

# High-speed AlGaAs/GaAs HBTs with a Reduced Base-Collector Capacitance

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## Abstract

We present a new layout for high-speed AlGaAs/GaAs HBTs. The layout is horse-shoe shaped and is designed to simultaneously reduce base resistance ( $R_B$ ) and base-collector capacitance ( $C_{BC}$ ). A horse-shoe shaped HBT and a conventional single-finger HBT with the same emitter width of  $2\ \mu\text{m}$  were fabricated and tested. The reduction of  $R_B$  and  $C_{BC}$  using the horse-shoe shaped HBT resulted in 25 % improvement of maximum oscillation frequency ( $f_{\text{max}} = 130\ \text{GHz}$ ).

## 1. Introduction

Since HBTs were first suggested by Kroemer [1], much effort has been made to develop high-speed HBTs. The process techniques to reduce  $R_B$  and  $C_{BC}$  such as isolation implantation of the extrinsic base and collector region [2], laterally etched undercut [3], epi regrowth for the thick base layer [4], L-shaped base electrode [5], transferred-substrate technique [6] have contributed to the remarkable improvement on the device performance. However, a study of the device layout to obtain a high-speed performance has not been extensively studied yet.

In this letter, a new device layout structure for a high-speed HBT is presented. The layout seeks a reduced base-collector junction area, while simultaneously shortening the effective base length for a curtailment of the base metal resistance,  $R_{Bm}$ . The layout resembles a horse-shoe. A horse-shoe shaped HBT and a conventional single-finger HBT with the same emitter size were fabricated and compared for high-speed performance. An  $f_{\text{max}}$ s of 130 GHz and 100 GHz, respectively, were achieved for  $2\ \mu\text{m} \times 22\ \mu\text{m}$  AlGaAs/GaAs HBTs, indicating that this layout structure is very favorable for high-speed HBTs.

## 2. Device Design and Fabrication

Fig. 1 shows the basic features of the horse-shoe type and single-finger type HBTs. Each of HBT has  $44\ \mu\text{m}^2$  emitter areas, but the layouts are quite different. The horse-shoe type HBT has  $161\ \mu\text{m}^2$  base-collector areas, while the single-finger type of HBT is  $190\ \mu\text{m}^2$ . The longest path length of the base current in the horse-shoe type HBT is about  $14\ \mu\text{m}$ , while the single-finger device shows  $23\ \mu\text{m}$ . Fig. 2 shows the layouts of the two HBTs. The emitter widening metal is used for an easy alignment of the following patterns. Emitter and base metals are connected to pad metals by Au air-bridges. The process is depicted in detail in Fig. 3. Self-aligned HBTs were fabricated using contact alignment, with standard lift-off techniques for metalizations. A AuGe/Ni/Au emitter metal was first deposited and used to mask the emitter etch. The InGaAs layer was wet-etched. The GaAs emitter layer was selectively etched by having RIE stop at the AlGaAs layer and was undercut. The effective emitter-to-base spacing was about  $0.1\ \mu\text{m}$ . Next, Pt/Ti/Pt/Au base contact metal was deposited (Fig. 3(a)). Polyimide was deposited and was etched without a mask using RIE until the emitter metal was exposed. Next, a Ti/Au emitter widening metal was deposited (Fig. 3(b)), and polyimide was removed. The base-collector and sub-collector layers were etched and AuGe/Ni/Au collector metal and pad metal were deposited and alloyed (Fig. 3(c)). Au air-bridge process followed (Fig. 3(d)).

Substrate was lapped to the thickness of  $100\ \mu\text{m}$  and emitter is grounded through a via hole. The epitaxial layer structures of the fabricated AlGaAs/GaAs HBTs are outlined in Table I.

## 3. Device Performance

The maximum current DC gains of the HBTs are approximately 30. The breakdown voltages of both type HBTs at an open base,  $BV_{\text{ceo}}$  are 10 V for the thin-collector HBT and 17 V for the thick-collector one. RF performances of the  $2 \times 22\ \mu\text{m}^2$  emitter HBTs were measured using a network analyzer from 0.1 to 40 GHz. Fig. 4(a) and (b) show a comparison of gain-frequency characteristics of the horse-shoe type with the single-finger type. For HBTs with a collector thickness of  $1\ \mu\text{m}$ , the  $f_T$  and  $f_{\text{max}}$  are 52 GHz and 105 GHz respectively at  $I_C=16\ \text{mA}$  and  $V_{\text{CE}}=2.3\ \text{V}$  for the single finger type, and 50 GHz and 130 GHz at the same bias point for the horse-shoe type. For  $0.4\ \mu\text{m}$  thick-collector HBT, the  $f_T$  and  $f_{\text{max}}$  are 67 GHz and 60 GHz respectively at  $I_C=18\ \text{mA}$  and  $V_{\text{CE}}=2.0\ \text{V}$  for the single finger type HBT, and 68 GHz and 80 GHz at the same bias point for the horse-shoe type.  $f_{\text{max}}$ s are increased by about 25 % as a result of the new layout.

## 4. Conclusion

A new device layout for high-speed AlGaAs/GaAs HBTs was represented using a simple process technique. This layout is horse-shoe shaped and is designed to simultaneously reduce  $R_B$  and  $C_{BC}$ . A horse-shoe shaped HBT and a conventional single-finger HBT with the same emitter width of  $2\ \mu\text{m}$  were fabricated for a comparison. The  $f_T$  and  $f_{\text{max}}$  are 52 GHz and 105 GHz respectively at  $I_C=16\ \text{mA}$  and  $V_{\text{CE}}=2.3\ \text{V}$  for the single finger type of HBT with  $1.0\ \mu\text{m}$  thick collector, and 50 GHz and 130 GHz at the same bias point for the comparable horse-shoe type of HBT.

