“SiGe-BiCMOS Technologies with monolithic integrated THz-devices and photonic modules”

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The strategies to increase the functionality of an integrated circuit or system by the integration of new components as an adequate scaling level is well known as the “More-than-Moore” strategy in the semiconductor industry. These “MtM” approaches can be distinguished to monolithic and heterogeneous integration concepts, respectively. The latter one enables in general a high flexibility for the combination of different functionalities as CMOS, MEMS (micro-electro-mechanical systems) or III-V devices. However, a reliable packaging and therefore a sufficient yield can be a major concern for these systems. The monolithic integration of modules and devices with advanced functionality in a baseline CMOS process can overcome this concern. However these integration concepts have to consider issues during the integration of different modules like the interaction of process steps to the performance of the devices.
Here we present different technology platforms with monolithic integrated modules like THz devices, i.e. complementary SiGe heterojunction bipolar transistors and silicon photonics components as waveguides, photo detectors and modulators.

The continuous improvement of SiGe-BiCMOS technologies have proven their demand for instance in the automotive radar market. Mid- and long-range radar systems at 77 GHz can be realized by using HBTs with maximum oscillation frequencies (fmax) of 300 GHz. The power consumption of these systems can be significantly reduced by the use of available SiGe-BiCMOS technologies with fmax of 500 GHz. Addditional new applications as THz circuits for gas spectroscopy and chipsets for sensing and short-range wireless communication have been demonstrated with these technologies. In future novel systems as short-range-radar (SRR) or autonomous cruise control (ACC) at frequencies of 120 and 150GHz can be targeted by the use of next generation SiGe-BiCMOS technologies. In this work we review the continuous progress of high-speed npn-HBTs development starting with a low cost approach by adding only one additional mask to the underlying CMOS-process and HBTS with fT/fmax of 95/75 Ghz to high performance HBT-modules with fT/fmax of 300/500 Ghz. We discuss requirements and challenges for the different parts and design concepts of the HBT-processing.

Beside the progress in the development of high performance SiGe-BiCMOS technologies there is an increasing demand for opto-electronic technologies. In the market of big data processing centers the necessity to handle the steadily growing data volumes increase continuously. Recently IHP introduced the monolithic integration of photonic components as silicon-waveguides, high speed germanium-photo detectors and silicon based mach-zehnder-modulators (MZM) with high speed SiGe-BiCMOS devices in a joint technology. This new electro-photonic-integrated-circuit (EPIC) technology enables new applications as fully

integrated linear 40Gbps receiver or SP-QPSK receiver for 28Gbaud operation. These circuits are among best in class and outperform monolithically Si integrated receivers fabricated elsewhere, e.g. with a Photonics-CMOS platform. However, there are several challenges during the monolithic integration of these photonic components in a SiGe-BiCMOS environment as the realization of a mixed substrate (SOI and bulk) or process optimizations to enable high-performance SiGe-HBTs and high speed Ge-photo detectors on the same wafer.

References:

[1] D. Knoll et al.; "A flexible Low-Cost, High-Performance SiGe:C BiCMOS Process with aone mask HBT module"; IEDM2002
[2] H. Rücker et al.; „Half Terahertz SiGe-BiCMOS Technology"; IEEE SiRF2012
[3] D. Knoll et al.; "High Performance Photonic BiCMOS - A Novel Technology for the Large Bandwidth"; OSA Frontiers in Optics 2014 Era

