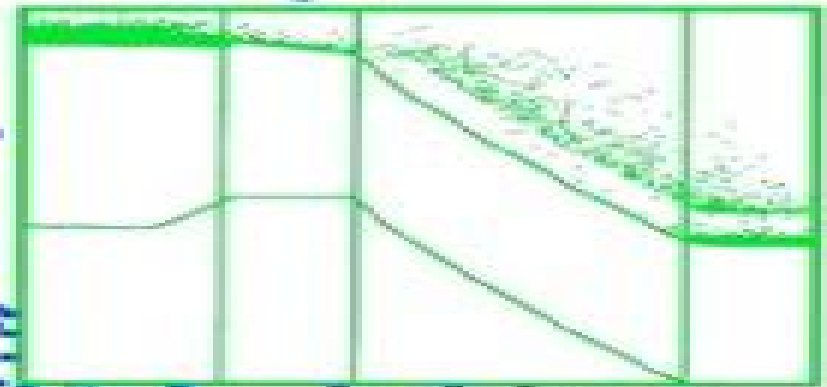


# NUMERICAL SIMULATION OF SUBMICRON SEMICONDUCTOR DEVICES



KAZUTAKA TOMIZAWA

# Numerical Simulation Of Submicron Semiconductor Devices

**W.H.A. SCHILDERS, E.J.W. TER MATEN**



## **Numerical Simulation Of Submicron 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

**Hierarchical Device Simulation** Christoph Jungemann,Bernd Meinerzhagen,2012-12-06 This book summarizes the research of more than a decade Its early motivation dates back to the eighties and to the memorable talks Dr C Moglestue FHG Freiburg gave on his Monte Carlo solutions of the Boltzmann transport equation at the NASECODE conferences in Ireland At that time numerical semiconductor device modeling basically implied the application of the drift diffusion model On the one hand those talks clearly showed the potential of the Monte Carlo model for an accurate description of many important transport issues that cannot adequately be addressed by the drift diffusion approximation On the other hand they also clearly demonstrated that at that time only very few experts were able to extract useful results from a Monte Carlo simulator With this background Monte Carlo research activities were started in 1986 at the University of Aachen RWTH Aachen Germany Different to many other Monte Carlo research groups the Monte Carlo research in Aachen took place in an environment of active drift diffusion and hydrodynamic model development

**Numerical Simulation** Mykhaylo Andriychuk,2012-09-19 Numerical Simulation from Theory to Industry is the edited book containing 25 chapters and divided into four parts Part 1 is devoted to the background and novel advances of numerical simulation second part contains simulation applications in the macro and micro electrodynamics Part 3 includes contributions related to fluid dynamics in the natural environment and scientific applications the last fourth part is dedicated to simulation in the industrial areas such as power engineering metallurgy and building Recent numerical techniques as well as software the most accurate and advanced in treating the physical phenomena are applied in order to explain the investigated processes in terms of numbers Since the numerical simulation plays a key role in both theoretical and industrial research this book related to simulation of many physical processes will be useful for the pure research scientists applied mathematicians industrial engineers and post graduate students

## **The Physics of Submicron Semiconductor Devices**

Harold L. Grubin,David K. Ferry,C. Jacoboni,2013-11-11 The papers contained in the volume represent lectures delivered as a 1983 NATO ASI held at Urbino Italy The lecture series was designed to identify the key submicron and ultrasubmicron device physics transport materials and contact issues Nonequilibrium transport quantum transport interfacial and size constraints issues were also highlighted The ASI was supported by NATO and the European Research Office H L Grubin D K Ferry C Jacoboni v CONTENTS MODELLING OF SUB MICRON DEVICES 1 E Constant BOLTZMANN TRANSPORT EQUATION 33 K Hess TRANSPORT AND MATERIAL CONSIDERATIONS FOR SUBMICRON DEVICES 45 H L Grubin EPITAXIAL GROWTH FOR SUB MICRON STRUCTURES 179 C E C Wood INSULATOR SEMICONDUCTOR INTERFACES 195 C W Wilms en THEORY OF THE ELECTRONIC STRUCTURE OF SEMICONDUCTOR SURFACES AND INTERFACES 223 C

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**Numerical Methods in Electromagnetics** W.H.A. SCHILDERS,E.J.W. TER MATEN,2005-04-04 This special volume provides a broad overview and insight in the way numerical methods are being used to solve the wide variety of problems in the electronics industry Furthermore its aim is to give researchers from other fields of application the opportunity to benefit from the results wich have been obtained in the electronics industry Complete survey of numerical methods used in the electronic industry Each chapter is selfcontained Presents state of the art applications and methods Internationally recognised authors

