

Dragica Vasileska
Stephen M. Goodnick *Editors*

Nano-Electronic Devices

Semiclassical and Quantum
Transport Modeling

 Springer

Nano Electronic Devices Semiclassical And Quantum Transport Modeling

**Esteban Tlelo-Cuautle, Sheldon X.-D.
Tan**



Nano Electronic Devices Semiclassical And Quantum Transport Modeling:

Nano-Electronic Devices Dragica Vasileska, Stephen M. Goodnick, 2011-06-10 This book surveys the advanced simulation methods needed for proper modeling of state of the art nanoscale devices It systematically describes theoretical approaches and the numerical solutions that are used in explaining the operation of both power devices as well as nano scale devices It clearly explains for what types of devices a particular method is suitable which is the most critical point that a researcher faces and has to decide upon when modeling semiconductor devices **Modeling Self-Heating Effects in**

Nanoscale Devices Katerina Raleva, Abdul Rawoof Sheik, Dragica Vasileska, Stephen M. Goodnick, 2017-09-13 It is generally acknowledged that modeling and simulation are preferred alternatives to trial and error approaches to semiconductor fabrication in the present environment where the cost of process runs and associated mask sets is increasing exponentially with successive technology nodes Hence accurate physical device simulation tools are essential to accurately predict device and circuit performance Accurate thermal modelling and the design of microelectronic devices and thin film structures at the micro and nanoscales poses a challenge to electrical engineers who are less familiar with the basic concepts and ideas in sub continuum heat transport This book aims to bridge that gap Efficient heat removal methods are necessary to increase device performance and device reliability The authors provide readers with a combination of nanoscale experimental techniques and accurate modelling methods that must be employed in order to determine a device s temperature profile **Advanced**

Physics of Electron Transport in Semiconductors and Nanostructures Massimo V. Fischetti, William G. Vandenberghe, 2016-05-20 This textbook is aimed at second year graduate students in Physics Electrical Engineering or Materials Science It presents a rigorous introduction to electronic transport in solids especially at the nanometer scale Understanding electronic transport in solids requires some basic knowledge of Hamiltonian Classical Mechanics Quantum Mechanics Condensed Matter Theory and Statistical Mechanics Hence this book discusses those sub topics which are required to deal with electronic transport in a single self contained course This will be useful for students who intend to work in academia or the nano micro electronics industry Further topics covered include the theory of energy bands in crystals of second quantization and elementary excitations in solids of the dielectric properties of semiconductors with an emphasis on dielectric screening and coupled interfacial modes of electron scattering with phonons plasmons electrons and photons of the derivation of transport equations in semiconductors and semiconductor nanostructures somewhat at the quantum level but mainly at the semi classical level The text presents examples relevant to current research thus not only about Si but also about III V compound semiconductors nanowires graphene and graphene nanoribbons In particular the text gives major emphasis to plane wave methods applied to the electronic structure of solids both DFT and empirical pseudopotentials always paying attention to their effects on electronic transport and its numerical treatment The core of the text is electronic transport with ample discussions of the transport equations derived both in the quantum picture the Liouville von Neumann

equation and semi classically the Boltzmann transport equation BTE An advanced chapter Chapter 18 is strictly related to the tricky transition from the time reversible Liouville von Neumann equation to the time irreversible Green s functions to the density matrix formalism and classically to the Boltzmann transport equation Finally several methods for solving the BTE are also reviewed including the method of moments iterative methods direct matrix inversion Cellular Automata and Monte Carlo Four appendices complete the text *Nanoelectronic Device Applications Handbook* James E. Morris,Krzysztof

