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Growth and quality control of MBE-based SiGe-HBT for amplifier applications

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Abstract

This study aims at getting precise growth and doping control of the well-designed multiple SiGe heterostructure layers for amplifier applications using MBE. Large efforts have been made in calibrating the deposition rates of Si and Ge, and the doping concentrations, in order to ensure the high quality growth. The measured cutoff frequency was 5.1 GHz, which is not high but in an agreement with the simulated value (5.6 GHz) made by Medici for such a large size device without using device isolation. Finally, the development of test amplifiers, using the developed SiGe HBT technology, is underway. The broad-band low-noise amplifier with the certain functions has been obtained.

Keywords: Amplifier; MBE; Doping

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1. Introduction

With the development of modern electronics, there are steadily increased demands for high performance analog ICs. The implementation of SiGe HBTs into the analog IC technology can bring important advantages in IC design for reaching a high operational frequency and a speed limit, but there are some critical requirements for the design of SiGe layer structures, which should be carefully produced.

2. SiGe growth and quality control

The growth of Si/SiGe multilayer structures was made using a solid-source MBE system. The 6-layer structure of SiGe HBT is shown in Fig. 1. The substrates used were n-type ($\rho \leq 5$ mΩ cm), 75 mm-diam, (100)-orientated Si wafers. For some structures, Si wafers with a buried layer and a 400 nm thick n-type MBE Si layer on top were also used. The background pressure in the MBE chamber was about 4×10^{-10} mbar, and it was increased to $\sim 1 \times 10^{-9}$ mbar during the MBE growth. The B-doping in the base layer was made by sublimation of elemental B using a high temperature cell. The Sb doping in emitter and collector layers was made by a low-energy ion beam source, but the heavy Sb doping in the top contact layer was made by an ordinary effusion cell.

During growth, the surface morphology and reconstruction were monitored by in situ reflection high-energy electron diffraction (RHEED). A 2×8 reconstructed pattern was usually observed after the SiGe layer growth, which is an indication of a well-ordered and strained SiGe surface [1,2].

3. Characterization and result

After growth, the dopant and Ge profiles in the structures were measured by secondary-ion mass spectrometry (SIMS). The structural parameters of the sample were characterized by high-resolution X-ray diffraction (XRD) together with dynamic simulations. The dopant activation was verified by the spreading resistance measurements. Finally, to further verify the quality of the MBE-grown SiGe/Si hetero-structures, SiGe HBTs were processed using

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n—Si $1\times10^{17}[\mathrm{cm}]^{-3}$ 100nm

i—$\mathrm{Si}_{0.85}\mathrm{Ge}_{0.15}$ 5nm

p—$\mathrm{Si}_{0.85}\mathrm{Ge}_{0.15}$ $1\times10^{19}[\mathrm{cm}]^{-3}$ 40nm

i—$\mathrm{Si}_{0.85}\mathrm{Ge}_{0.15}$ 5nm

n—Si 400nm

n—Sub (100) with buried layer

Fig. 1. The 6-layer structure of SiGe HBT.

specially designed multi-layer structures, like the one shown in Fig. 1. Polysilicon emitter contact is adopted. The device fabrication details were given elsewhere.

The test HBT structures were grown fully using MBE for all the emitter, base, and collector layers.

Due to the limitation of photolithography, the 3 μm device technology was used. The DC measurements of processed devices showed desired values of BVcbo (12 V) and β (80) with a very high yield (>90%). The Gummel plot of an MBE-grown SiGe HBT with common-emitter configuration was drawn in Fig. 2, where the collector-emitter voltage is 5 V. And Fig. 3 is SiGe/Si HBT output characteristics. The measured cutoff frequency, f_T, was 5.1 GHz, which is not high but in an agreement with the simulated value (5.6 GHz) made by Medici for such a large size device without using device isolation. Finally, the development of test amplifiers using the developed SiGe HBT technology is underway. As a matter of fact, the broad-band low-noise amplifier with the certain functions was achieved, and its layout was shown in Fig. 4.

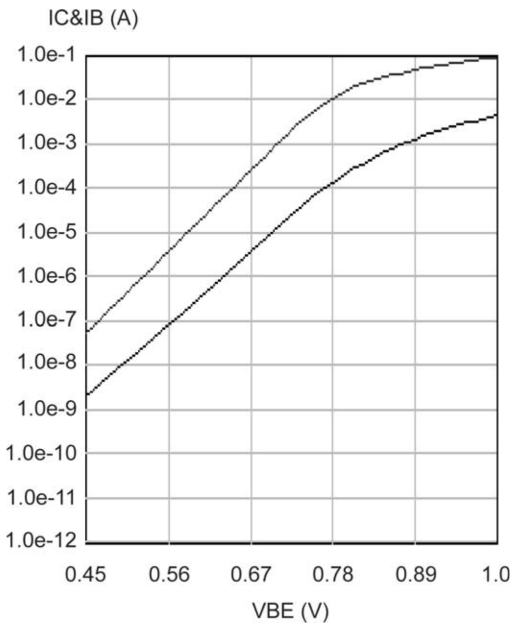

Fig. 2. The Gummel plot of an MBE-grown SiGe HBT with common-emitter configuration.

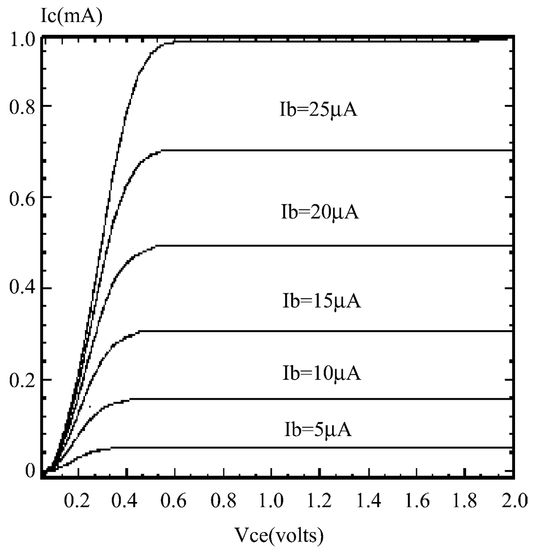

Fig. 3. SiGe/Si HBT output characteristics.

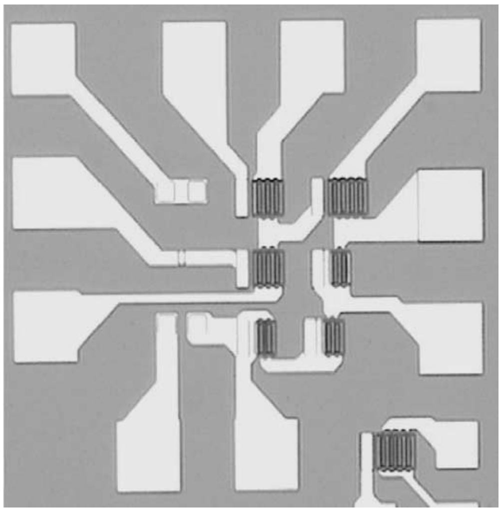

Fig. 4. Broad-band low-noise amplifier layout.

4. Conclusion

Using MBE-based SiGe materials, high-quality HBT devices have been made. Also test SiGe amplifiers have been developed.