Structure-related Characteristics of SiGe HBT and 2.4 GHz Down-conversion Mixer

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Abstract—**In this paper, the effect of base and collector structures on DC, small signal characteristics of SiGe HBTs fabricated by RPCVD was investigated. The structure of SiGe HBTs was designed into four types as follows: SiGe HBT structures which are standard, apply extrinsic-base SEG selective epitaxial growth (SEG), apply selective collector implantation (SCI), and apply both extrinsic-base SEG and SCI. We verified the devices could be applied to the fabrication of RFIC chip through a fully integrated 2.4 GHz down-conversion mixer.**

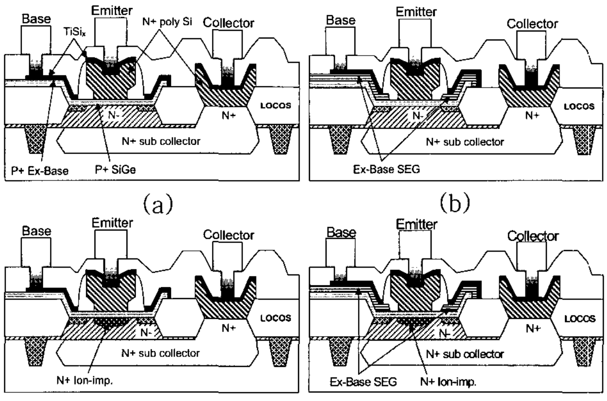
Index Terms—SiGe, HBT

I. INTRODUCTION

Device characteristics of SiGe heterostructure bipolar transistor (HBT) such as cutoff frequency (f_T), maximum oscillation frequency (f_{max}) and minimum noise figure (NF_{min}) decisively depend on the base and collector structures as well as the process technique [1-6]. In general ultra high vacuum CVD (UHVCVD) process has been adopted for the SiGe research because of the purity-assisted improvement of device characteristics. However, low throughput and high cost of the UHVCVD becomes a barrier to be overcome at an industrial point of view, giving a chance to reduced pressure CVD (RPCVD) as an alternative. It also is well known that the base and collector structures of SiGe HBT influences the device characteristics to a great extent [7-9]. Thus we came to investigate the effects of the base and collector structures on the DC and RF characteristics of self-aligned SiGe HBTs fabricated by RPCVD. We verified the devices could be applied to the fabrication of RFIC chip through a fully integrated 2.4 GHz down-conversion mixer.

II. STRUCTURED-BASED DESIGN AND FABRICATION OF SIGE HBT

The SiGe HBT was shown in Fig. 1. Briefly, the buried layer was formed by implant and collector epitaxy. After buried layer formation, the active regions were delimited by field oxide (LOCOS) isolation and collectors were formed by implants. Successively, the p+ base and n- emitter were grown using our standard "Epsilon One" rapid thermal chemical vapor deposition (RPCVD) system. The thicknesses of the different epitaxial layers were determined by simulation, so as to avoid boron out-diffusion of the SiGe layer and formation of parasitic barriers during thermal annealing. And conventional titanium salicidation was adopted as an interconnection process for the sake of the reduction of contact resistance and in turn parasitic components. The structure of SiGe HBT was designed into



(a) (b)

(c) (d)

Fig. 1. Schematic view of SiGe HBT. (a) Structure-A (standard), (b) Structure-B (extrinsic-base SEG), (c) Structure-C (SCI), and (d) Structure-D (extrinsic-base SEG & SCI).

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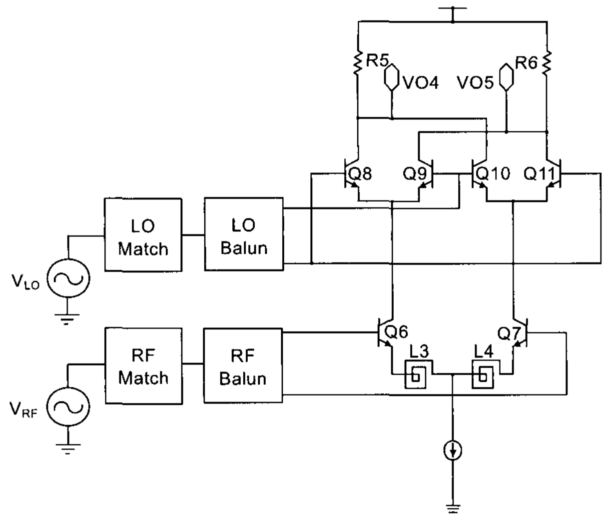


Fig. 2. Double-balanced mixer with matching and active balun circuits.

