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0.25-μm-Emitter InP HBTs with a Passivation Ledge Structure

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1. Introduction

InP HBTs are promising candidates for ultra-high-speed IC applications to optical fiber communication systems. Recently, there has been a rapid advance in the high-speed performance of InP HBTs with aggressive device scaling [1]. However, a decrease in the device dimension leads to an increase in surface recombination current at the emitter-base periphery, which results in degradation of current gain. Moreover, the surface recombination current may seriously influence device reliability. An effective way to suppress surface recombination current is to form a ledge structure on the extrinsic base region [2]. In this work, we investigated the performance of 0.25-μm-emitter InP HBTs with passivation ledge structures.

2. Device structure and fabrication

We used MBE-gown single HBT structures on InP substrates. The base and collector layers are 25-nm-thick p-type InGaAs and 75-nm-thick InGaAs. The base layer was doped to a concentration of 6×10^{19} cm^{-3}. The base sheet resistance was estimated to be 760 Ω/sq. from transmission-line-model measurements. The emitter consists of a degenerately-doped n-type InGaAs layer and a 15-nm-thick undoped InP layer. In this structure, a thin ledge structure can be easily formed by etching the InGaAs cap layer [2].

The device fabrication sequence started with the deposition of W/Au/W films on the emitter cap layer. The upper W film was patterned using i-line lithography and reactive ion etching (RIE). The Au film was etched by inductive coupled plasma (ICP)-RIE with Ar/O_2 mixture gas. Here, the upper and bottom W films were used as a mask and etching stopper layer, respectively. After the W films were etched away by RIE, the combination of selective wet etching and ICP-RIE was used to form the emitter mesa. A silicon nitride film was deposited. The silicon nitride film and the InP barrier layer were patterned to cover the extrinsic base region. The barrier layer acts as a ledge layer. Base metals were formed by a lift-off process and electron-beam lithography. The base-collector mesa was formed by wet etching. Each device was isolated by wet etching. For device layout, a base-pad isolation structure was used to eliminate extrinsic base-collector capacitance [3]. Finally, a benzocyclobutene film was spin-coated and cured. Figure 1 shows a SEM image of the fabricated HBT. A 0.25-μm-emitter mesa structure was successfully fabricated. The width of the base metal is 0.25 μm and the emitter-base spacing is 0.15 μm.

3. Device characterization

Figure 2 shows the common-emitter collector I-V characteristics. The fabricated HBT provides excellent turn-on characteristics and high collector current density, J_c, of over 20 mA/μm^2. The breakdown voltage, BV_{CEO}, is over 2 V. We measured a Gummel plot for the HBT at a collector-base voltage, V_{CB}, of 0 V. As shown in Fig. 3, even at a low J_c, there is no crossover in the Gummel plot. The current gain is 62 at a J_c of 10 mA/μm^2. To investigate the effectiveness of the ledge layer further, we measured Gummel plots of HBTs with various emitter-base spacing. Figure 4 shows the current gain characteristics as a function of J_c. The current gain does not depend on the emitter-base spacing. In addition, the current gain for the HBT with a 0.25-μm-emitter is comparable to that for the HBT with a 50-μm-emitter. On the basis of these results, we conclude that this ledge structure sufficiently suppresses the surface recombination current.

Figure 5 shows the current gain (h_{21}) and Mason's unilateral gain (*UG*) as a function of frequency. The f_t and f_{max} were obtained by extrapolation of h_{21} and *UG* with -20 dB/decade slope line. Figure 6 summarizes the f_t, f_{max}, and total collector capacitance, C_{Tc}, as a function of J_c. The HBT exhibits an f_t of 442 GHz and f_{max} of 214 GHz at a J_c of 12 mA/μm^2. The C_{Tc} is 11 fF. The f_{max} is relatively low, which is due to the large base resistance. The f_{max} could be improved by using a pseudomorphic base [3].

4. Conclusions

We have demonstrated 0.25-μm-emitter InP HBTs with a passivation ledge structure. The HBTs exhibit a reasonably high current gain of over 60 and an f_t of 442 GHz. These results indicate that this technology is promising for making high-speed 0.25-μm-emitter InP HBTs with a reasonably high current gain.

Acknowledgements

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References

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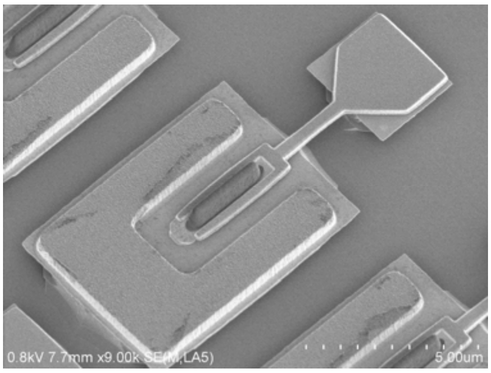

Fig. 1. SEM image of a fabricated HBT with an emitter size of 0.25 µm x 3 µm.