Iniewski,2017-11-22 *Nanoelectronic Device Applications Handbook* gives a comprehensive snapshot of the state of the art in nanodevices for nanoelectronics applications Combining breadth and depth the book includes 68 chapters on topics that range from nano scaled complementary metal oxide semiconductor CMOS devices through recent developments in nano capacitors and AlGaAs GaAs devices The contributors are world renowned experts from academia and industry from around the globe The handbook explores current research into potentially disruptive technologies for a post CMOS world These include Nanoscale advances in current MOSFET CMOS technology Nano capacitors for applications such as electronics packaging and humidity sensors Single electron transistors and other electron tunneling devices Quantum cellular automata and nanomagnetic logic Memristors as switching devices and for memory Graphene preparation properties and devices Carbon nanotubes CNTs both single CNT and random network Other CNT applications such as terahertz sensors interconnects and capacitors Nano system architectures for reliability Nanowire device fabrication and applications Nanowire transistors Nanodevices for spintronics The book closes with a call for a new generation of simulation tools to handle nanoscale mechanisms in realistic nanodevice geometries This timely handbook offers a wealth of insights into the application of nanoelectronics It is an invaluable reference and source of ideas for anyone working in the rapidly expanding field of nanoelectronics Simulation of Transport in Nanodevices François Triozon,Philippe Dollfus,2016-11-22

Linear current voltage pattern has been and continues to be the basis for characterizing evaluating performance and designing integrated circuits but is shown not to hold its supremacy as channel lengths are being scaled down In a nanoscale circuit with reduced dimensionality in one or more of the three Cartesian directions quantum effects transform the carrier statistics In the high electric field the collision free ballistic transport is predicted while in low electric field the transport remains predominantly scattering limited In a micro nano circuit even a low logic voltage of 1 V is above the critical voltage triggering nonohmic behavior that results in ballistic current saturation A quantum emission may lower this ballistic velocity

The Wigner Monte Carlo Method for Nanoelectronic Devices Damien Querlioz,Philippe Dollfus,2013-03-01 The emergence of nanoelectronics has led us to renew the concepts of transport theory used in semiconductor device physics and the engineering community It has become crucial to question the traditional semi classical view of charge carrier transport and to adequately take into account the wave like nature of electrons by considering not only their coherent evolution but also the out of equilibrium states and the scattering effects This book gives an overview of the quantum transport approaches

for nanodevices and focuses on the Wigner formalism. It details the implementation of a particle based Monte Carlo solution of the Wigner transport equation and how the technique is applied to typical devices exhibiting quantum phenomena such as the resonant tunnelling diode, the ultra short silicon MOSFET and the carbon nanotube transistor. In the final part, decoherence theory is used to explain the emergence of the semi classical transport in nanodevices.

Conductive Atomic Force Microscopy Mario Lanza, 2017-08-03. The first book to summarize the applications of CAFM as the most important method in the study of electronic properties of materials and devices at the nanoscale. To provide a global perspective, the chapters are written by leading researchers and application scientists from all over the world and cover novel strategies, configurations and setups where new information will be obtained with the help of CAFM. With its substantial content and logical structure, this is a valuable reference for researchers working with CAFM or planning to use it in their own fields of research.

Progress in Industrial Mathematics at ECMI 2014 Giovanni Russo, Vincenzo Capasso, Giuseppe Nicosia, Vittorio Romano, 2017-09-04. This book presents a collection of papers emphasizing applications of mathematical models and methods to real world problems of relevance for industry, life science, environment, finance and so on. The biannual Conference of ECMI, the European Consortium of Mathematics in Industry, held in 2014, focused on various aspects of industrial and applied mathematics. The five main topics addressed at the conference were: mathematical models in life science, material science and semiconductors; mathematical methods in the environment; design automation and industrial applications; and computational finance. Several other topics have been treated, such as, among others, optimization and inverse problems, education, numerical methods for stiff PDEs, model reduction, imaging, processing, multi physics simulation, mathematical models in textile industry. The conference, which brought together applied mathematicians and experts from industry, provided a unique opportunity to exchange ideas, problems and methodologies, bridging the gap between mathematics and industry and contributing to the advancement of science and technology. The conference has included a presentation of EU Maths In European Network of Mathematics for Industry and Innovation, a recent joint initiative of ECMI and EMS. The proceedings from this conference represent a snapshot of the current activity in industrial mathematics in Europe and are highly relevant to anybody interested in the latest applications of mathematics to industrial problems.

