# An 8.5 GHz SiGe-Based Amplifier Using Fully Self-Aligned Double Mesa SiGe HBTs

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***Abstract*— We are reporting an 8.5 GHz fully integrated SiGe amplifier developed using a novel fully self-aligned double mesa HBT process technology. The common-base HBT demonstrates a $G_{max} > 14$ dB and an $f_{max} > 37$ GHz. At 8.5 GHz, the small-signal gain of the amplifier is better than 4 dB, with input and output return loss of -10 dB and -5 dB, respectively. The amplifier is also shown to be unconditionally stable.**

***Index Terms*— Amplifier, HBT, MMIC, SiGe, transistor.**

## I. INTRODUCTION

This work describes the development of a 8.5 GHz integrated amplifier based on a novel fully self-aligned Silicon Germanium (SiGe) Heterojunction Bipolar Transistor (HBT) technology.

## II. MMIC DESIGN AND FABRICATION

Processing technology for SiGe Monolithic Microwave Integrated Circuit (MMIC) used to develop high frequency amplifiers is discussed in this section. The important attribute of this technology is high performance and reduced process tolerance of the developed HBT. One step Chemical Vapour Deposition (CVD) is used to grow the Si/SiGe heterostructure as shown in Table I. The measured Secondary Ion Mass Spectroscopy (SIMS) profile of the device is shown in Fig. 1. Device layout and heterostructure design are optimized taking into account the requirements for high power handling, thermal stability and high frequency operation as discussed in [1].

TABLE I
SI/SIGE/SI HBT HETEROSTRUCTURE.

| | | | | | |
|---|---|---|---|---|---|
| Emitter cap | Si | n+ | P | $2 \times 10^{19}\mathrm{cm}^{-3}$ | 2000Å |
| Emitter | Si | n | P | $1 \times 10^{18}\mathrm{cm}^{-3}$ | 1000Å |
| Spacer | $Si_{0.75}Ge_{0.25}$ | i | | | 50Å |
| Base | $Si_{0.75}Ge_{0.25}$ | p+ | B | $1 \times 10^{20}\mathrm{cm}^{-3}$ | 200Å |
| Spacer | $Si_{0.75}Ge_{0.25}$ | i | | | 50Å |
| Collector | Si | n- | P | $1 \times 10^{16}\mathrm{cm}^{-3}$ | 5000Å |
| Subcollector | Si | n+ | P | $2 \times 10^{19}\mathrm{cm}^{-3}$ | $1\mu$m |
| Substrate | Si(100) | p- | | $1 \times 10^{12}\mathrm{cm}^{-3}$ | $540\mu$m |

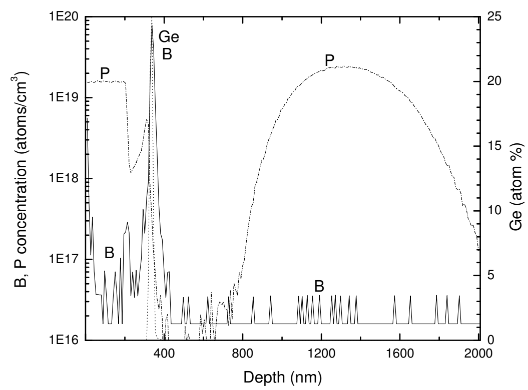


Fig. 1. SIMS profile of CVD-grown device (20371S).

To improve the process tolerance, a novel fully self-aligned process technology was developed. This technology follows the ideas of [2] while trying to overcome the weakness of the thin base overhang. Fig. 2 shows the schematic of the technology highlighting the fully self-aligned process. Fig. 3 shows the Scanning Electron Microscope (SEM) photograph of the completed 10 finger HBT. The process follows [1] except that base metal deposition is composed of Pt/Au = 200/600 Å. The base mesa is formed using isotropic Reactive Ion Etching (RIE) etching with photoresist protecting the emitter-base area. The isotropic RIE etching is achieved by increasing the chamber pressure to reduce the mean free path of the ions. This reduces the vertical etching profile of the RIE. The collector metal is then deposited self-aligned to the base metal using Ti/Pt/Au/Ti = 100/100/800/50 Å. The 50 Åthin layer of Ti acts as a visual cue for a later contact via holes process step by changing the underlaying color of the gold. A completely etched via hole will show a bright gold color as the Ti will also etch away, while an incompletely etched via hole will still show a dull gold color due to the presence of the Ti layer.