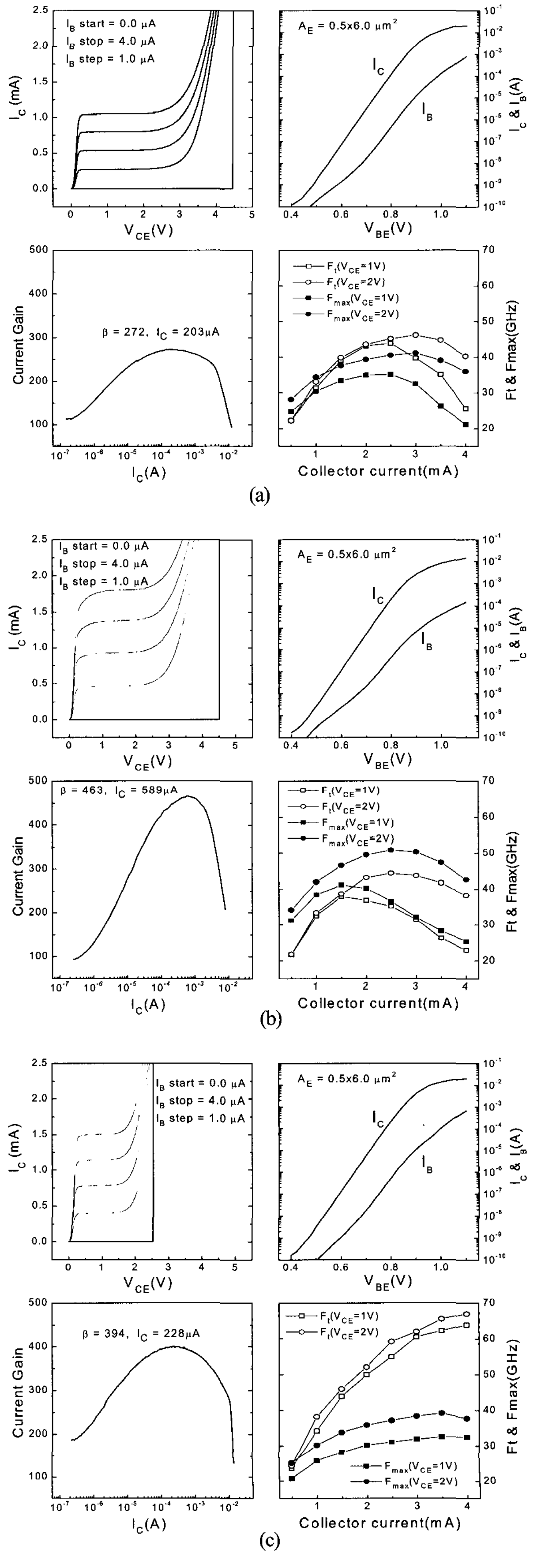
four types as shown in Fig. 1. SiGe HBTs of Fig. 1 are standard structure (structure-A), structure applying extrinsic-base selective epitaxial growth (SEG) (structure-B) for improvement of f_{max}, structure applying selective collector implantation (SCI) (structure-C) for improvement of f_T, and structure applying both extrinsic-base SEG and SCI (structure-D) for improvement of f_T and f_{max}. We prepared 1-finger SiGe HBTs with the emitter size of 0.5 x 6.0 μm^2. To make the most of the device, we designed and tested a fully integrated doubled-balanced mixer using Structure-A device, as shown in Fig. 2 [7].

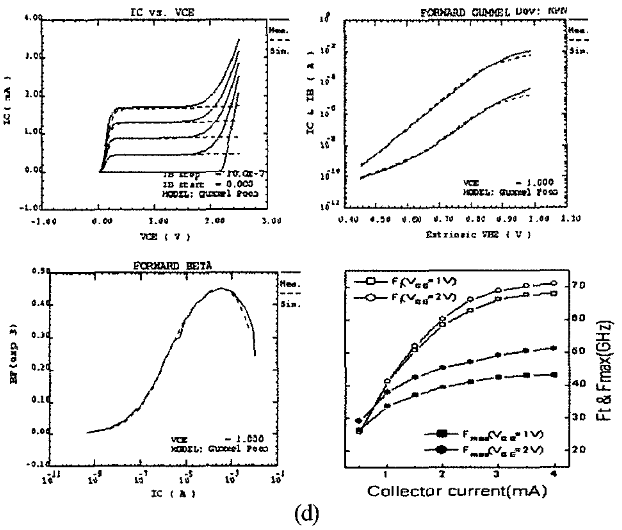
Making use of HP 4145B parameter analyzer and HP 8510C network analyzer, we analyzed DC characteristics such as I-V curve and Gummel plots and small signal characteristics with scattering parameter, respectively. We evaluated the characteristics of fabricated RFIC chip using two RF power sources HP83650B, HP83752B, and a spectrum analyzer HP8563E.

III. RESULTS AND DISCUSSION

All the structure showed an ideal I-V curve as shown in Fig. 3 where the BV_{CEO} of Structure-A and -B was more than 3.3 volts while that of Structure-C and -D (including SCI) was 2.3 volts. Also typical Gummel plots were obtained with the current gain of 272, 463, 394, and 443 at Structure-A, -B, -C, and -D, respectively, as shown in Fig. 3.