**Numerical Simulation of Semiconductor Structures** Abel Garcia-Barrientos,Vladimir Grimalsky,2013-10-21 The investigation of new materials devices and techniques to improve the performance of telecommunications spectroscopy and radar systems applications has caused that the study of non stationary effects of space charge in semiconductor structures be a strategy research area in the field of high speed semiconductor devices Therefore this book focuses in the study of the non stationary effects of the space charge in semiconductor structures where the nonlinear wave interaction in active media may serve to improve the high frequency performance of semiconductor devices

Applications of Silicon-Germanium Heterostructure Devices C.K Maiti,G.A Armstrong,2001-07-20 The first book to deal with the design and optimization of transistors made from strained layers Applications of Silicon Germanium Heterostructure Devices combines three distinct topics technology device design and simulation and applications in a comprehensive way Important aspects of the book include key technology issues for the growth of st

**Viscous Profiles and Numerical Methods for Shock Waves** Michael Shearer,1991-01-01 One strongly represented theme is the power of ideas from dynamical systems that are being adapted and developed in the context of shock waves

*RF and Microwave Semiconductor Device Handbook* Mike Golio,2017-12-19 Offering a single volume reference for high frequency semiconductor devices this handbook covers basic material characteristics system level concerns and constraints simulation and modeling of devices and packaging Individual chapters detail the properties and characteristics of each semiconductor device type including Varactors Schottky diodes transit time devices BJTs HBTs MOSFETs MESFETs and HEMTs Written by leading researchers in the field the RF and Microwave Semiconductor Device Handbook provides an excellent starting point for programs involving development technology comparison or acquisition of

RF and wireless semiconductor devices      *Modelling of Interface Carrier Transport for Device Simulation* Dietmar Schroeder, 2013-03-09 This book represents a comprehensive text devoted to charge transport at semiconductor interfaces and its consideration in device simulation by interface and boundary conditions. It contains a broad review of the physics modelling and simulation of electron transport at interfaces in semiconductor devices. Particular emphasis is put on the consistent derivation of interface or boundary conditions for semiconductor device simulation. The book is of interest with respect to a wide range of electronic engineering activities as process design, device design, process characterization, research in microelectronics or device simulator development. It is also useful for students and lecturers in courses of electronic engineering and it supplements the library of technically oriented solid state physicists. The deepest roots of this book date back to the mid seventies. Being a student of electrical engineering who was exposed for the first time to the material of semiconductor device electronics, I was puzzled by noticing that much emphasis was put on a thorough introduction and understanding of the basic semiconductor equations while the boundary conditions for these equations received very much less attention. Until today on many occasions one could get the impression that boundary conditions are unimportant accessories; they do not stand on their own besides the bulk transport equations although it is clear that they are of course a necessary complement of these.

**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.

**Computational Methods for Electromagnetic Phenomena** Wei Cai, 2013-01-03 A unique and comprehensive graduate text and reference on numerical methods for electromagnetic phenomena from atomistic to continuum scales in biology, optical to micro waves, photonics, nanoelectronics and plasmas. The state of the art numerical methods described include Statistical fluctuation formulae for the dielectric constant, Particle Mesh Ewald, Fast Multipole Method and image based reaction field method for long range interactions, High order singular hypersingular Nyström collocation, Galerkin boundary and volume integral methods in layered media for Poisson Boltzmann electrostatics, electromagnetic wave scattering and electron density waves in quantum dots, Absorbing and UPML boundary conditions, High order hierarchical Nd-leaf edge elements, High order discontinuous Galerkin DG and Yee finite difference time domain methods, Finite element and plane wave frequency domain methods for periodic structures, Generalized DG beam propagation method for optical

waveguides NEGF Non equilibrium Green s function and Wigner kinetic methods for quantum transport High order WENO and Godunov and central schemes for hydrodynamic transport Vlasov Fokker Planck and PIC and constrained MHD transport in plasmas

**Wave Propagation** Andrey Petrin,2011-03-16 The book collects original and innovative research studies of the experienced and actively working scientists in the field of wave propagation which produced new methods in this area of research and obtained new and important results Every chapter of this book is the result of the authors achieved in the particular field of research The themes of the studies vary from investigation on modern applications such as metamaterials photonic crystals and nanofocusing of light to the traditional engineering applications of electrodynamics such as antennas waveguides and radar investigations

