Numerical Analysis of Compound Semiconductor RF Devices

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Abstract

An overview of heterostructure RF device simulation for industrial application based on III-V compound semiconductors has been given in [1]. Here, we present the most recent achievements in numerical simulation for industrial heterostructure devices, together with relevant industrial applications (GaAs, InP, and SiGe HBTs).

INTRODUCTION

To cope with explosive development costs and strong competition in the semiconductor industry today, Technology Computer-Aided Design (TCAD) methodologies are extensively used in development and production. Several questions during device fabrication, such as performance optimization and process control, can be addressed by simulation. The choice of a given simulation tool or a combination of tools depends to a large extent on the complexity of the particular task, on the desired accuracy of the problem solution, and on the available human, computer, and time resources.

Optimization of geometry, doping, materials, and material compositions targets high output power, high breakdown voltage, high speed (high f_T and f_{max}), low leakage, low noise, and low power consumption. This is a challenging task that can be significantly supported by device simulation. While DC simulation is sufficient for optimization of breakdown voltages, turn-on voltages, or leakage currents, AC simulation is required for speed, noise, and power issues.

There are several challenges which are specific for modeling and simulation of heterostructure devices [2]. The characterization of the physical properties of III-V and SiGe compounds is required for wide ranges of material compositions, temperatures, doping concentrations, etc. The model parameters must be verified against several independent HEMT and HBT technologies to obtain a concise set used for all simulations.

For example, the database for novel materials, such as the GaN or the GaSb systems, which have entered the III-V world with impressive device results, is still relatively poor. Modeling of stress-induced changes of the physical properties of strained material layers and consideration of piezoelectrical effects is a subject of ongoing research [2]. Heterointerface modeling is a key issue for devices which include abrupt junctions. Thermionic emission, field emission, and tunneling effects critically determine the current transport, especially in double heterojunction bipolar transistors (DHBTs).

Advanced device simulation allows a precise physics-based extraction of small-signal parameters [2]. Measured bias-dependent S-parameters serve as a valuable source of information when compared at different bias points to simulated S-parameters from a device simulator. By simulating in the frequency domain, important small-signal figures of merit, such as the cut-off frequency f_T and the maximum oscillation frequency f_{max} can be efficiently extracted [3]. On the other hand, non-linear periodic steady-state analysis can be performed in the time domain to obtain large-signal figure-of-merit parameters, such as distortion, power, frequency, noise, etc. [4] as well in the context of coupled device and circuit simulation.

HETEROSTRUCTURE DEVICE SIMULATORS

The continuously increasing computational power of computer systems allows the use of TCAD tools on a very large scale. Several commercial device simulators (such as [5]-[10]) company-developed simulators (such as [11]-[13]), and university-developed simulators (like [14]-[19]) have been successfully employed for device engineering applications. These simulators differ considerably in dimensionality (one, quasi-two, two, quasi-three, or three), in choice of carrier transport model (drift-diffusion, energy-transport, or Monte Carlo statistical solution of the Boltzmann transport equation), and in the capability of including electrothermal effects. The drift-diffusion transport model [20] is by now the most popular model used for device simulation. With down-scaling of the feature sizes, non-local effects become more pronounced and must be accounted for by applying an energy-transport model or a hydrodynamic transport model [21]. During the last two decades, Monte Carlo methods for solving the Boltzmann transport equation have been developed [22] and applied for device simulation [23, 24]. However, reduction of computational resources is still an issue, and therefore Monte Carlo device simulation is still not feasible for industrial application on daily basis. An approach to preserve accuracy at lower computational cost is to calibrate lower order transport parameters to Monte Carlo simulation data.

Numerical Analysis For Semiconductor Devices

Pascal Swei Lin Chen

Numerical Analysis For Semiconductor Devices:

Numerical Analysis for Semiconductor Devices Mamoru Kurata,1982 *Analysis and Simulation of Semiconductor Devices* S. Selberherr,1984-07 The invention of semiconductor devices is a fairly recent one considering classical time scales in human life The bipolar transistor was announced in 1947 and the MOS transistor in a practically usable manner was demonstrated in 1960 From these beginnings the semiconductor device field has grown rapidly The first integrated circuits which contained just a few devices became commercially available in the early 1960s Immediately thereafter an evolution has taken place so that today less than 25 years later the manufacture of integrated circuits with over 400 000 devices per single chip is possible Coincident with the growth in semiconductor device development the literature concerning semiconductor device and technology issues has literally exploded In the last decade about 50 000 papers have been published on these subjects The advent of so called Very Large Scale Integration VLSI has certainly revealed the need for a better understanding of basic device behavior The miniaturization of the single transistor which is the major prerequisite for VLSI nearly led to a breakdown of the classical models of semiconductor devices **Numerical Simulation of Submicron Semiconductor Devices** Kazutaka Tomizawa,1993-01-01 Describes the basic theory of carrier transport develops numerical algorithms used for transport problems or device simulations and presents real world examples of implementation

