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Si/SiGe Power Heterojunction Bipolar Transistors for Ku-Band Applications

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We report the first Si/SiGe power HBT at Ku-Band (12.6GHz) with a maximum output power of 25dBm. The HBT layer structure, physical layout and fabrication technology are optimized to achieve reduced parasitic impedances, high power handling capability and thermal stability. As a result, a unique Si-based technology with Johnson's figure of merit ($f_T \times BV_{CEO}$) in excess of 400GHzV has been realized. The performance characteristics are compatible with those of GaAs HBTs. However, the Si/SiGe devices can be integrated with CMOS circuitry and is expected to significantly reduce the cost of the future wireless systems.

The HBT layer structure is grown at Daimler-Chrysler on a high-resistivity Si substrate (ρ=10kΩ-cm), starting with a 1μm CVD buried layer serving as the sub-collector. The remainder of the heterostructure, as shown in Table 1, is grown in one step by MBE. In this design, a $Si_{0.7}Ge_{0.3}$ base layer with a thickness of 200 Å has been employed to optimize the f_{max} of the device, while a relatively thick Si collector layer (5000 Å 2×10^{16}cm^{-3}) has been designed to achieve high power operation. Effort has been made to design the layout of the device with minimal parasitics. Every three 1.4×20 μm^2 emitter fingers were grouped together, surrounded by base electrodes with 1.5 μm width to form the sub-cell. Multi-finger HBT devices have been designed in both common-emitter and common-base configurations by combining a number of sub-cells. Emitter and base contact pads are isolated from the intrinsic device to achieve higher power gain. The processing technique developed at the University of Michigan consists of a combination of dry and wet-etching steps, thin film metalizations and SiO_2 passivation. This technology has been optimized to produce 1 μm emitter fingers with a high yield. Figure 1 shows the SEM photomicrograph and a three-dimensional schematic of the fabricated device.

Power HBTs with different device geometry were characterized for their DC, small-signal and high power performance. Figure 2 depicts the DC characteristics of a 15 finger 1.4×20 μm^2 HBT device in common-base configurations. Figure 3 shows the results of small-signal S-parameter measurements for the same device. A maximum available gain of 14dB was achieved for this HBT. Finally, these devices were measured for their power performance at Ku-Band (12.6GHz) using a Focus Microwave automatic load-pull system. The peak PAE achieved for the 15 finger 1.4×20 μm^2 HBT in common-base configuration was 23% with an associated power gain of 7.5dB at an output power of 22dBm in class AB amplification (Figure 4). The device delivered a maximum output power of 25dBm under the same bias and matching conditions. In summary, a novel Si/SiGe HBT technology with excellent power performance characteristics, suitable for the RF front-end of the future mobile communication systems, is presented.

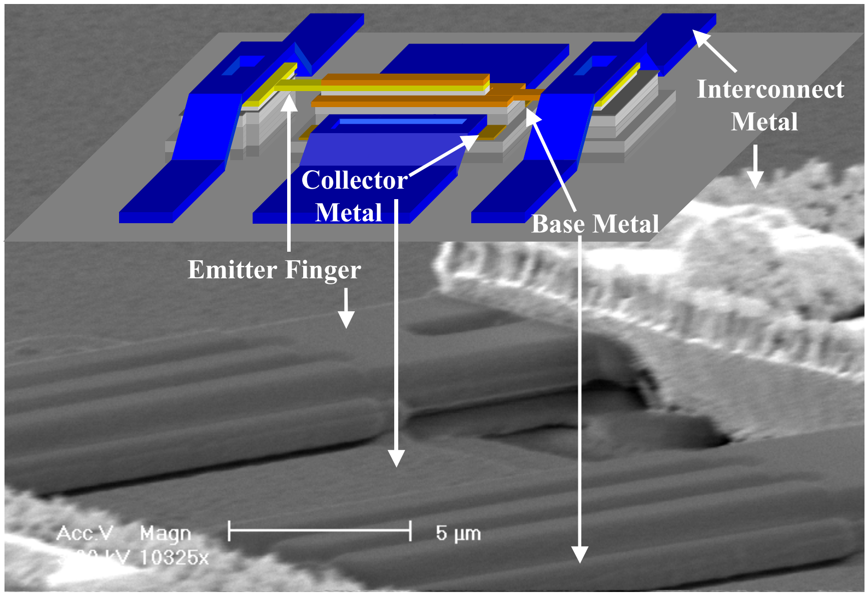

Figure 1: Si/SiGe HBT Technology.