Based on the measured scattering parameters, f_T and f_{max} of each structure were derived at several bias points as shown in Fig. 3. f_T was higher at Structure-C (67 GHz) and -D (71 GHz) adopting SCI, because the critical current occuring Kirk effect was shifted toward high current. On the other hand f_{max} was





(d)

Fig. 3. I-V characteristics, Gummel plots, current gain, and fT & fmax. (a) Structure-A (standard), (b) Structure-B (extrinsic-base SEG), (c) Structure-C (SCI), and (d) Structure-D (extrinsic-base SEG & SCI).

higher at Structure-B (51 GHz) and -D (51 GHz) adopting extrinsic-base SEG, because increase of base thickness leaded to decrease of base resistance. Both f_T and f_{max} was higher at Structure-D adopting both SCI and extrinsic-base SEG. For high-frequency RF/microwave operation, the design must be optimized so that f_{max} as well as f_T are as high as possible. Therefore, it can be said that the Structure-D is more effective to improve high frequency characteristics of SiGe HBT.

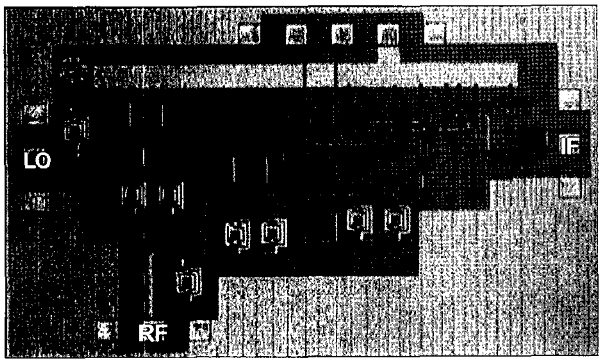


Fig. 4. Chip microphotograph of the fabricated mixer.

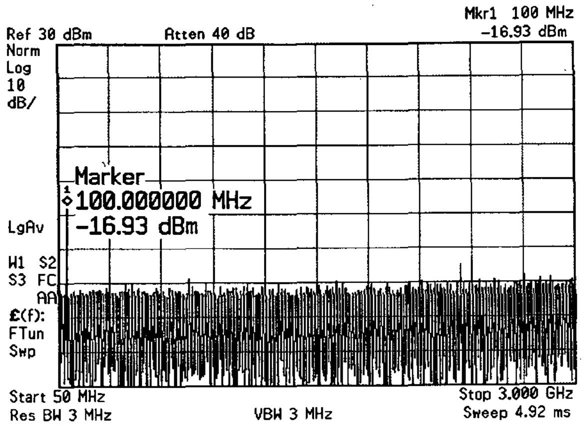


Fig. 5. Output spectrum of mixer.

To make the most of the device, for example we fabricated and tested a fully integrated 2.4 GHz doubled-balanced mixer shown in Fig. 2. Fig. 4 shows chip microphotograph of the fabricated mixer with 1.9 mm × 1.2 mm, where LO is local oscillator input, RF is radio frequency input, and IF is intermediate frequency output. We obtained conversion gain of 13.1 dB as shown in Fig. 5 when RF power of -30 dBm (with 2.45 GHz) and LO power of 0 dBm (with 2.35 GHz) were applied. Also, we obtained about IIP3 of 3.3 dBm as shown in Fig. 6 when two-tone RF input frequencies of 2.45 GHz and 2.46 GHz and LO input frequency of 2.35 GHz with LO power of 0 dBm was fixed and RF input frequencies were swept in the range of -30 dBm ~ +2 dBm. We verified the SiGe HBT could be used to design and fabricate RFIC chip.

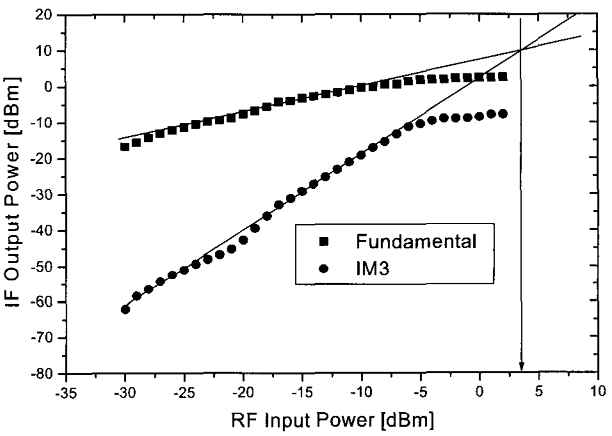


Fig. 6. 3rd intercept point characteristics of mixer.

IV. CONCLUSIONS

In this paper, the effect of base and collector structures on DC, small signal characteristics of SiGe HBTs fabricated by RPCVD was investigated. Both f_T and f_{max} was higher at Structure-D adopting both SCI and extrinsic-base SEG. Therefore, it can be said that the Structure-D is more effective to improve high frequency characteristics of SiGe HBT. Also, we fabricated and evaluated a fully integrated 2.4 GHz SiGe HBT mixer. From the measured result of the fabricated chip, we verified the SiGe HBT designed could be used to design and fabricate RFIC chip.

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