



Quantum Transport in Ultrasmall Devices

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Quantum Transport In Ultrasmall Devices

**David K. Ferry, Stephen M.
Goodnick, Jonathan Bird**



Quantum Transport In Ultrasmall Devices:

Quantum Transport in Ultrasmall Devices David K. Ferry, Harold L. Grubin, Carlo Jacoboni, A.-P. Jauho, 2012-12-06 The operation of semiconductor devices depends upon the use of electrical potential barriers such as gate depletion in controlling the carrier densities electrons and holes and their transport Although a successful device design is quite complicated and involves many aspects the device engineering is mostly to devise a best device design by defining optimal device structures and manipulating impurity profiles to obtain optimal control of the carrier flow through the device This becomes increasingly difficult as the device scale becomes smaller and smaller Since the introduction of integrated circuits the number of individual transistors on a single chip has doubled approximately every three years As the number of devices has grown the critical dimension of the smallest feature such as a gate length which is related to the transport length defining the channel has consequently declined The reduction of this design rule proceeds approximately by a factor of 1.4 each generation which means we will be using 0.1015 μm rules for the 4 Gb chips a decade from now If we continue this extrapolation current technology will require 30 nm design rules and a cell 3.2 size

Quantum Transport in Ultrasmall Devices David K. Ferry, Harold L. Grubin, Carlo Jacoboni, A.-P. Jauho, 2012-10-24 The operation of semiconductor devices depends upon the use of electrical potential barriers such as gate depletion in controlling the carrier densities electrons and holes and their transport Although a successful device design is quite complicated and involves many aspects the device engineering is mostly to devise a best device design by defining optimal device structures and manipulating impurity profiles to obtain optimal control of the carrier flow through the device This becomes increasingly difficult as the device scale becomes smaller and smaller Since the introduction of integrated circuits the number of individual transistors on a single chip has doubled approximately every three years As the number of devices has grown the critical dimension of the smallest feature such as a gate length which is related to the transport length defining the channel has consequently declined The reduction of this design rule proceeds approximately by a factor of 1.4 each generation which means we will be using 0.1015 μm rules for the 4 Gb chips a decade from now If we continue this extrapolation current technology will require 30 nm design rules and a cell 3.2 size

Quantum Waveguide in Microcircuits Jian-Bai Xia, Duan-Yang Liu, Wei-Dong Sheng, 2017-12-01 Moore's Law predicts that the degree of microprocessor integration of circuits would double every 18 months in DRAM Although the scaling of microelectronic circuit elements still follows Moore's Law the unit density of power consumption becomes unacceptable Therefore on one hand people develop continuously the microelectronic technology On the other people consider the developing road after Moore's rule is broken This book introduces theories and experiments of quantum transport and intends to provide foundations of semiconductor micro and nano electronics for after the Moore age

Transport in Nanostructures David K. Ferry, Stephen M. Goodnick, Jonathan Bird, 2009-08-20 The advent of semiconductor structures whose characteristic dimensions are smaller than the mean free path of carriers has led to the

development of novel devices and advances in theoretical understanding of mesoscopic systems or nanostructures This book has been thoroughly revised and provides a much needed update on the very latest experimental research into mesoscopic devices and develops a detailed theoretical framework for understanding their behaviour Beginning with the key observable phenomena in nanostructures the authors describe quantum confined systems transmission in nanostructures quantum dots and single electron phenomena Separate chapters are devoted to interference in diffusive transport temperature decay of fluctuations and non equilibrium transport and nanodevices Throughout the book the authors interweave experimental results with the appropriate theoretical formalism The book will be of great interest to graduate students taking courses in mesoscopic physics or nanoelectronics and researchers working on semiconductor nanostructures

Topics In High Field Transport In Semiconductors Kevin F Brennan,P Paul Ruden,2001-07-31 This book examines some of the charge carrier transport issues encountered in the field of modern semiconductor devices and novel materials Theoretical approaches to the understanding and modeling of the relevant physical phenomena seen in devices that have very small spatial dimensions and that operate under high electric field strength are described in papers written by leading experts and pioneers in this field In addition the book examines the transport physics encountered in novel materials such as wide band gap semiconductors GaN SiC etc as well as organic semiconductors Topics in High Field Transport in Semiconductors provides a comprehensive overview that will be beneficial to newcomers as well as engineers and researchers engaged in this exciting field