Introduction to the Physics of Electron Emission Kevin L. Jensen,2024-08-19 A practical in depth description of the physics behind electron emission physics and its usage in science and technology Electron emission is both a fundamental phenomenon and an enabling component that lies at the very heart of modern science and technology Written by a recognized authority in the field with expertise in both electron emission physics and electron beam physics An Introduction to Electron Emission provides an in depth look at the physics behind thermal field photo and secondary electron emission mechanisms how that physics affects the beams that result through space charge and emittance growth and explores the physics behind their utilization in an array of applications The book addresses mathematical and numerical methods underlying electron emission describing where the equations originated how they are related and how they may be correctly used to model actual sources for devices using electron beams Writing for the beam physics and solid state communities the author explores applications of electron emission methodology to solid state statistical and quantum mechanical ideas and concepts related to simulations of electron beams to condensed matter solid state and fabrication communities Provides an extensive description of the physics behind four electron emission mechanisms field photo and secondary and how that physics relates to factors such as space charge and emittance that affect electron beams Introduces readers to mathematical and numerical methods their origins and how they may be correctly used to model actual sources for devices using electron beams Demonstrates applications of electron methodology as well as quantum mechanical concepts related to simulations of electron beams to solid state design and manufacture Designed to function as both a graduate level text and a reference for research professionals Introduction to the Physics of Electron Emission is a valuable learning tool for postgraduates studying quantum mechanics statistical mechanics solid state physics electron transport and beam physics It is also an indispensable resource for academic researchers and professionals who use electron sources model electron emission develop cathode technologies or utilize electron beams

**Handbook of Nanostructured Materials and Nanotechnology, Five-Volume Set** Hari Singh Nalwa,1999-10-29 Nanostructured materials is one of the hottest and fastest growing areas in today s materials science field along with the related field of solid state physics Nanostructured materials and their based technologies have opened up exciting new possibilities for future applications in a

number of areas including aerospace automotive x ray technology batteries sensors color imaging printing computer chips medical implants pharmacy and cosmetics The ability to change properties on the atomic level promises a revolution in many realms of science and technology Thus this book details the high level of activity and significant findings are available for those involved in research and development in the field It also covers industrial findings and corporate support This five volume set summarizes fundamentals of nano science in a comprehensive way The contributors enlisted by the editor are at elite institutions worldwide Key Features Provides comprehensive coverage of the dominant technology of the 21st century Written by 127 authors from 16 countries making this truly international First and only reference to cover all aspects of nanostructured materials and nanotechnology *Thermal Transport for Applications in Micro/Nanomachining* Basil T. Wong, Pinar M. Mengüç, 2008-07-19 Beginning with an overview of nanomachining this monograph introduces the relevant concepts from solid state physics thermodynamics and lattice structures It then covers modeling of thermal transport at the nanoscale and details simulations of different processes relevant to nanomachining The final chapter summarizes the important points and discusses directions for future work to improve the modeling of nanomachining

*Quasi-hydrodynamic Semiconductor Equations* Ansgar Jüngel, 2011-04-27 In this book a hierarchy of macroscopic models for semiconductor devices is presented Three classes of models are studied in detail isentropic drift diffusion equations energy transport models and quantum hydrodynamic equations The derivation of each of the models is shown including physical discussions Furthermore the corresponding mathematical problems are analyzed using modern techniques for nonlinear partial differential equations The equations are discretized employing mixed finite element methods Also numerical simulations for modern semiconductor devices are performed showing the particular features of the models Modern analytical techniques have been used and further developed such as positive solution methods local energy methods for free boundary problems and entropy methods The book is aimed at applied mathematicians and physicists interested in mathematics as well as graduate and postdoc students and researchers in these fields Terahertz Sensing Technology William R. Loerop, 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 OC THz gapOCO Contents THz Frequency Spectroscopic