## 5. Acknowledgements

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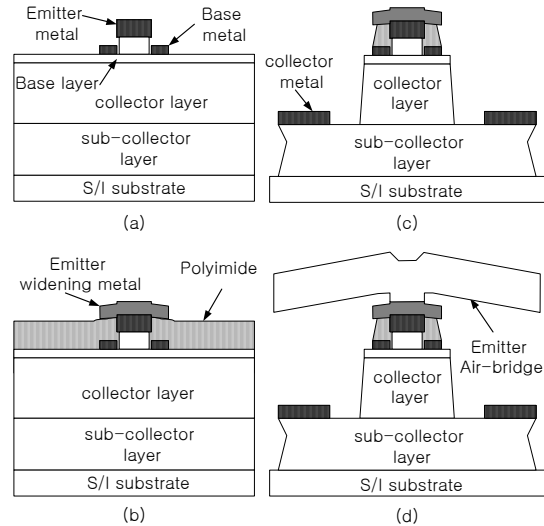


Fig. 3. Processing steps for AlGaAs/GaAs HBTs.

Composition	Thickness ( $\mu\text{m}$ )	Conc. ( $\text{cm}^{-3}$ )	Dopant
$\text{Ga}_{0.5}\text{In}_{0.5}\text{As}$	0.02	$2 \times 10^{19}$	Si
$\text{Ga}_{1-y}\text{In}_y\text{As}$ ( $y=0.5 \rightarrow 0$ )	0.02	$2 \times 10^{19}$	Si
GaAs	0.09	$5 \times 10^{18}$	Si
GaAs	0.07	$5 \times 10^{17}$	Si
$\text{Ga}_{1-x}\text{Al}_x\text{As}$ ( $x=0.3 \rightarrow 0$ )	0.03	$5 \times 10^{17}$	Si
$\text{Ga}_{0.7}\text{Al}_{0.3}\text{As}$	0.07	$5 \times 10^{17}$	Si
GaAs	0.07	$5 \times 10^{19}$	C
GaAs	1.00/0.40	$2 \times 10^{16}$	Si
GaAs	0.60	$5 \times 10^{18}$	Si

Table I. Epitaxial layer structures of AlGaAs/GaAs HBTs.

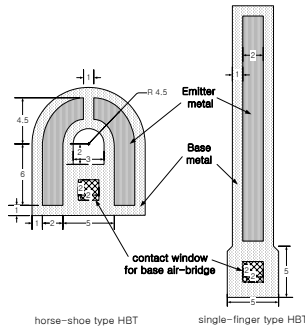


Fig. 1. Basic features of the HBTs with  $2 \times 22 \mu\text{m}^2$  emitter areas.

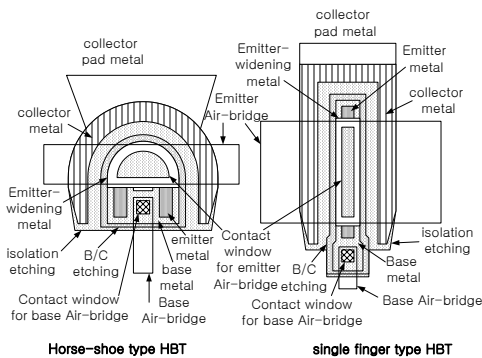
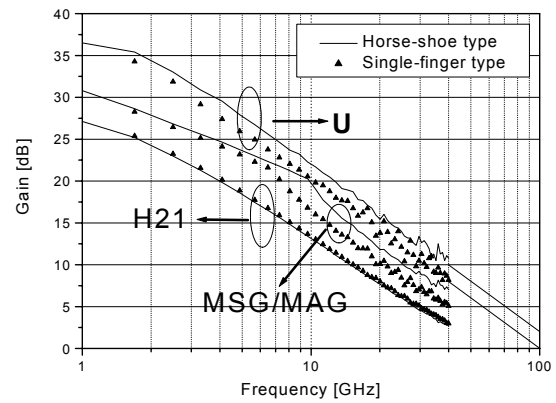
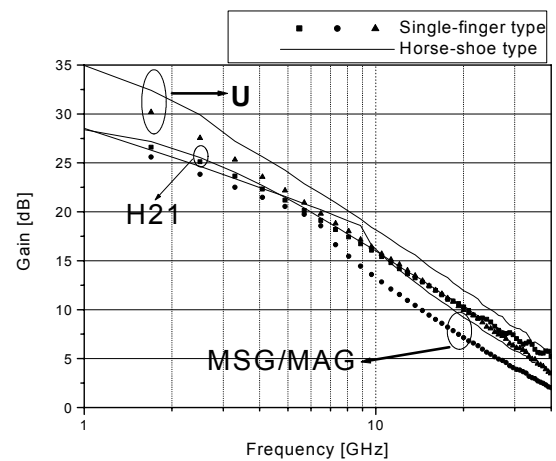


Fig. 2. Layouts of the horse-shoe type and single-finger type HBT with  $2 \times 22 \mu\text{m}^2$  emitter areas.



(a)



(b)

Fig. 4. Microwave performances of the horse-shoe type and single-finger type HBTs with  $2 \times 22 \mu\text{m}^2$  emitter areas. (a) HBTs with  $1.0 \mu\text{m}$ -thick collector (b) HBTs with  $0.4 \mu\text{m}$ -thick collector.