Terahertz Sensing Technology - Vol 2: Emerging Scientific Applications And Novel Device Concepts Michael S Shur,Dwight L Woolard,William R Loerop,2004-02-06 The last research frontier in high frequency electronics lies in the so called terahertz or submillimeter wave regime between the traditional microwave and the infrared domains Significant scientific and technical challenges within the terahertz THz frequency regime have recently motivated an array of new research activities During the last few years major research programs have emerged that are focused on advancing the state of the art in THz frequency electronic technology and on investigating novel applications of THz frequency sensing This book provides a detailed review of the new THz frequency technological developments that are emerging across a wide spectrum of sensing and technology areas Volume II presents cutting edge results in two primary areas 1 research that is attempting to establish THz frequency sensing as a new characterization tool for chemical biological and semiconductor materials and 2 theoretical and experimental efforts to define new device concepts within the THz gap

Quantum Waveguide in Microcircuits (Second Edition) Jian-Bai Xia,Duan-Yang Liu,Wei-Dong Sheng,2025-08-07 Integrated circuits were developed following Moore s law Moore s law predicts that the degree of microprocessor integration would double every 18 months in DRAM However as the size of circuit elements approaches its physical limit the optical method used in manufacturing 16 nm node chips is also approaching a limit Although the scaling of microelectronic circuit elements still follows Moore s law the unit density of power consumption will become unacceptable Therefore on the one hand people continuously develop the

microelectronic technology and on the other they consider the developing road after Moore's law is broken i.e. more Moore's law or more than Moore's law. Physically when the scale of a circuit element decreases to 10 nm or even less the quantum effect will appear and play a more and more important role. The electron transport becomes non classical and non linear and even the electron motion like the waveguide motion. This book introduces some theories and experiments of quantum transport and consists of two parts: 1 Non Classical and Non Linear Transport and 2 Quantum Waveguide Theory. It provides some foundations of semiconductor micro and nanoelectronics for the after Moore age. The two new chapters in this edition present investigations on 1 mesoscopic transport and 2 Rashba electron's spin transport in a straight waveguide with a stub that has a smooth boundary.

Transport in Nanostructures David Ferry, Stephen Marshall Goodnick, 1999-10-28 A comprehensive detailed description of the properties and behaviour of mesoscopic devices

Carrier Transport in Nanoscale MOS Transistors Hideaki Tsuchiya, Yoshinari Kamakura, 2017-06-13 A comprehensive advanced level examination of the transport theory of nanoscale devices. Provides advanced level material of electron transport in nanoscale devices from basic principles of quantum mechanics through to advanced theory and various numerical techniques for electron transport. Combines several up to date theoretical and numerical approaches in a unified manner such as Wigner Boltzmann equation, the recent progress of carrier transport research for nanoscale MOS transistors and quantum correction approximations. The authors approach the subject in a logical and systematic way reflecting their extensive teaching and research backgrounds.

Terahertz Sensing Technology: Emerging scientific applications & novel device concepts Dwight L. Woolard, William R. Loerop, Michael Shur, 2003 The last research frontier in high frequency electronics lies in the so called terahertz or submillimeter wave regime between the traditional microwave and the infrared domains. Significant scientific and technical challenges within the terahertz THz frequency regime have recently motivated an array of new research activities. During the last few years major research programs have emerged that are focused on advancing the state of the art in THz frequency electronic technology and on investigating novel applications of THz frequency sensing. This book provides a detailed review of the new THz frequency technological developments that are emerging across a wide spectrum of sensing and technology areas. Volume II presents cutting edge results in two primary areas: 1 research that is attempting to establish THz frequency sensing as a new characterization tool for chemical biological and semiconductor materials and 2 theoretical and experimental efforts to define new device concepts within the THz gap.