Emitter cap	Si	n+		2×10^{20} cm^{-3}	250 nm
Emitter	Si	n		2×10^{18} cm^{-3}	50 nm
Spacer	$Si_{0.7}Ge_{0.3}$	i			3 nm
Base	$Si_{0.7}Ge_{0.3}$	p+		1×10^{20} cm^{-3}	25 nm
Spacer	$Si_{0.7}Ge_{0.3}$	i			7 nm
Collector	Si	n-		2×10^{16} cm^{-3}	500 nm
Sub-collector	Si (CVD)	n+	As	1×10^{19} cm^{-3}	1000 nm
High-resistivity Substrate					

Table 1: Si/SiGe HBT layer structure.

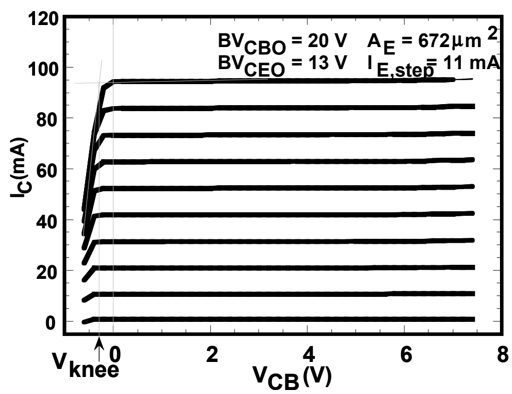

Figure 2: I_C-V_{CB} characteristics of CB 15 finger 1.4×20 µm^2 Si/SiGe HBT.

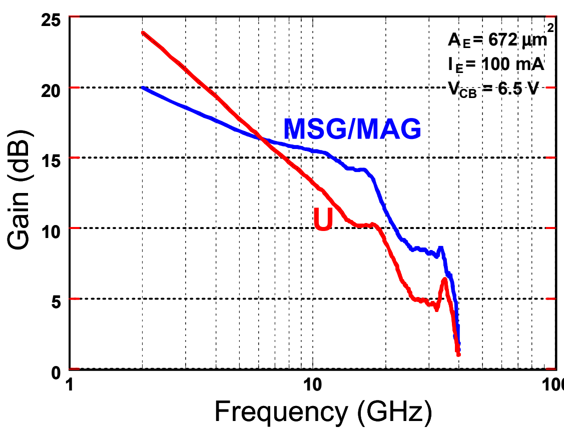

Figure 3: Measured power gains of 15 finger 1.4×20 µm^2 Si/SiGe HBT in common-base configuration.

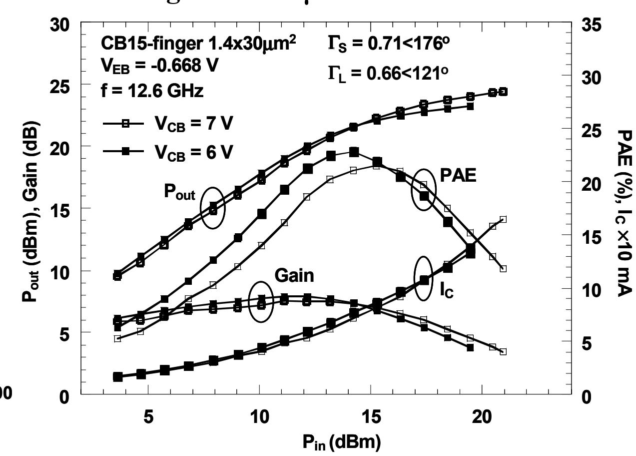

Figure 4: Measured power performance for 15 finger 1.4×20 µm^2 Si/SiGe HBT under class AB amplification.