SiGe High-Frequency Devices

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After more than 13 years of research the speed race of SiGe HBTs has arrived at 180 GHz f_{max} and 156 GHz f_T. Even in high-volume production now are devices with around 100 GHz. The main reasons are a steadily improving epitaxy with a huge freedom in thickness and composition and the reduction of parasitics.

The main focus in this presentation is put on SiGe HFETs which are still on the research level. In SiGe HFETs the well known principle of III/V HEMTs is transferred to Si microelectronics. High mobilities up to 2900 cm²/Vs for n-channels and up to 3600 cm²/Vs for p-channels have been found, 5 to 15 times above respectively doped Si. In addition there is evidence for an increased velocity overshoot due to strain in the channels.

For Schottky- or MOS-gate devices IBM and DaimlerChrysler have reached transconductances around 300 mS/mm for depletion mode n-HFETs and around 500 mS/mm for enhancement mode. p-HFETs showed around 250 mS/mm. High currents above 600 mA/mm have been obtained for p-MOS HFETs. Cut-off frequencies for both n- and p-HFETs are for f_{max} up to 135 GHz and for f_T around 80 GHz, which have been achieved for n-HFETs already with a gate length of 0.25 µm, for p-HFETs with 0.1µm. Recently the performance at cryo-operation was investigated. 195 GHz was measured for n-HFETs at 50K, 180 GHz for p-HFETs at 35K. Such a pronounced frequency increase is related to the 2-dimensional electron or hole transport in the Si or Ge channels, respectively.

There is a gate length dependence visible for all frequency data reported so far, but the range below 0.2 µm is hardly exploited. Better self-aligned layouts are demanded. Simulations forecast frequencies above 200 GHz at RT assuming reduced parasitics.

Concerning noise, n- and p-type HFETs exhibit the very low noise figures of 0.3 dB at 1 – 2.5 GHz. Conservative semi-quantitative simulations for the high-frequency noise predict 0.5 dB at 10 GHz. Siemens has established outstanding low-frequency noise represented by corner frequencies below 200 Hz for p-SiGe MOSFETs.

First test circuits elucidate the potential of this novel device category. E.g., inverter delays are 22 ps for a 0.25 µm HFET, transimpedance amplifiers operate with a transimpedance above 50 dBΩ and up to a bandwidth of 2 GHz. If finally a new CMOS generation can be created, consisting of a Si-channel n-HFET and a Ge-channel p-HFET, the power-delay product can even reach values below 1fJ.