Quantum Heterostructures Vladimir Vasil'evich Mitin, Viacheslav Kochelap, Michael A. Strosio, 1999-07-13 Quantum Heterostructures provides a detailed description of the key physical and engineering principles of quantum semiconductor heterostructures. Blending important concepts from physics materials science and electrical engineering it also explains clearly the behavior and operating features of modern microelectronic and optoelectronic devices. The authors begin by outlining the trends that have driven development in this field most importantly the need for high performance devices in computer information and

communications technologies They then describe the basics of quantum nanoelectronics including various transport mechanisms In the latter part of the book they cover novel microelectronic devices and optical devices based on quantum heterostructures The book contains many homework problems and is suitable as a textbook for undergraduate and graduate courses in electrical engineering physics or materials science It will also be of great interest to those involved in research or development in microelectronic or optoelectronic devices

Introduction To Semiconductor Device Modelling Christopher M Snowden, 1998-09-29 This book deals mainly with physical device models which are developed from the carrier transport physics and device geometry considerations The text concentrates on silicon and gallium arsenide devices and includes models of silicon bipolar junction transistors junction field effect transistors JFETs MESFETs silicon and GaAs MESFETs transferred electron devices pn junction diodes and Schottky varactor diodes The modelling techniques of more recent devices such as the heterojunction bipolar transistors HBT and the high electron mobility transistors are discussed This book contains details of models for both equilibrium and non equilibrium transport conditions The modelling Technique of Small scale devices is discussed and techniques applicable to submicron dimensioned devices are included A section on modern quantum transport analysis techniques is included Details of essential numerical schemes are given and a variety of device models are used to illustrate the application of these techniques in various fields

Theory of Transport Properties of Semiconductor Nanostructures Eckehard Schöll, 2013-11-27 Recent advances in the fabrication of semiconductors have created almost unlimited possibilities to design structures on a nanometre scale with extraordinary electronic and optoelectronic properties The theoretical understanding of electrical transport in such nanostructures is of utmost importance for future device applications This represents a challenging issue of today's basic research since it requires advanced theoretical techniques to cope with the quantum limit of charge transport ultrafast carrier dynamics and strongly nonlinear high field effects This book which appears in the electronic materials series presents an overview of the theoretical background and recent developments in the theory of electrical transport in semiconductor nanostructures It contains 11 chapters which are written by experts in their fields Starting with a tutorial introduction to the subject in Chapter 1 it proceeds to present different approaches to transport theory The semiclassical Boltzmann transport equation is in the centre of the next three chapters Hydrodynamic moment equations Chapter 2 Monte Carlo techniques Chapter 3 and the cellular automaton approach Chapter 4 are introduced and illustrated with applications to nanometre structures and device simulation A full quantum transport theory covering the Kubo formalism and nonequilibrium Green's functions Chapter 5 as well as the density matrix theory Chapter 6 is then presented

Hot Carrier Design Considerations for MOS Devices and Circuits Cheng Wang, 2012-12-06 As device dimensions decrease hot carrier effects which are due mainly to the presence of a high electric field inside the device are becoming a major design concern On the one hand the detrimental effects such as transconductance degradation and threshold shift need to be minimized or if possible avoided altogether On

the other hand performance such as the programming efficiency of nonvolatile memories or the carrier velocity inside the devices need to be maintained or improved through the use of submicron technologies even in the presence of a reduced power supply As a result one of the major challenges facing MOS design engineers today is to harness the hot carrier effects so that without sacrificing product performance degradation can be kept to a minimum and a reliable design obtained To accomplish this the physical mechanisms responsible for the degradations should first be experimentally identified and characterized With adequate models thus obtained steps can be taken to optimize the design so that an adequate level of quality assurance in device or circuit performance can be achieved This book addresses these hot carrier design issues for MOS devices and circuits and is used primarily as a professional guide for process development engineers device engineers and circuit designers who are interested in the latest developments in hot carrier degradation modeling and hot carrier reliability design techniques It may also be considered as a reference book for graduate students who have some research interests in this exciting yet sometime controversial field

