Development of a SiGeC Heterojunction Bipolar Transistor for Ultra-high-speed/High-frequency Communication LSIs

- Ultra-high maximum oscillation frequency of 174 GHz -

Tokyo Japan, December 5, 2001 - Hitachi, Ltd. (NYSE:HIT)has developed a prototype SiGeC heterojunction bipolar transistor (HBT) by using selective epitaxial growth of a mixture of silicon (Si), germanium (Ge) and carbon (C), and has achieved the world's fastest device performance; cutoff frequency [1)] of 124 GHz and a maximum oscillation frequency [2)] of 174 GHz. As SiGeC HBT features little change in performance after high temperature processing, it is well suited to application in bipolar CMOS (combination of HBT and CMOS) device technology, which is expected to be the most promising candidate for next generation communication LSIs. The high-speed performance developed is expected to accelerate the application of the bipolar CMOS to transmitter/receivers in ultra-high-speed communication systems.

The demand for large-capacity data transmission in optical and mobile communication systems is increasing with the rapid proliferation of the Internet and cellular phones. Thus, a significant improvement in high-speed performance is being required of LSIs (Large Scale Integrated Circuits) embedded in transmitters and receivers for communication systems. Bipolar CMOS (BiCMOS), a combination of the ultra-high-speed HBT and the mid-to-low speed signal processing CMOS (Complementary Metal-Oxide Semiconductor), is currently considered a viable solution to the above-mentioned requirement, and research is being focused on this device. Although, SiGe HBTs can operate at a high speed alone, a rapid deterioration in performance occurs due to heat-treatment when integrated with the CMOS, resulting in the lower performance than expected. Thus, SiGeC has been receiving much attention as a new material suitable for BiCMOS due to its high tolerance to heat treatment[3)]. Until now, however, it was not possible to fabricate a SiGeC HBT with a self-aligned structure[4)] by using selective epitaxial growth, and thus high-speed performance could not be obtained.

Given this background, Hitachi developed a high-speed SiGeC HBT technology suitable for BiCMOS and achieved the world's fastest performance. The two technology developed are as follows:

(1) **Formation of a SiGeC base using selective epitaxial growth:** A selective epitaxial growth technology to form a SiGeC single crystal only on a Si substrate, by using UHV/CVD (ultra-high-vacuum chemical vapor deposition) method, was developed.
(2) **Self-aligned SiGeC HBT technology:** A self-aligned fabrication process technology using SiGeC selective epitaxial growth was developed, and the active area of the transistor was formed without mask alignment.

As a result, the following performances were achieved:

(1) **Improvement in transistor operating speed:** A self-aligned SiGeC HBT with low parasitic resistance and low parasitic capacitance was fabricated using a high-quality base layer of SiGeC containing 0.4% carbon, and high-speed high-frequency performances of

124-GHz cutoff frequency and 174-GHz maximum oscillation frequency were achieved.

(2) **Achievement of ultra-high-speed circuit performance:** Using these transistors, an ultra-high-speed circuit performance of a 5.7-ps propagation gate delay in a ECL circuit[5)] was obtained.

Using this technology, it will now be possible to integrate high-speed HBT and 0.1 μm CMOS. This ultra-high-speed high-functional device technology is expected to play an important role in supporting next-generation information technology such as multi-media services offered by next-generation backbone transmission systems, large-capacity radio communication systems, and intelligent traffic control systems using millimeter-wave bands.

<Definitions & Explanations of Terms>

(*1) Cutoff frequency: Frequency at which current gain of a transistor becomes unity; that is, the highest frequency that a transistor can amplify current. It is used as a figure of merit for high-speed characteristics in digital circuits.

(*2) Maximum oscillation frequency: Frequency at which the maximum power gain of transistor becomes unity; that is, the highest frequency that a transistor can amplify power. It is used as a figure of merit for high-frequency characteristics in analog circuits.

(*3) High heat-treatment tolerance of SiGeC HBT: Diffusion of the impurity (boron) in the base can be suppressed by adding C to the base layer of the bipolar transistor, and the thickness of the base layer can be reduced even though high-temperature heat treatment is conducted. Therefore, both HBT and scaled-down CMOS can be integrated on the same substrate, and a high-performance LSI realized.

(*4) Self-aligned structure: Fabrication of transistor active regions using only one photo lithography process permits a device design, without the need to consider tolerance of mask alignment. As a result, the extrinsic regions, which increase the parasitic capacitance and parasitic resistance, can be reduced, and device performance (high-speed operation) can be improved.

(*5) ECL circuit: Emitter-coupled logic circuit.

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