Stochastic Approaches to Electron Transport in Micro- and Nanostructures Mihail Nedjalkov, Ivan Dimov, Siegfried Selberherr, 2021-04-05. The book serves as a synergistic link between the development of mathematical models and the emergence of stochastic Monte Carlo methods applied for the simulation of current transport in electronic devices. Regarding the models, the historical evolution path, beginning from the classical charge carrier transport models for microelectronics to current quantum based nanoelectronics, is explictively followed. Accordingly, the solution methods are elucidated from the early phenomenological single particle algorithms applicable for stationary homogeneous physical conditions up to the complex algorithms required for quantum transport based on particle generation and annihilation. The book fills the gap between monographs focusing on the development of the

theory and the physical aspects of models their application and their solution methods and monographs dealing with the purely theoretical approaches for finding stochastic solutions of Fredholm integral equations

Formulation and Numerical Solution of Quantum Control Problems Alfio Borzi, Gabriele Ciaramella, Martin Sprengel, 2017-07-06 This book provides an introduction to representative nonrelativistic quantum control problems and their theoretical analysis and solution via modern computational techniques The quantum theory framework is based on the Schrödinger picture and the optimization theory which focuses on functional spaces is based on the Lagrange formalism The computational techniques represent recent developments that have resulted from combining modern numerical techniques for quantum evolutionary equations with sophisticated optimization schemes Both finite and infinite dimensional models are discussed including the three level Lambda system arising in quantum optics multispin systems in NMR a charged particle in a well potential Bose Einstein condensates multiparticle spin systems and multiparticle models in the time dependent density functional framework This self contained book covers the formulation analysis and numerical solution of quantum control problems and bridges scientific computing optimal control and exact controllability optimization with differential models and the sciences and engineering that require quantum control methods

Computer Aided Design Of Micro- And Nanoelectronic Devices Chinmay Kumar Maiti, 2016-10-27 Micro and nanoelectronic devices are the prime movers for electronics which is essential for the current information age This unique monograph identifies the key stages of advanced device design and integration in semiconductor manufacturing It brings into one resource a comprehensive device design using simulation The book presents state of the art semiconductor device design using the latest TCAD tools Professionals researchers academics and graduate students in electrical electronic engineering and microelectronics will benefit from this reference text

Nuclear Electronics with Quantum Cryogenic Detectors Vladimir Polushkin, 2022-08-02 NUCLEAR ELECTRONICS WITH QUANTUM CRYOGENIC DETECTORS An ideal comprehensive reference on quantum cryogenic detector instrumentation for the semiconductor and nuclear electronics industries Quantum nuclear electronics is an important scientific and technological field that overviews the development of the most advanced analytical instrumentation This instrumentation covers a broad range of applications such as astrophysics fundamental nuclear research facilities chemical nano spectroscopy laboratories remote sensing security systems forensic investigations and more In the years since the first edition of this popular resource the discipline has developed from demonstrating the unprecedented energy resolving power of individual devices to building large frame cameras with hundreds of thousands of pixel arrays capable of measuring and processing massive information flow Building upon its first edition the second edition of Nuclear Electronics with Quantum Cryogenic Detectors reflects the latest advances by focusing on novel microwave kinetic inductance detection devices MKIDs the microwave superconducting quantum interferometers MSQUIDS extending by orders of magnitude the scalability of cryogenic detectors implementing newly developed multiplexing techniques and decoding algorithms More it reflects on the interaction of quantum cryogenic

detectors which in turn can be paired with semiconductor large frame cameras to provide a broad picture of a sky or chemical sample and quantum devices making this second edition of Nuclear Electronics a one stop reference for the combined technologies The book also provides an overview of latest developments in front end electronics signal processing channels and cryogenics all components of quantum spectroscopic systems and provides guidance on the design and applications of the future quantum cryogenic ultra high resolution spectrometers Nuclear Electronics with Quantum Cryogenic Detectors readers will also find Fully revised material from the first edition relating to cryogenic requirements Brand new chapters on semiconductor radiation sensors cooling and magnetic shielding for cryogenic detector systems front end readout electronic circuits for quantum cryogenic detectors energy resolution of quantum cryogenic spectrometers and applications of spectrometers based on cryogenic detectors A number of brand new chapters dedicated to applications using MSQUID multiplexing technique an area that will dominate the cryogenic detector field in the next decades Nuclear Electronics with Quantum Cryogenic Detectors provides a comprehensive overview of the entire discipline for researchers industrial engineers and graduate students involved in the development of high precision nuclear measurements nuclear analytical instrumentation and advanced superconductor primary sensors It is also a helpful resource for electrical and electronic engineers and physicists in the nuclear industry as well as specialist researchers or professionals working in cryogenics applications like biomagnetism quantum computing gravitation measurement and more

