SiGe HBT in Mixed-Mode Device and Circuit Simulation

V. Palankovski, T. Grasser, and S. Selberherr

Institute for Microelectronics, TU Vienna
Gusshausstrasse 27–29, A-1040 Vienna, Austria
Phone: +43/1/58801-3851, Fax: +43/1/5059224
E-Mail: palankovski@iue.tuwien.ac.at

Abstract

We present simulation results for SiGe Heterojunction Bipolar Transistor (HBT), obtained with a hydrodynamic (HD) mixed-mode analysis of a Colpitts oscillator using MINIMOS-NT.

Introduction

Recently the development of heterostructure devices has proceeded with very rapid steps. Analyses of HBTs are of great importance for studying the device characteristics and are prerequisite for further improvements. Accurate simulation of HBT circuits must account for non-local effects and therefore requires hydrodynamic mixed-mode simulation.

Models in MINIMOS-NT

MINIMOS-NT is our two-dimensional device simulator with approved capabilities of simulating devices with complex structure [1]. Splitting the device geometry into segments results in high flexibility which allows, for example, to use a HD model on one segment and a drift diffusion (DD) model on another segment.

For accurate simulation of HBTs for various compound materials the respective temperature and mole fraction dependent models of the physical parameters (e.g. conduction and valence band-edge energies, electron and hole effective masses, effective density of states) on one hand, and of the mobilities on the other hand, were implemented.

The correct modeling of the conduction and valence band-edge energies has basic importance for the simulation results. Band gap narrowing is one of the crucial heavy-doping effects to be considered for bipolar devices. Using the physically-based approach from [2], we implemented a new band gap narrowing model which considers the semiconductor material and the dopant species for arbitrary finite temperatures, and therefore contributes to different changes in the conduction and the valence band-edge energies, respectively. As a particular example we present in Fig. 1 the results for P-doped Si at different temperatures. Note the stronger band gap narrowing at 77K, caused by higher degeneracy. Neglecting of this effect results in an error of about 50%.

As the minority carrier mobility is of considerable importance for modeling advanced n-p-n bipolar transistors, we implemented a new universal low field mobility model [2]. This model distinguishes between majority and minority electron mobilities on one hand, and between different dopant species on the other hand, both as a function of temperature and dopant concentration. This unified treatment is especially useful for accurate device simulation.

The models for the effective density of states take into account a material composition dependent electron and hole effective masses. The effect of valley degeneracy is taken into account for the strained layers.

Results and Conclusion

As a particular example, we simulated a Colpitts oscillator in common emitter configuration. In Fig. 2 we present the output result obtained after transient simulation using a hydrodynamic transport model. Fig. 3 shows the diagram of the oscillator. The SiGe HBT structure used is shown in Fig. 4 where the electron temperature inside the device is presented. The complexity of the HBT structure leaves ample room for a material dependent performance optimization. Thus, a discussion of constraints is required in order to project performance superiority with respect to certain applications of a particular HBT structure.

Acknowledgment

This work is supported by Siemens AG, Munich, Germany.

References

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[2] G. Kaiblinger-Grujin, H. Kosina, and S. Selberherr. Influence of the Doping Element on the Electron Mobility in *n*-Silicon. *J.Appl.Phys.*, 15(3), 1998.

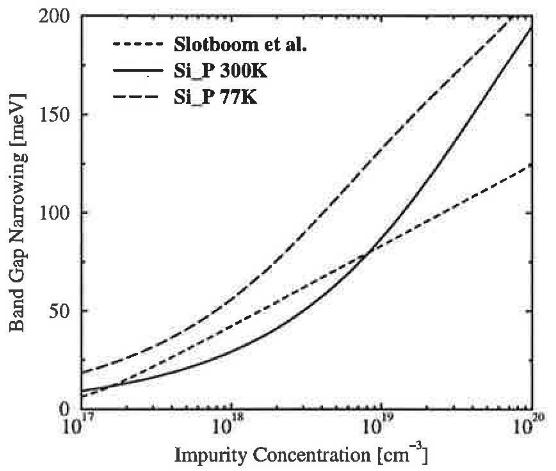

Figure 1: Band gap narrowing versus impurity concentration

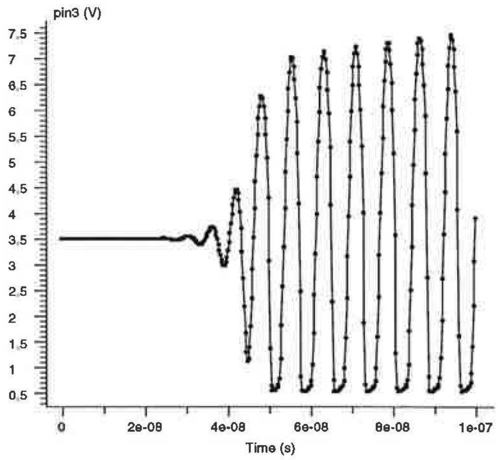

Figure 2: Output voltage versus time

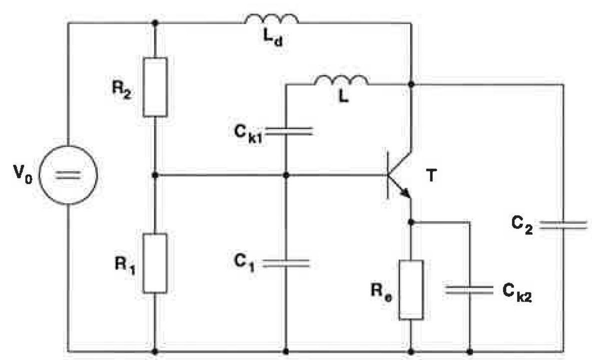

Figure 3: Circuit diagram of a Colpitts oscillator

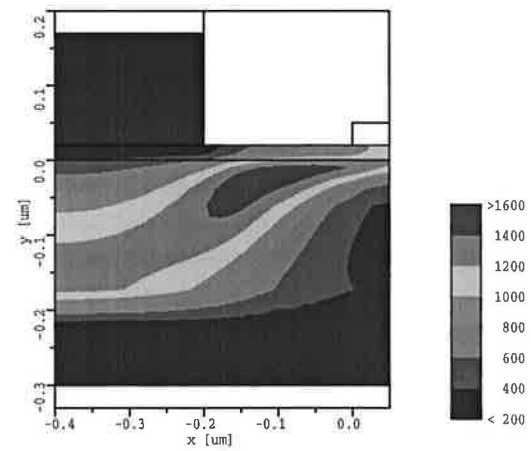

Figure 4: Electron temperature in the device