SiGe BiCMOS Baseline Technology for More than Moore Functional Diversification

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“More Than Moore” functional diversification by combining different technologies is enlarging the spectrum for embedded system applications. In this paper we focus on the monolithic integration approach of optical components into the front-end-off-line (FEOL) to combine electronics and photonics (Si Photonics), and of MEMS (micro-electro-mechanical systems) into the back-end-off-line (BEOL) of SiGe BiCMOS technologies. Moreover the combination of InP and SiGe BiCMOS in an “on top of chip” wafer level process is discussed targeting on high frequency and making use of the potentially higher output power of the III-V semiconductor. This project is a joint activity with the FBH in Berlin, where the InP processing part is performed.

The SiGe BiCMOS baseline process combines high-speed SiGe HBTs and computing power of CMOS on a single chip with HBTs reaching up to 300/500 GHz f_T/f_{max} and 2.0 ps CML gate delay [1, 2]. The half THz HBTs are available within the 0.13 µm BiCMOS technology SG13G2 of IHP [3] making operating frequencies from 100 GHz up to several hundred GHz accessible for monolithically integrated millimeter-wave systems for high-speed wireless and fiber-optics communications, mm-wave imaging, and radar systems [e.g. 4-7].

Many present developments focus on integrated photonics technologies, in particular on the convergence of silicon IC technology and integrated optics (silicon photonics). A main advantage of using an ultrafast SiGe BiCMOS technology for the integration of optical components is its capability for high speed multilevel optical communication e.g. trans impedance amplifier (TIA) for optical receivers, modulator drivers with high voltage swing, laser drivers, multilevel high-speed drivers for optical modulators. As an example for the fabrication of photonics components, a cross section of a Ge photodiode is shown in Fig. 1. The photodiode was fabricated in a BiCMOS compatible process flow. Photodiodes with very low dark current have been shown [8].

Several concepts have been suggested to integrate MEMS components into semiconductor processes using hybrid and monolithic approaches. The key advantage of the monolithic integration is the potentially lower interconnect loss compared to hybrid integration concepts. Whereas the interconnect loss for hybrid or heterogeneously integrated systems is acceptable for frequencies below 40 GHz, it becomes much more important for frequencies above 60 GHz, limiting the overall system performance. Fully embedded solutions at higher mm-wave frequencies become attractive for applications, such as 60 GHz personal area networks, automotive radars in the 76-81 GHz range, or security radar/imaging at 94 and 140 GHz. Moreover, multi-band/wide-band operation and phased-array antennas for next generation high-frequency systems would be feasible by integrating MEMS modules into SiGe BiCMOS technology. As an example, measured and simulated S parameter results are shown in Fig. 2 for a RF switch integrated in the BEOL of the SiGe BiCMOS process. The insertion loss of the switch in the 1-110 GHz frequency range is below 1.65 dB. The isolation for frequencies between 60 GHz and 100 GHz is better than 15 dB [9].

To demonstrate the capabilities of the SiGe BiCMOS – InP heterointegration scheme different combinations of BiCMOS and InP circuit building blocks were design and fabricated. Fig.3 shows an integrated signal source at 164 GHz as an example [10]. The source consists of a fundamental voltage-controlled oscillator (VCO) in BiCMOS technology which is interconnected by an optimized high frequency via transition to a doubler-amplifier combination in InP technology.

In summary, the paper shows examples of the integration of modules into BiCMOS technologies with fast SiGe HBTs enabling More than Moore functional diversification for cost effective multifunctional systems.

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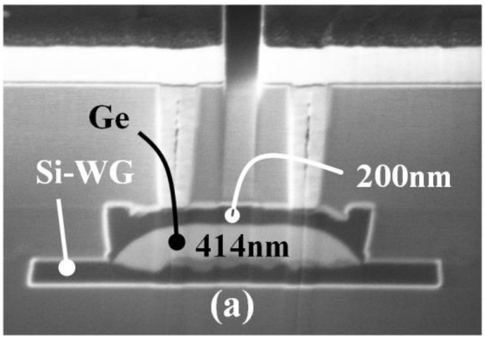

Fig. 1: SEM cross-sections of a Ge photodiode fabricated in a BiCMOS compatible process flow [8].

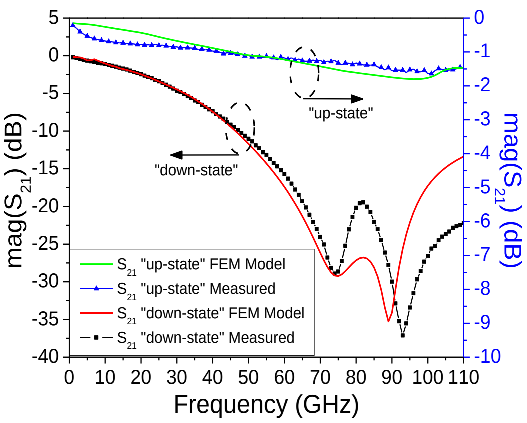

Fig. 2: Measured and simulated S parameter results of the MEMS switch for both “up” and “down” states [9].

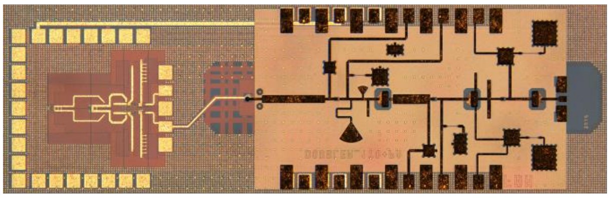

Fig. 3: Chip photo of the heterogeneous integrated signal source at 164 GHz. VCO in BiCMOS and doubler-amplifier combination in InP [10].