Towards 0.5 TeraHertz Silicon/Germanium Heterojunction bipolar technology

DOTFIVE is an FP7 project addressing the area of "More than Moore" technologies targeting heterogeneous Systems-on-Chip (SoC) solutions for the Information Society Technologies.

At A Glance: DOTFIVE

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Project Coordinator

Gilles Thomas
ST Microelectronics
Tel: 33 4 38 92 27 91
Fax: 33 4 76 08 98 25
Email: gilles.thomas@st.com
Project website: http://www.dotfive.eu

Partners:

STMicroelectronics SA (ST SA), STMicroelectronics SAS (ST SAS), Infineon Technologies AG (IFX), Interuniversitair Micro-Elektronica Centrum vzw (IMEC), Innovation for High Performance Microelectronics (IHP), Institut Polytechnique Bordeaux (IPB), Technische Universitat Dresden (TUD), University of Siegen (UoS), Johannes Kepler University of Linz (JKU), Bundeswehr University Munchen (BU), Università di Napoli (UoN), Université Paris-Sud (UPS), XMOD technologies (XMOD), Alma Consulting Group (ALMA), GWT-TUD Gmbh (GWT), University of Wuppertal (UoW)

Duration: *01.2008 – 07.2011*

Funding scheme: *IP*

Total Cost: *€ 14 081 873*

EC Contribution: *€ 9 699 969*

Contract Number: INFSO-ICT-216110

Main Objectives

The main objective of the DOTFIVE project is to demonstrate the realization of SiGe Heterojunction Bipolar Transistors (HBTs) operating at a maximum frequency close to 0.5 THz (500 GHz) at room temperature, and evaluate the achievable performance of integrated mmWave circuits using those HBTs.

At project start such performance was only possible with very expensive III-V technologies, making it difficult to integrate circuits for large volume consumer applications.

Initiated with existing 200GHz technology background the DOTFIVE consortium embarked on a 3 years ambitious project focused on advanced RTD activities necessary to move the Silicon/Germanium Heterojunction Bipolar Transistor (HBT) into the operating frequency range of 500 GHz.

The project will enable the future development of communications, imaging or radar Integrated Circuits (IC) working at frequencies up to 160 GHz. For a given lithography node bipolar transistors and more recently HBTs have always led the frequency race compared to MOS devices, while offering higher power density and better analogue performances (transconductance, noise, transistor matching).

Si/Ge (HBT) operating in frequency range of 500(GHz) for circuit operation at 160GHz

One objective of this highly qualified consortium is to establish a leadership position for the European semiconductor industry in the area of millimeter wave (mmW) by research and development work on silicon based transistor devices and circuit design capabilities and know-how.

In order to reach these ambitious objectives the consortium consists of 15 partners from industry and academia in 5 European countries (Austria, Belgium, France, Germany and Italy).

Technical Approach

WP1: "physics-based predictive modeling" using Technology Computer Aided Design (TCAD) tools, which allow the simulation of processing steps and electrical characteristics of devices.
WP2: "evolutionary SiGe HBT technology". In WP2 the improvements of the performance of this technology, such as 500 GHz max. oscillation frequency and 2.5 ps gate delay will be done. In 3 years 3 successive incremental improvements are targeted.
WP3: "advanced and novel SiGe HBT process modules and architectures". Next to the evolutionary scaling of self-aligned selective epitaxial base HBTs in WP2, advanced and possibly revolutionary process modules are further developed and characterized in WP3.
WP4: "compact modeling and device characterization", it means setting up the methodology to accurately characterize transistors and to provide models that are valid and usable for circuit design all the way to 500 GHz.
WP5: "application and technology benchmarking" will provide, at each learning cycle, feedback to technology through benchmarking and verifiable prototyping of critical RF functional blocks.

WP6 is dedicated to "RF circuit and technology training" for the European scientific community, while **WP7** is related to the management.

Key Issues/Challenges

The consortium faced many challenges in its endeavour to double the SiGe HBT during the 3 year period. Challenges ranged from understanding fundamental limitations, upgrade of models to incorporate atomic level physical effect, develop new parameter extraction methods, define a unified set of test structures, devise novel all self aligned HBT architecture, and innovate in design solutions.

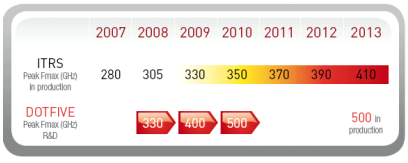


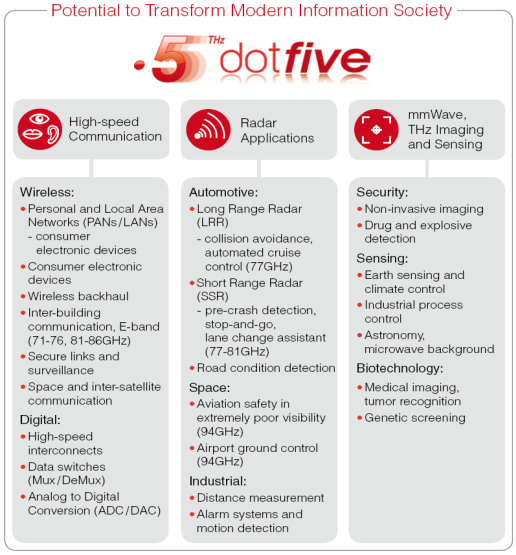
Figure 1: Comparison between International Technology roadmap for Semiconductors and DOTFIVE roadmap.

After 3 years, all technology providers reached Fmax=400GHz 2.5ps CML gate delay; one reached 500GHz 2.0ps CML gate delay (IEDM 2010 paper). World first were achieved for circuit blocks in the range of 160 to 220GHz. A successful innovative design at 820GHz where circuits operate their transistors sub-harmonically and expand their application beyond their cut-off frequency was demonstrated.

Expected Impact

DOTFIVE will strengthen the European semiconductor industry in the area of SiGe heterojunction bipolar transistors technology, particularly for millimetre-wave applications, a field in which both STMicroelectronics and Infineon Technologies are key players. With this project, Europe will be getting ahead of the ITRS roadmap. The new transistors developed by DOTFIVE will be used for designing circuits enabling new millimetre-wave applications such as automotive radars (77 GHz) or WLAN communications systems (60 GHz – Wireless Local Area Network).

DOTFIVE technology sets out to be a key enabler for silicon based millimetre wave circuits with applications in the security, medical and scientific areas. A higher operating speed can open up new application areas at very high frequencies, or can be traded in for lower power dissipation, or can help to reduce the impact of process, voltage and temperature variations at lower frequencies for better circuit reliability.



Awards

Designers and technologists of STMicroelectronics and University of Wuppertal were awarded the 40th EuMC Microwave Prize, in Paris (September 2010), for the best contributed paper to the European Microwave Conference. Paper by E. Öjefors, F. Pourchon, P. Chevalier, and U.R. Pfeiffer, for their work "A 160-GHz Low-Noise Downconverter in a SiGe HBT Technology".