Numerical Analysis of Semiconductor Devices Pascal Swei Lin Chen,1982 *Numerical Analysis of Semiconductor Devices and Integrated Circuits* B. T. Browne,John James Henry Miller,1981 **Noise in Semiconductor Devices** Fabrizio Bonani,Giovanni Ghione,2013-03-09 The design and optimization of electronic systems often requires appraisal an of the electrical noise generated by active devices and at a technological level the ability to properly design active elements in order to minimize when possible their noise Examples of critical applications are of course receiver front ends in RF and optoelectronic transmission systems but also front end stages in sensors and in a completely different context nonlinear circuits such as oscillators mixers and frequency multipliers The rapid de velopment of silicon RF applications has recently fostered the interest toward low noise silicon devices for the lower microwave band such as low noise MOS transistors at the same time the RF and microwave ranges are be coming increasingly important in fast optical communication systems Thus high frequency noise modeling and simulation of both silicon and compound semiconductor based bipolar and field effect transistors can be considered as an important and timely topic This does not exclude of course low frequency noise which is relevant also in the RF and microwave ranges when ever it is up converted within a nonlinear system either autonomous as an oscillator or non autonomous as a mixer or frequency multiplier The aim of the present book is to provide a thorough introduction to the physics based numerical modeling of semiconductor devices operating both in small signal and in large signal conditions In the latter instance only the non autonomous case was considered and thus the present treatment does not directly extend to oscillators An Introduction to the Numerical Analysis of Semiconductor Devices and Integrated

Circuits John James Henry Miller,1981 Companion volume to NASECODE II Conference proceedings *The Stationary Semiconductor Device Equations* P.A. Markowich,2013-03-09 In the last two decades semiconductor device simulation has become a research area which thrives on a cooperation of physicists electrical engineers and mathe maticians In this book the static semiconductor device problem is presented and analysed from an applied mathematician s point of view I shall derive the device equations as obtained for the first time by Van Roosbroeck in 1950 from physical principles present a mathematical analysis discuss their numerical solu tion by discretisation techniques and report on selected device simulation runs To me personally the most fascinating aspect of mathematical device analysis is that an interplay of abstract mathematics perturbation theory numerical analysis and device physics is prompting the design and development of new technology I very much hope to convey to the reader the importance of applied mathematics for technological progress Each chapter of this book is designed to be as selfcontained as possible however the mathematical analysis of the device problem requires tools which cannot be presented completely here Those readers who are not interested in the mathemati cal methodology and rigor can extract the desired information by simply ignoring details and proofs of theorems Also at the beginning of each chapter I refer to textbooks which introduce the interested reader to the required mathematical concepts

Numerical Analysis of Semiconductor Devices John Gary Shaw,2014 **NASECODE** ,1985 Numerical Analysis of Semiconductor Devices and Integrated Circuits J. J. H. Miller,1983 **Simulation of Semiconductor Devices and Processes** Siegfried Selberherr,Hannes Stippel,Ernst Strasser,2012-12-06 The Fifth International Conference on Simulation of Semiconductor Devices and Processes SISDEP 93 continues a series of conferences which was initiated in 1984 by K Board and D R J Owen at the University College of Wales Swansea where it took place a second time in 1986 Its organization was succeeded by G Baccarani and M Rudan at the University of Bologna in 1988 and W Fichtner and D Aemmer at the Federal Institute of Technology in Zurich in 1991 This year the conference is held at the Technical University of Vienna Austria September 7 9 1993 This conference shall provide an international forum for the presentation of out standing research and development results in the area of numerical process and de vice simulation The miniaturization of today s semiconductor devices the usage of new materials and advanced process steps in the development of new semiconduc tor technologies suggests the design of new computer programs This trend towards more complex structures and increasingly sophisticated processes demands advanced simulators such as fully three dimensional tools for almost arbitrarily complicated geometries With the increasing need for better models and improved understand ing of physical effects the Conference on Simulation of Semiconductor Devices and Processes brings together the simulation community and the process and device en gineers who need reliable numerical simulation tools for characterization prediction and development *Mathematical Modelling and Simulation of Electrical Circuits and Semiconductor Devices* Randolph E. Bank,1994 Progress in today s high technology industries is strongly associated with the development of new mathematical tools A typical illustration of this partnership is the mathematical modelling and numerical simulation of electric circuits and semiconductor devices At the second Oberwolfach conference devoted to this important and timely field scientists from around the world mainly applied mathematicians and electrical engineers from industry and universities presented their new results Their contributions forming the body of this work cover electric circuit simulation device simulation and process simulation Discussions on experiences with standard software packages and improvements of such packages are included In the semiconductor area special lectures were given on new modelling approaches numerical techniques and existence and uniqueness results In this connection mention is made for example of mixed finite element methods an extension of the Baliga Patankar technique for a three dimensional simulation and the connection between semiconductor equations and the Boltzmann equations

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Numerical Analysis of Semiconductor Devices NASECODE Conference (1, 1979, Dublin),1981 *Numerical analysis of semiconductor devices. Proceedings of the NASECODE Conference ; 7* ,1991

Unveiling the Power of Verbal Artistry: An Emotional Sojourn through **Numerical Analysis For Semiconductor Devices**

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