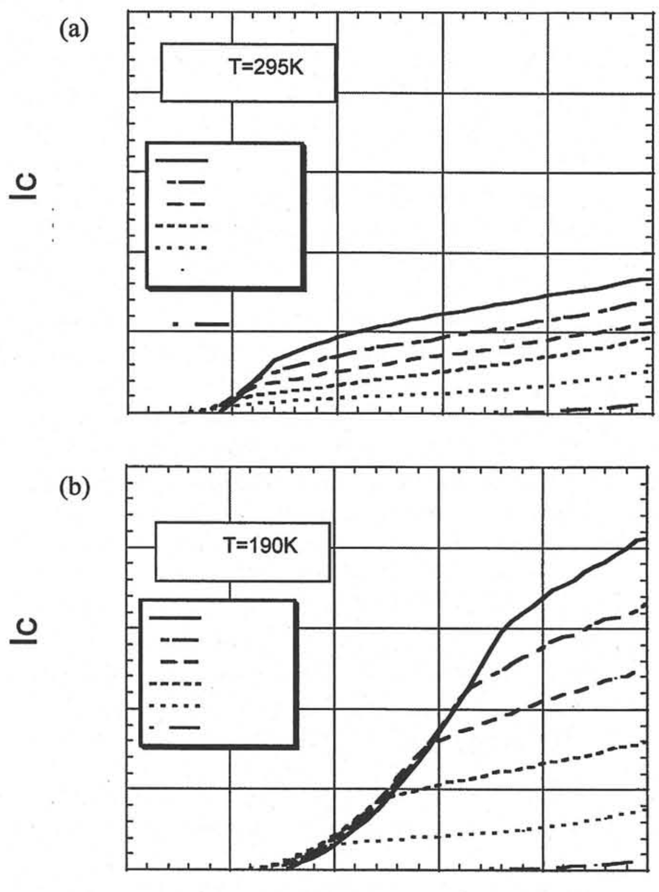

Figure 1. Common-emitter I_C-V_{CE} curve in GaN HBT at (a) 295K and (b) 190K. The base currents in (a) and (b) range from I_B = 0 to 15μA in steps of 3μA.

Figures 2 (a) and (b) show the common emitter V_{BE} vs. V_{CE} curves at 295K and 190K, respectively. A Schottky base contact was observed from these curves. When I_B =0, there is only a very small voltage drop across the Schottky diode. Once I_B >0, a huge voltage drop across the reversed diode makes V_{BE} large. When the temperature drops to 175K, a large current gain and thus large collector and emitter current increases the voltage drop across the parasitic emitter resistor. The parasitic resistor behaves as a feedback path and limits the collector current level. When I_B =15μA and V_{CE} =50V at 175K, V_{CB} is only 1V, which probably is the reason current gain decreases as I_B increases.

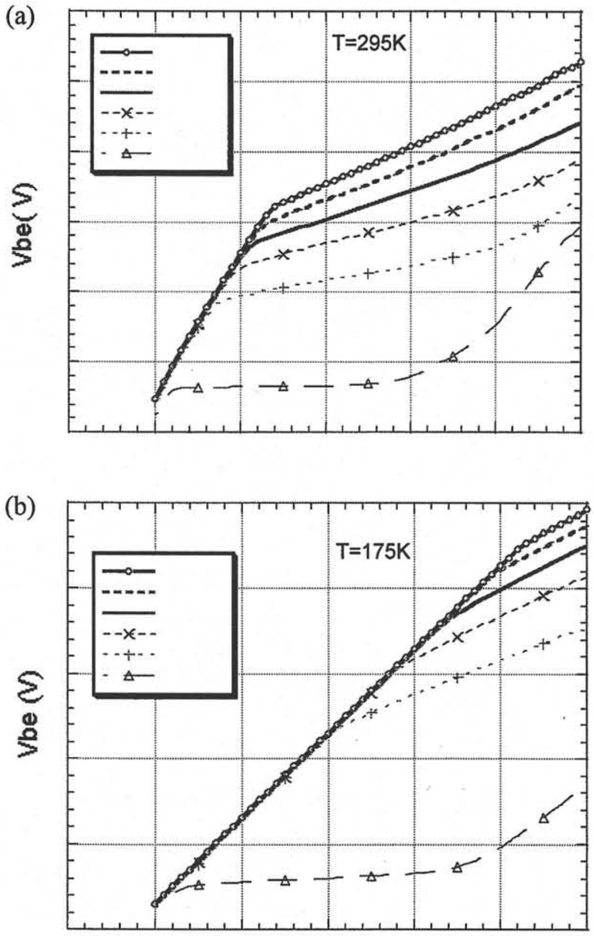

Figure 2. Common-emitter V_{BE}-V_{CE} curve in GaN HBT at (a) 295K and (b) 190K. The base currents in (a) and (b) range from I_B = 0 to 15μA in steps of 3μA.

4. Conclusion

We have demonstrated graded-emitter AlGaN/GaN HBTs with a common-emitter DC current gain of β=4-10 and an offset voltage $V_{CE\text{-}off}$ = 4V. The common-emitter current gain and offset voltage are by far the best results reported to date for AlGaN/GaN HBTs. However, the high base contact resistance and lateral base layer resistance limit the operating current range. We think that a heterojunction recombination current at the emitter-base junction, arising from dislocation centers is responsible for the phenomena we observed in I_C-V_{CE}, V_{BE}-V_{CE} curves at different temperatures. Further study is required to fit the parameters of the emitter-base diode.

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