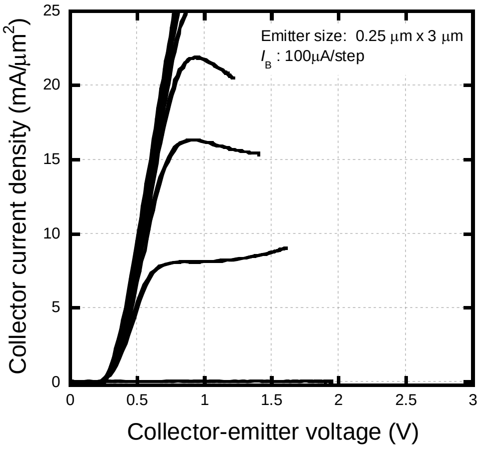

Fig. 2. Common-emitter collector I-V characteristics for the HBT with an emitter size of 0.25 µm x 3 µm.

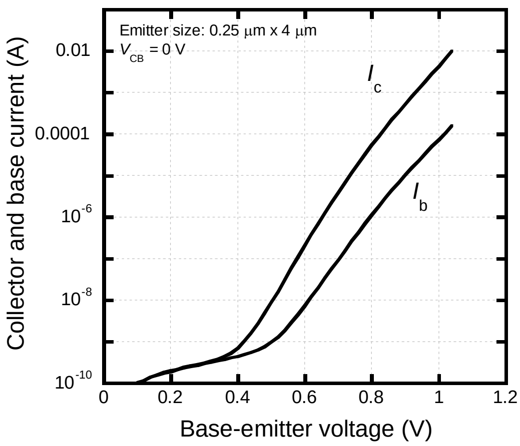

Fig. 3. Gummel plot of the HBT with an emitter size of 0.25 µm x 4 µm. The collector-base voltage, V_{CB}, is 0 V.

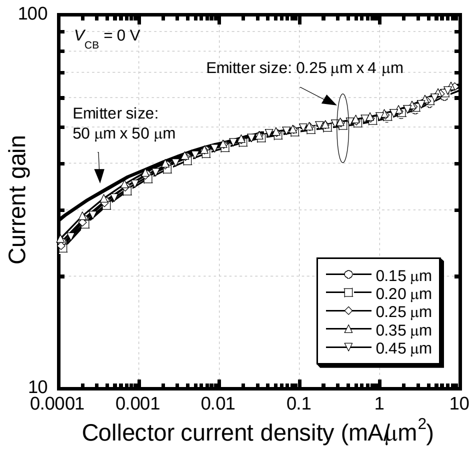

Fig. 4. Current gain characteristics for HBTs with various emitter-base spacing.

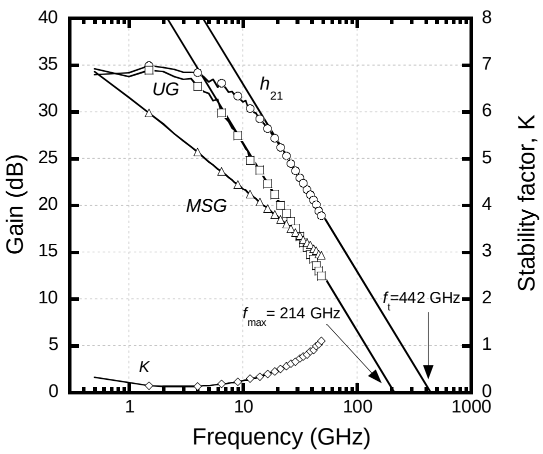

Fig. 5. Current gain (h_{21}), Mason's unilateral gain (*UG*), maximum stable gain (*MSG*), and stability factor, *K*, as a function of frequency.

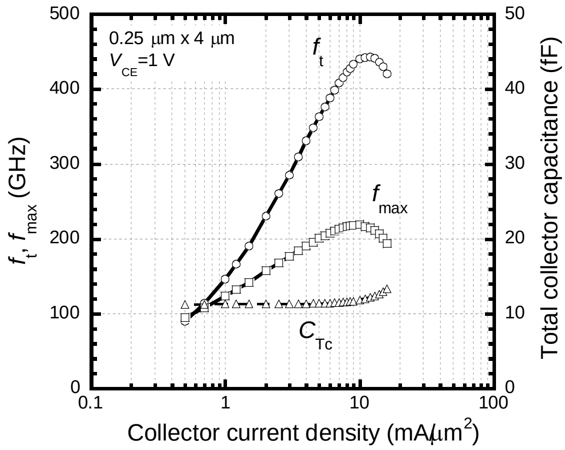

Fig. 6. f_t, f_{max}, and total collector capacitance, C_{Tc}, as a function of collector current density.