Electrically Driven Quantum Dot Based Single-Photon Sources Markus Kantner, 2020-01-25 Semiconductor quantum optics is on the verge of moving from the lab to real world applications When stepping from basic research to new technologies device engineers will need new simulation tools for the design and optimization of quantum light sources which combine classical device physics with cavity quantum electrodynamics This thesis aims to provide a holistic description of single photon emitting diodes by bridging the gap between microscopic and macroscopic modeling approaches The central result is a novel hybrid quantum classical model system that self consistently couples semi classical carrier transport theory with open quantum many body systems This allows for a comprehensive description of quantum light emitting diodes on multiple scales It enables the calculation of the quantum optical figures of merit together with the simulation of the spatially resolved current flow in complex multi dimensional semiconductor device geometries out of one box The hybrid system is shown to be consistent with fundamental laws of non equilibrium thermodynamics and is demonstrated by numerical simulations of realistic devices

Handbook of Optoelectronic Device Modeling and Simulation Joachim Piprek, 2017-10-12 Optoelectronic devices are now ubiquitous in our daily lives from light emitting diodes LEDs in many household appliances to solar cells for energy This handbook shows how we can probe the underlying and highly complex physical processes using modern mathematical models and numerical simulation for optoelectronic device design analysis and performance optimization It reflects the wide availability of powerful computers and advanced commercial software which have opened

the door for non specialists to perform sophisticated modeling and simulation tasks The chapters comprise the know how of more than a hundred experts from all over the world The handbook is an ideal starting point for beginners but also gives experienced researchers the opportunity to renew and broaden their knowledge in this expanding field VLSI Design Esteban Tlelo-Cuautle, Sheldon X.-D. Tan, 2012-01-20 This book provides some recent advances in design nanometer VLSI chips The selected topics try to present some open problems and challenges with important topics ranging from design tools new post silicon devices GPU based parallel computing emerging 3D integration and antenna design The book consists of two parts with chapters such as VLSI design for multi sensor smart systems on a chip Three dimensional integrated circuits design for thousand core processors Parallel symbolic analysis of large analog circuits on GPU platforms Algorithms for CAD tools VLSI design A multilevel memetic algorithm for large SAT encoded problems etc **Proceedings of 16th World Nano Conference 2017** ConferenceSeries, 2017-05-30 June 05 06 2017 Milan Italy Key Topics Nanoscience and Technology Nano Medicine Nano Electronics Molecular Nanotechnology Nano Toxicology Nano Topography Nano Fluidics Nano Weapons Nano Biotechnology Nanotechnology in Water treatment Nano Composites Nanoscale Advanced Nanomaterials Nanotech for Energy and Environment Nano Computational Modelling Nano Materials Synthesis and Characterisation Nanobiomaterials Molecular Mimics Nanotechnology Safety Nanophotonics Nanotechnology and Cosmetics Nanotechnology in Tissue Engineering Nanotechnology in Agriculture and Food Industry **Multi-Band Effective Mass Approximations** Matthias Ehrhardt, Thomas Koprucki, 2014-07-17 This book addresses several mathematical models from the most relevant class of k_p Schrödinger systems Both mathematical models and state of the art numerical methods for adequately solving the arising systems of differential equations are presented The operational principle of modern semiconductor nano structures such as quantum wells quantum wires or quantum dots relies on quantum mechanical effects The goal of numerical simulations using quantum mechanical models in the development of semiconductor nano structures is threefold First they are needed for a deeper understanding of experimental data and of the operational principle Secondly they allow us to predict and optimize in advance the qualitative and quantitative properties of new devices in order to minimize the number of prototypes needed Semiconductor nano structures are embedded as an active region in semiconductor devices Thirdly and finally the results of quantum mechanical simulations of semiconductor nano structures can be used with upscaling methods to deliver parameters needed in semi classical models for semiconductor devices such as quantum well lasers This book covers in detail all these three aspects using a variety of illustrative examples Readers will gain detailed insights into the status of the multiband effective mass method for semiconductor nano structures Both users of the k_p method as well as advanced researchers who want to advance the k_p method further will find helpful information on how to best work with this method and use it as a tool for characterizing the physical properties of semiconductor nano structures The book is primarily intended for graduate and Ph D students in applied mathematics mathematical physics and theoretical physics as well as all