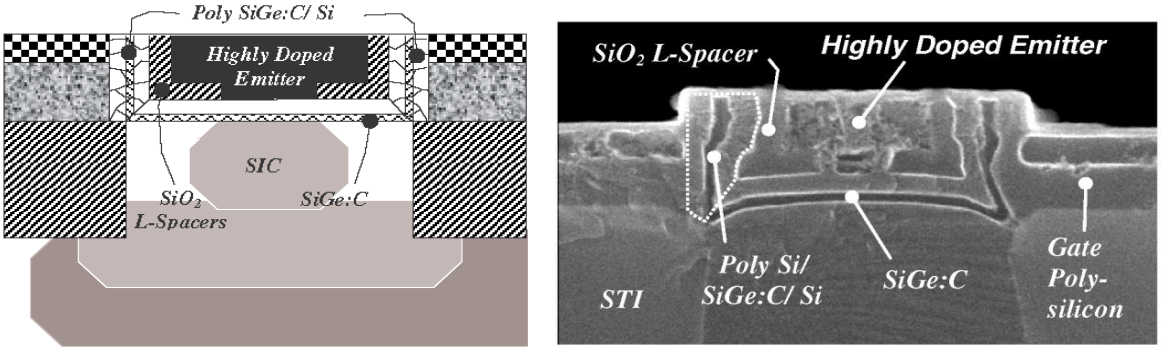

Figure 1: Schematic (left) and silicon processed (right) cross section of a SiGe-HBT realized by only one additional mask to the underlying CMOS process. Peak cutoff-frequencies (fT) and maximum oscillation frequencies (fmax) of 90 and 75 GHz can be achieved at BVCEo of 2.4V [1].

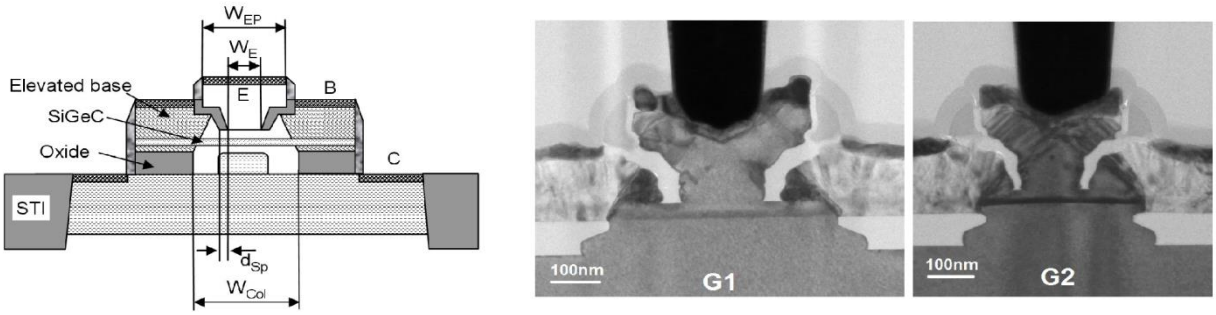

Figure 2: Schematic (left) and silicon processed (right) cross section of two types of high performance SiGe-HBTs featuring devices with peak cutoff-frequencies (fT) and maximum oscillation frequencies (fmax) of 300 and 500 GHz can be achieved at BVCEo of 1.7V. [2]

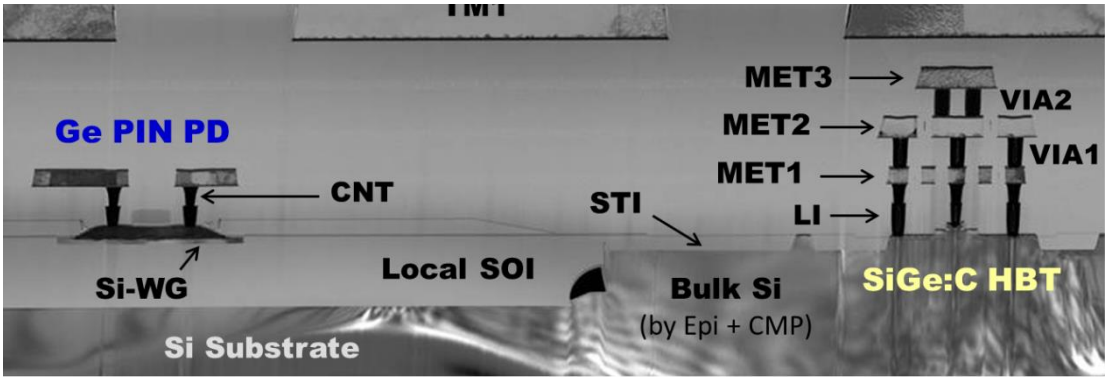

Figure 3: Cross section of photonic SiGe-BiCMOS technology components including Ge-photo detectors (left) and HBT devices (right) with peak cutoff-frequencies (fT) and maximum oscillation frequencies (fmax) of 190 GHz at BVCEo of 1.9V. [3]