Characteristics of InP/InGaAs superlattice-emitter resonant tunneling bipolar transistors (SE'RTBT)

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INTRODUCTION

Recently, the remarkable growth technologies have attracted considerable interest in the development of superlattice, quantum-well, quantum-dot, and quantum-wire related devices. The concept of resonant-tunneling bipolar transistor (RTBT) was first proposed by Capasso and Kiehl in 1984. Due to the good potential for power generation in the microwave regime, the functional RTBT has been considered to be the promising high-frequency oscillators and high speed switches.

EXPERIMENTS

Both of the studied SE-RTBT's were grown on a Fe-doped semi-insulating (100) InP substrate by a low-pressure metal organic chemical vapor deposition (LP-MOCVD) system. The epitaxial structure consisted of a 3000Å InP undoped buffer layer, a 3000Å InP collector ohmic contact layer ($n^+=5\times10^{18}cm^{-3}$), a 5000Å collector layer ($n^-=5\times10^{16}cm^{-3}$), a 50Å undoped $In_{0.53}Ga_{0.47}As$ setback layer, an 800Å $In_{0.53}Ga_{0.47}As$ base layer ($p^+=2\times10^{19}cm^{-3}$), a 50Å undoped $In_{0.53}Ga_{0.47}As$ setback layer, an InP emitter layer ($n=5\times10^{17}cm^{-3}$), a 500Å InP cap layer ($n^+=5\times10^{18}cm^{-3}$), and a 2000Å $In_{0.53}Ga_{0.47}As$ cap layer ($n^+=5\times10^{18}cm^{-3}$). The superlattice inserted between the InP-emitter and cap layers consist of 50Å i-InP barriers and 50Å n-InGaAs wells ($n=5\times10^{17}cm^{-3}$). The differences between two devices are emitter thickness and periods of superlattice. For device A, the emitter thickness of 800Å and 5-period superlattice were selected. For device B, the emitter thickness of 150Å and 3-period superlattice were used.

RESULTS AND DISCUSSION

Figure 1 shows the common-emitter current-voltage (I-V) characteristics of the device A. β_{ac} up to 170 is obtained under the applied base current of I_B=100μA/step. There is about 6% decline in the current gain as the temperature is decreased from 300K to 77K. The kink phenomenon at 77K shows the presence of RT through 5-period superlattice. Figure 2 shows the common-emitter I-V characteristics of the device B under the same applied base current of I_B=100μA/step. β_{ac} of 54 is acquired which is lower than device A. The current gain shows about 7.4% degradation at low temperature of 77K. Based on the specified structure, the lower offset voltage and saturation voltage (≤1.5V) are obtained. Experimentally, the device with a 5-period superlattice and emitter thickness of 800Å provides higher D.C. performances and stable temperature-dependent characteristics as shown in Fig. 3.

CONCLUSION

In summary, due to the use of superlattice and critical-designed emitter, the D.C. performance is improved and more stable temperature-dependent characteristics is achieved. The RT effect is observed in device A at 77K. The lower offset voltage shows that the potential spike at E-B heterojunction is effectively suppressed. The performance of the studied device provides a good potentiality in parity-bit generators, multiple-valued logic circuit, ADC's (DAC's), and frequency multipliers applications.

ACKNOWLEDGMENT

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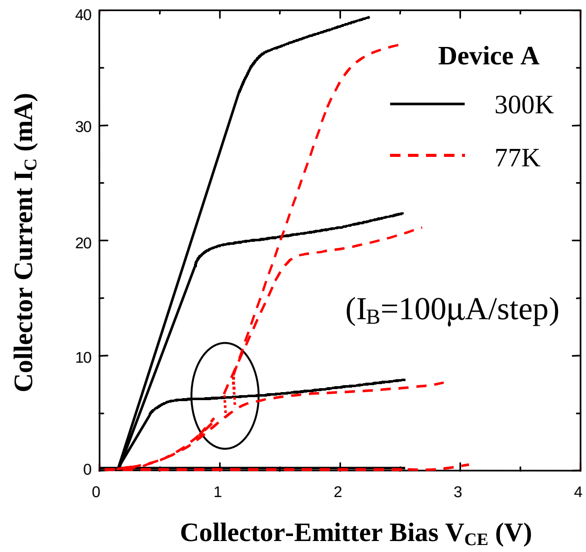

Fig.1 The common-emitter current-voltage (I-V) characteristics of the studied device A at 300K and 77K. The applied base current is I_B=100μA/step.

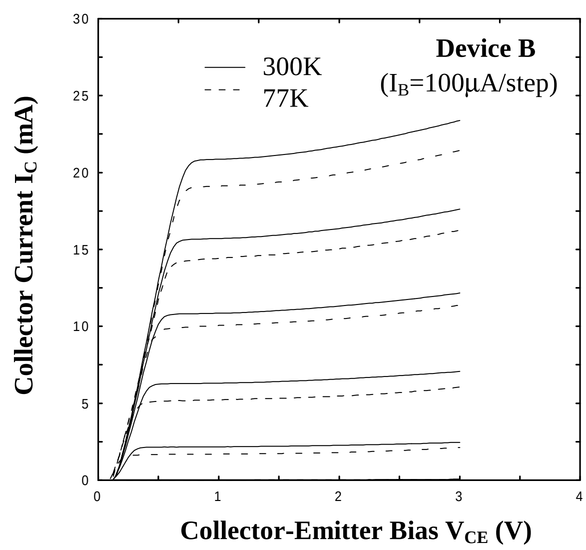

Fig.2 The common-emitter current-voltage (I-V) characteristics of the studied device B at 300K and 77K. The applied base current is I_B=100μA/step.

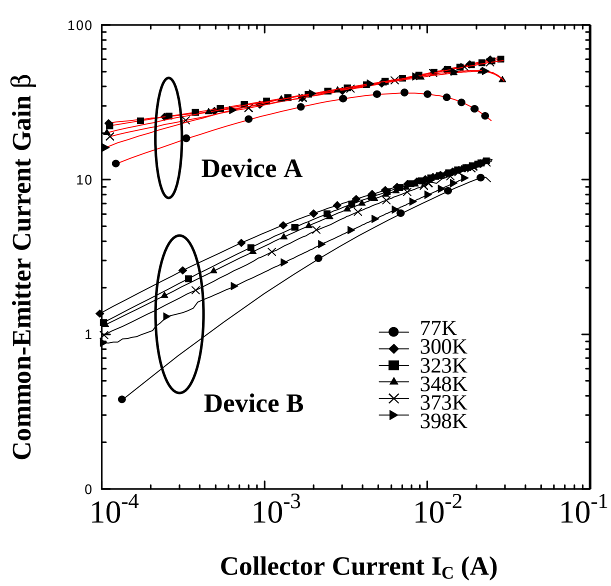

Fig.3 Dependence of D.C. current gains β on the collector current I_C at the measured temperature range from 77K to 398K.