those working in quantum mechanical research or the semiconductor opto electronic industry who are interested in new mathematical aspects *Springer Handbook of Semiconductor Devices* Massimo Rudan, Rossella Brunetti, Susanna Reggiani, 2022-11-10 This Springer Handbook comprehensively covers the topic of semiconductor devices embracing all aspects from theoretical background to fabrication modeling and applications Nearly 100 leading scientists from industry and academia were selected to write the handbook's chapters which were conceived for professionals and practitioners material scientists physicists and electrical engineers working at universities industrial R D and manufacturers Starting from the description of the relevant technological aspects and fabrication steps the handbook proceeds with a section fully devoted to the main conventional semiconductor devices like e g bipolar transistors and MOS capacitors and transistors used in the production of the standard integrated circuits and the corresponding physical models In the subsequent chapters the scaling issues of the semiconductor device technology are addressed followed by the description of novel concept based semiconductor devices The last section illustrates the numerical simulation methods ranging from the fabrication processes to the device performances Each chapter is self contained and refers to related topics treated in other chapters when necessary so that the reader interested in a specific subject can easily identify a personal reading path through the vast contents of the handbook **Nanophononics** Zlatan Aksamija, 2017-11-22 Heat in most semiconductor materials including the traditional group IV elements Si Ge diamond III V compounds GaAs wide bandgap GaN and carbon allotropes graphene CNTs as well as emerging new materials like transition metal dichalcogenides TMDCs is stored and transported by lattice vibrations phonons Phonon generation through interactions with electrons in nanoelectronics power and nonequilibrium devices and light optoelectronics is the central mechanism of heat dissipation in nanoelectronics This book focuses on the area of thermal effects in nanostructures including the generation transport and conversion of heat at the nanoscale level Phonon transport including thermal conductivity in nanostructured materials as well as numerical simulation methods such as phonon Monte Carlo Green's functions and first principles methods feature prominently in the book which comprises four main themes i phonon generation heat dissipation ii nanoscale phonon transport iii applications devices including thermoelectrics and iv emerging materials graphene 2D The book also covers recent advances in nanophononics the study of phonons at the nanoscale Applications of nanophononics focus on thermoelectric TE and tandem TE photovoltaic energy conversion The applications are augmented by a chapter on heat dissipation and self heating in nanoelectronic devices The book concludes with a chapter on thermal transport in nanoscale graphene ribbons covering recent advances in phonon transport in 2D materials The book will be an excellent reference for researchers and graduate students of nanoelectronics device engineering nanoscale heat transfer and thermoelectric energy conversion The book could also be a basis for a graduate special topics course in the field of nanoscale heat and energy **Deterministic, Stochastic, and Deep Learning Methods for Computational Electromagnetics** Wei Cai, 2025-03-02 This book provides a well balanced and

comprehensive picture based on clear physics solid mathematical formulation and state of the art useful numerical methods in deterministic stochastic deep neural network machine learning approaches for computer simulations of electromagnetic and transport processes in biology microwave and optical wave devices and nano electronics Computational research has become strongly influenced by interactions from many different areas including biology physics chemistry engineering etc A multifaceted approach addressing the interconnection among mathematical algorithms and physical foundation and application is much needed to prepare graduate students and researchers in applied mathematics and sciences and engineering for innovative advanced computational research in many applications areas such as biomolecular solvation in solvents radar wave scattering the interaction of lights with plasmonic materials plasma physics quantum dots electronic structure current flows in nano electronics and microchip designs etc

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