A ten finger common-emitter HBT exhibits an IV characteristics show in Fig. 4 where a maximum collector

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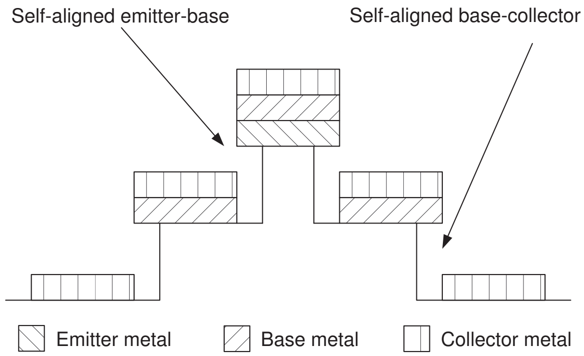


Fig. 2. Fully self-aligned HBT process technology.

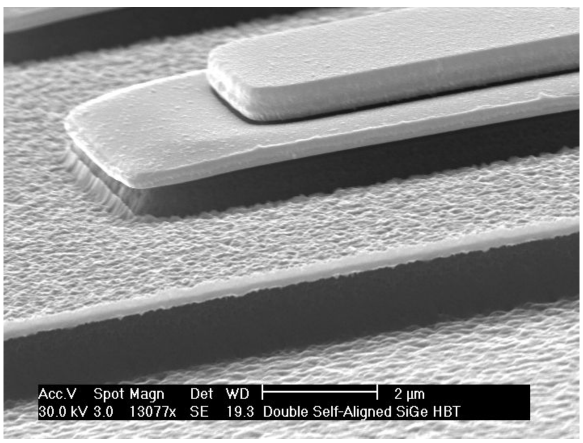


Fig. 3. SEM photograph of fully self-aligned HBT using developed technology.

current here is about 200 mA, and a collector-emitter voltage swing of 8 V was easily tolerated. Using (1), it is estimated that the device will have a linear high power performance of about 23 dBm.

$$P_{out} = \left(\frac{V_{swing}}{2\sqrt{2}}\right) \cdot \left(\frac{I_{swing}}{2\sqrt{2}}\right) \quad (1)$$

On-wafer small signal RF characteristics of a 10 finger common-base HBT were measured using an HP8510C vector network analyzer from 50 MHz to 18 GHz. Fig. 5 shows that the $f_{max}$ of the 10 finger device is better than 37 GHz and the $G_{max} > 14$ dB at 8.5 GHz.

The HBT Gummel-Poon model was extracted from measured DC and small-signal S-parameters and subsequently used for the design of the amplifier. The microphotograph of the completed amplifier is shown in Fig. 6.

## III. Amplifier Performance

The MMIC amplifier was tested on-wafer under continuous wave operation at room temperature with no wafer thinning or extra heat sinking. Fig. 7 shows the measured small-signal gain and input/output return losses of the amplifier. At 8.5 GHz, the small-signal gain is better than

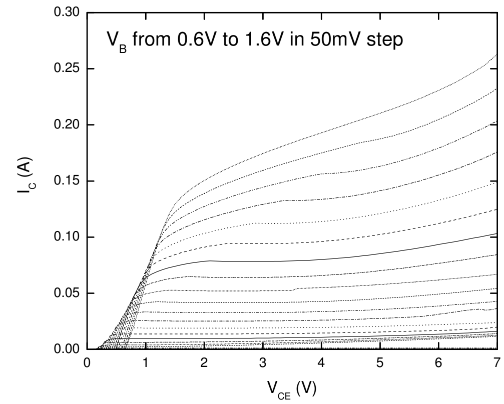


Fig. 4. DC I-V characteristics measured in common-emitter configuration of 10 finger HBT.

