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High-Performance, Low-Cost SiGe:C BiCMOS Technology

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1. Introduction

SiGe and SiGe:C BiCMOS technologies are key enabler for single-chip solutions for broadband and wireless communication systems because combining highest bipolar RF performance with the high level of CMOS integration. Here, we demonstrate two modular SiGe:C BiCMOS processes combining an 0.25µm RF CMOS backbone with different HBT modules. The first process fabricates 200GHz HBTs with much lower process complexity compared to the state-of-the-art. The second process uses a novel one-mask HBT module. It offers ample bipolar performance for the majority of high volume applications at lowest cost. Both the high-speed and the low-cost HBT module take benefit from the suppressed B diffusion due to C doping [1].

2. SiGe:C BiCMOS Processes

High Speed SiGe:C HBT Module

High-speed HBTs with above 200GHz operation have been demonstrated recently [2, 3]. Here we show high frequency devices integrated in a 0.25 µm CMOS technology, which use a novel construction without deep trenches, without epitaxially-buried subcollectors and with low-resistance collectors. This facilitates a modular BiCMOS integration with minimal changes of the CMOS process. Fig. 1 shows the cross section of the new HBT structure. The whole HBT is fabricated in one active area without shallow trench isolation between emitter and collector contact. By this way, collector resistances as low as the emitter resistances, reduced device dimensions and lower parasitic capacitances have been achieved. HBTs with f_T/f_{max} values of 200/200 GHz are demonstrated (Fig. 2). Excellent CML ring oscillator delays of 4.2 ps are obtained. Excellent static characteristics and high yield of 4k transistor arrays have been achieved. Details of the process are described in [3].

Low-cost, High Performance HBT Module

This technology is a 0.25µm BiCMOS SiGe:C HBT process with 19 lithographic steps, offering 4 levels of Al and a full menu of active and passive devices. Three different SiGe:C HBTs can be fabricated by adding a single lithography level to the RF CMOS process. These devices offer a wide range of BV_{CEO}. We demonstrate HBTs with f_T/ f_{max}/ BV_{CEO} values of 28GHz/ 67GHz/ 7.5V; 52GHz/ 98GHz/ 3.8V; and 75GHz/ 90GHz/ 2.4V. The 19-mask process offers the following key features: 2.5V V_{DD} MOS transistors for digital applications, including an isolated NMOS device for improved signal isolation [4]; high-Q MOS varactors; three polysilicon resistors with sheet resistances of 94Ω, 1.1kΩ, and 5kΩ; a 2µm thick upper Al layer for high-Q inductor fabrication; and a 1fF/µm^2 MIM. Note also that by adding only two implant masks, a fourth SiGe:C HBT with f_T and f_{max} values in excess of 100GHz and 2.5V BV_{CEO}, and a high-performance LDMOS can easily be included without compromising the other devices [5, 6]. HBT fabrication starts after depositing the MOS gates and a Si_3N_4 protection layer. Fig.3 shows the SEM cross section of the HBT region obtained after SiGe:C base and Si low-doped emitter layer deposition, L-shaped inside spacers formation, SIC implantation, As-doped emitter Si layer deposition, and applying CMP to remove the emitter and base material from the Si_3N_4 layer surface to isolate the emitter from the external base. The protective nitride film was removed already by wet etching. Details of the process are presented in [7]. The manufacturability of the new HBT module is demonstrated by Gummel plots for 4k HBT arrays (Fig. 4). The yield exceeds 90%, matching the values obtained with our previous technology generations.

Circuit Applications of SiGe:C BiCMOS Technology

Various circuits have been designed demonstrating the capability of the SiGe:C BiCMOS technology for high frequency applications [8]. A selection of circuits obtained with a previous generation of high-speed HBTs, featuring f_T and f_{max} values of 120 and 140 GHz, respectively, are summarized in table 1.

3. Conclusions

The demonstrated high-speed HBT module combines highest RF performance with low process complexity. It is targeting on very high frequency applications.