Sensing of DNA and Related Biological Materials T Globus et al Spectroscopy with Electronic Terahertz Techniques for Chemical and Biological Sensing M K Choi et al Terahertz Applications to Biomolecular Sensing A G Markelz Characteristics of Nano Scale Composites at THz and IR Spectral Regions J F Federici Fundamentals of Terrestrial Millimeter Wave and THz Remote Sensing E R Brown Terahertz Emission Using Quantum Dots and Microcavities G S Solomon et al Terahertz Transport in Semiconductor Quantum Structures S J Allen Advanced Theory of Instability in Tunneling Nanostructures D L Woolard et al Wigner Function Simulations of Quantum DeviceOCircuits Interactions H L Grubin Continuous Wave Terahertz Spectroscopy of Plasmas and Biomolecules D F Plusquellic et al Readership Undergraduates graduate students academics and researchers in engineering and science     The Mathematica GuideBook for Numerics Michael Trott,2006-10-27 Provides the reader with working knowledge of Mathematica and key aspects of Mathematica s numerical capabilities needed to deal with virtually any real life problem Clear organization complete topic coverage and an accessible writing style for both novices and experts Website for book with additional materials <http://www.MathematicaGuideBooks.org> Accompanying DVD containing all materials as an electronic book with complete executable Mathematica 5.1 compatible code and programs rendered color graphics and animations     Computational Science and Its Applications - ICCSA 2003 Vipin Kumar, Marina L. Gavrilova, C.J. Kenneth Tan, Pierre L'Ecuyer, 2003-08-03 The three volume set LNCS 2667 LNCS 2668 and LNCS 2669 constitutes the refereed proceedings of the International Conference on Computational Science and Its Applications ICCSA 2003 held in Montreal Canada in May 2003 The three volumes present more than 300 papers and span the whole range of computational science from foundational issues in computer science and mathematics to advanced applications in virtually all sciences making use of computational techniques The proceedings give a unique account of recent results in computational science



## The Enigmatic Realm of **Numerical Simulation Of Submicron Semiconductor Devices**: Unleashing the Language is Inner Magic

In a fast-paced digital era where connections and knowledge intertwine, the enigmatic realm of language reveals its inherent magic. Its capacity to stir emotions, ignite contemplation, and catalyze profound transformations is nothing short of extraordinary. Within the captivating pages of **Numerical Simulation Of Submicron Semiconductor Devices** a literary masterpiece penned by a renowned author, readers attempt a transformative journey, unlocking the secrets and untapped potential embedded within each word. In this evaluation, we shall explore the book's core themes, assess its distinct writing style, and delve into its lasting impact on the hearts and minds of people who partake in its reading experience.

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patterns can be utilized

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maximum internal pressure 395 mpa 5 a cylinder with closed ends has outer diameter  $d$  and a wall thickness  $t$  0 1d

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common use is  $t/d \geq 2500/0.3$

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web thin wall cylinder objective to study the stress and strain developed in a thin wall cylinder under internal pressure to

determine the poisson's ratio  $\nu$  and the young's modulus of elasticity  $E$  for the cylinder material apparatus fig 1 shows a thin

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web consider now a simple spherical vessel of radius  $r$  and wall thickness  $b$  such as a round the accuracy of this result depends on the vessel being thin walled i.e.  $r \gg b$  at the inner cylinder now expands according to the difference  $p - p_c$  while

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web thin walled vessels are typically either spherical or cylindrical other geometries are possible but their complexity precludes their inclusion in this webpage spherical cylinder stress and deflection filled to depth  $d$  with liquid of density  $\rho$  force unit volume tangential edge support equation and calculator

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web thin walled circular cylinders these stresses which entail a triaxial stress state can be readily obtained by simply setting equilibrium conditions i.e. without making use of compatibility conditions

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web in chapter 2 we examined the stresses in thin walled cylinders subjected to internal pressure the assumption of thin walls allowed us to develop a simple analysis that ignored the variation of radial stress when the wall thickness becomes appreciable in proportion

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web oct 12 2011 if the cylinder walls are thin and the ratio of the thickness to the internal diameter is less than about 0.1 then it can be assumed that the hoop and longitudinal stresses are constant across the thickness it may also be assumed that the radial stress is small and can be neglected

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web a fluid container sealed by a piston is open c in this case an external axial force  $f_a$  is mandatory for equilibrium of the overall piston and cylinder assembly a bicycle pump is a common example if  $a_i$  is the internal circular area then a free body of either piston or cylinder end c must have  $f_a p_i a_i$  and there is no need for axial wall stresses to

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web the classic equation for hoop stress created by an internal pressure on a thin wall cylindrical pressure vessel is  $\sigma_\theta = p d / 2 t$  for the hoop stress thin wall pressure vessel hoop stress calculator where  $p$  is the internal pressure  $t$  is the wall thickness  $r$  is the inside radius of the cylinder

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