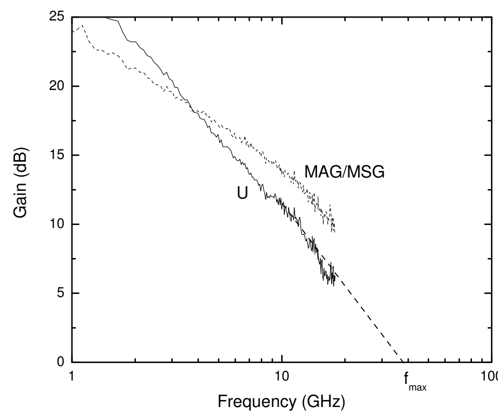


Fig. 5. Measured high frequency characteristics of a 10 finger common-base HBT.

4 dB, with input and output return loss of -10 dB and -5 dB, respectively. Fig. 8 also shows that the amplifier is unconditionally stable across frequency.

## IV. Conclusion

We have developed an 8.5 GHz fully integrated SiGe amplifier developed using a novel fully self-aligned double mesa HBT process technology. The common-base HBT demonstrates a $G_{max} > 14$ dB and an $f_{max} > 37$ GHz. At 8.5 GHz, the small-signal gain of the amplifier is better than 4 dB, with input and output return loss of -10 dB and -5 dB, respectively. The amplifier is also shown to be unconditionally stable.

## References

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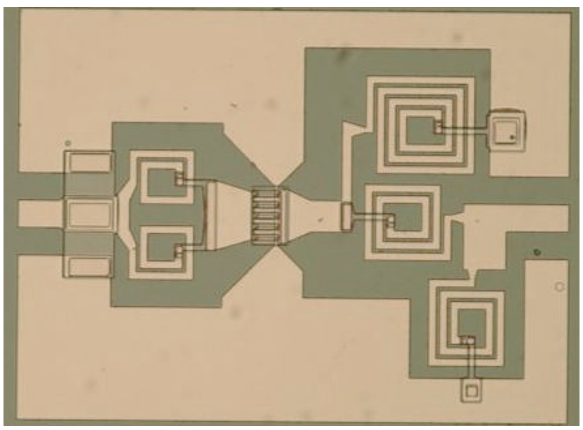

Fig. 6. Microphotograph of completed amplifier.

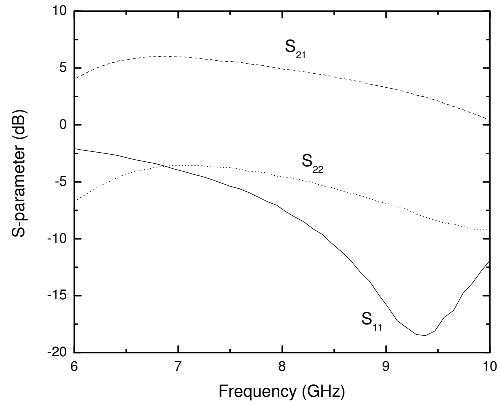


Fig. 7. Microphotograph of completed amplifier.

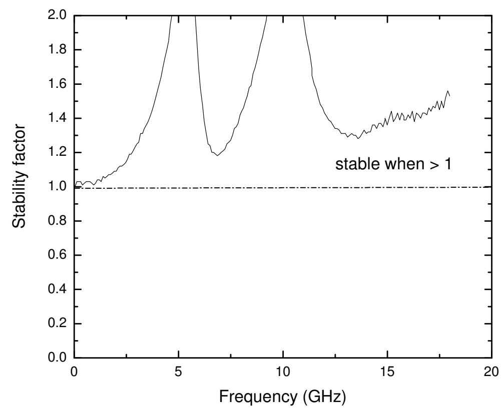


Fig. 8. Microphotograph of completed amplifier.

 