The presented single-mask HBT SiGe:C BiCMOS process is of exceptional simplicity and flexibility, offering three different devices by adding a single mask level to standard RF CMOS. The bipolar performance of this low cost technology allows the usage for the majority of high volume applications.

Table I Circuits applications of the SiGe:C BiCMOS technology using HBTs with f_T and f_{max} of 120 and 140 GHz, respectively.

Circuit	Parameter	Result
Voltage controlled oscillator	Tuning range	58.7 – 68.5 GHz
LC oscillator	Max. output frequency	76 GHz
Static divider	Max. input frequency	62 GHz
Dynamic divider	Max. input frequency	73 GHz

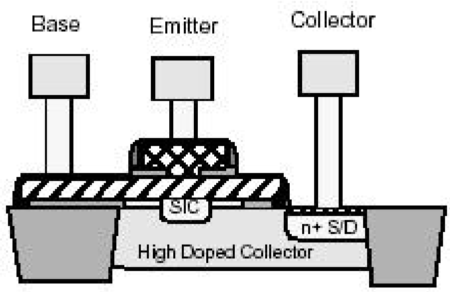

Fig.1 Cross section of the high-speed HBT

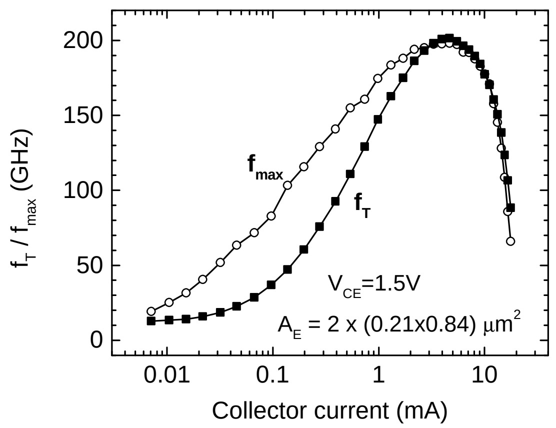

Fig. 2 Transit frequency f_T and maximum oscillation frequency f_{max} vs. collector current.

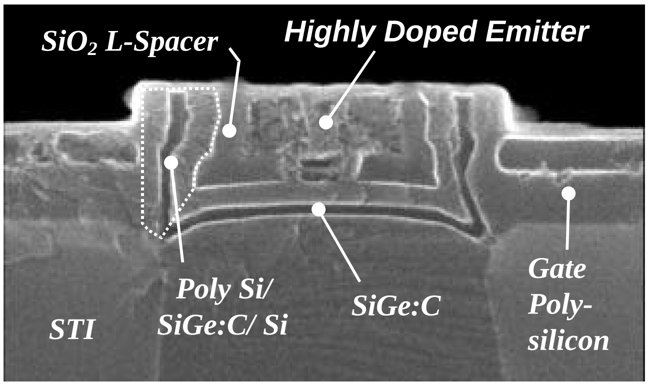

Fig. 3 SEM cross section of the single-mask HBT active region before CMOS gate structuring starts.

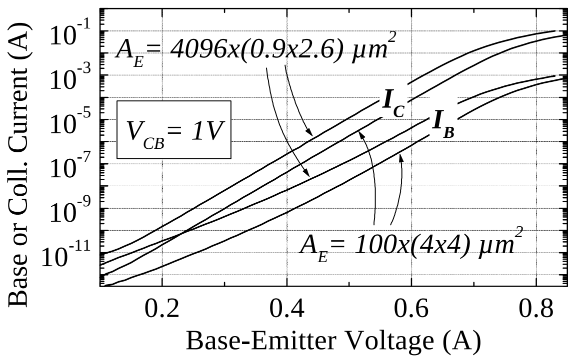

Fig.4 Gummel plots of arrays with up to 4096 HBTs in parallel fabricated with the single-mask HBT process.

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