Physics of Nanostructured Solid State Devices Supriyo Bandyopadhyay, 2012-02-17 Physics of Nanostructured Solid State Devices introduces readers to theories and concepts such as semi classical and quantum mechanical descriptions of electron transport methods for calculations of band structures in solids with applications in calculation of optical constants and other advanced concepts The information presented here will equip readers with the necessary tools to carry out cutting edge research in modern solid state nanodevices Mesoscopic Systems Yoshimasa Murayama, 2008-09-26 Future high tech applications such as nanotechnology require a deep understanding of the physics of mesoscopic systems These systems form a bridge between macroscopic systems governed by classical physics and microscopic systems governed by quantum physics This introduction discusses a variety of typical surface optical transport and magnetic properties of mesoscopic systems with reference to many experimental observations It is written for physicists materials scientists and engineers who want to stay abreast of current research or high tech development Physics of Low-Dimensional Semiconductor Structures Paul N. Butcher, Norman H. March, Mario P.

Tosi, 2013-11-11 Presenting the latest advances in artificial structures this volume discusses in depth the structure and electron transport mechanisms of quantum wells superlattices quantum wires and quantum dots It will serve as an invaluable reference and review for researchers and graduate students in solid state physics materials science and electrical and electronic engineering **Ultrafast Phenomena in Semiconductors** Kong-Thon Tsen, 2012-12-06 There are many books in the market devoted to the review of certain fields This book is different from those in that authors not only provide reviews of the fields but also present their own important contributions to the fields in a tutorial way As a result researchers who are already in the field of ultrafast dynamics in semiconductors and its device applications as well as researchers and graduate students just entering the field will benefit from it This book is made up of recent new developments in the field of ultrafast dynamics in semiconductors It consists of nine chapters Chapter 1 reviews a microscopic many body theory which allows

one to compute the linear and non linear optical properties of semiconductor superlattices in the presence of homogeneous electric fields Chapter 2 deals with ultrafast intersubband dynamics in quantum wells and device structures Chapter 3 is devoted to Bloch oscillations in semicon ductors and their applications Chapter 4 discusses transient electron transport phenomena such as electron ballistic transport and electron velocity overshoot phenomena as well as non equilibrium phonon dynamics in nanostructure semicon ductors Chapter 5 reviews experimental and theoretical work on the use of the phase properties of one or more ultrashort optical pulses to generate and control electrical currents in semiconductors

Advances in Research and Applications ,1996-01-26 Solid State Physics Volume 49 continues the Series tradition of excellence by focusing on the optical and electronic properties and applications of semiconductors Three of the chapters deal with stress applications as well as the basic underlying science of semiconductors All of the topics in this volume are at the cutting edge of research in the semiconductor field and will be of great interest to the scientific community Evolution of Spontaneous Structures in Dissipative Continuous Systems Friedrich H. Busse, Stefan C. Müller, 2003-07-01 In the decades the of the formation of structures past subject spontaneous in far from has into a branch of systems equilibrium major physics grown search with ties to It has become evident that strong neighboring disciplines a diverse of can be understood within a common mat phenomena range matical framework which has been called nonlinear of continuous dynamics This name the close to the field of nonlinear systems emphasizes relationship of with few of freedom which has evolved into a dynamics systems degrees mature in the recent features mathematically subject past Many dynamical of continuous be described reduction few can a to a systems actually through of freedom and of the latter of continue to degrees properties type systems of continuous the inspire study systems The of this book is to demonstrate the numerous goal through examples that exist for the of nonlinear the opportunities study phenomena through tools of mathematical and use of common analyses dynamical interpretations Instead of overview of the a providing comprehensive rapidly evolving field the contributors to this book are to communicate to a wide scientific trying audience the of what have learnt about the formation of essence they spon neous structures in continuous and about the dissipative systems competition between order and chaos that characterizes these It is that systems hoped the book will be even to those scientists whose not helpful are disciplines the authors

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In some sort of defined by information and interconnectivity, the enchanting power of words has acquired unparalleled significance. Their capability to kindle emotions, provoke contemplation, and ignite transformative change is truly awe-inspiring. Enter the realm of "**Quantum Transport In Ultrasmall Devices**," a mesmerizing literary masterpiece penned by way of a distinguished author, guiding readers on a profound journey to unravel the secrets and potential hidden within every word. In this critique, we shall delve to the book is central themes, examine its distinctive writing style, and assess its profound impact on the souls of its readers.

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