

Equilibrium Carrier Concentration

In silicon and other semiconductors,

$$n_0 = N_c \exp\left(\frac{-(E_c - E_F)}{kT}\right) \quad \text{conduction band}$$

$$p_0 = N_v \exp\left(\frac{-(E_F - E_v)}{kT}\right) \quad \text{valence band}$$

n_0 : electron concentration at thermal equilibrium (cm^{-3})

p_0 : hole concentration at thermal equilibrium (cm^{-3})

N_c : effective density of states for conduction band (cm^{-3})

N_v : effective density of states for valence band (cm^{-3})

E_F : Fermi energy (eV)

k : Boltzmann constant (J/K)

T : absolute temperature (K)

Semiconductor Equations

**Peter A. Markowich, Christian A.
Ringhofer, Christian Schmeiser**



Semiconductor Equations:

Semiconductor Equations Peter A. Markowich, Christian A. Ringhofer, Christian Schmeiser, 2012-12-06 In recent years the mathematical modeling of charge transport in semi conductors has become a thriving area in applied mathematics The drift diffusion equations which constitute the most popular model for the simulation of the electrical behavior of semiconductor devices are by now mathematically quite well understood As a consequence numerical methods have been developed which allow for reasonably efficient computer simulations in many cases of practical relevance Nowadays research on the drift diffusion model is of a highly specialized nature It concentrates on the exploration of possibly more efficient discretization methods e.g. mixed finite elements streamline diffusion on the improvement of the performance of nonlinear iteration and linear equation solvers and on three dimensional applications The ongoing miniaturization of semiconductor devices has prompted a shift of the focus of the modeling research lately since the drift diffusion model does not account well for charge transport in ultra integrated devices Extensions of the drift diffusion model so called hydrodynamic models are under investigation for the modeling of hot electron effects in submicron MOS transistors and supercomputer technology has made it possible to employ kinetic models semiclassical Boltzmann Poisson and Wigner Poisson equations for the simulation of certain highly integrated devices

Transport Equations for Semiconductors Ansgar Jüngel, 2009-03-17 This volume presents a systematic and mathematically accurate description and derivation of transport equations in solid state physics in particular semiconductor devices

The Stationary Semiconductor Device Equations P.A. Markowich, 1985-12-12 In the last two decades semiconductor device simulation has become a research area which thrives on a cooperation of physicists electrical engineers and mathematicians 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 solution 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 mathematical 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

Semiconductor Device Physics and Simulation J.S. Yuan, Juin-Jei Liou, 1998-05-31 The advent of the microelectronics technology has made ever increasing numbers of small devices on a same chip The rapid emergence of ultra large scaled integrated ULSI technology has moved device dimension

into the sub quarter micron regime and put more than 10 million transistors on a single chip While traditional closed form analytical models furnish useful intuition into how semiconductor devices behave they no longer provide consistently accurate results for all modes of operation of these very small devices The reason is that in such devices various physical mechanisms affect the device performance in a complex manner and the conventional assumptions i e one dimensional treatment low level injection quasi static approximation etc employed in developing analytical models become questionable Thus the use of numerical device simulation becomes important in device modeling Researchers and engineers will rely even more on device simulation for device design and analysis in the future This book provides comprehensive coverage of device simulation and analysis for various modern semiconductor devices It will serve as a reference for researchers engineers and students who require in depth up to date information and understanding of semiconductor device physics and characteristics The materials of the book are limited to conventional and mainstream semiconductor devices photonic devices such as light emitting and laser diodes are not included nor does the book cover device modeling device fabrication and circuit applications

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

Rate Equations in

Semiconductor Electronics John E. Carroll, J. E. Carroll, 1990-03-30 This book presents a novel approach to the teaching of dynamic aspects of the operation of semiconductor and opto electronic devices Such dynamic aspects often determine the steady state conditions Also the dynamical operation of such devices is of increasing importance as modern methods of communicating data and information require electronic devices that switch electrical or optical signals at ever faster rates The author discusses the rates at which electrons and holes can reach equilibrium the rates at which transistors and diodes can switch and the rates at which electrons and holes can interact with photons and with protons He also applies the rate equations in a unified way to models of light emitting diodes injection lasers and photodiodes Finally the author discusses more advanced topics on the photon statistics of injection lasers mode locking and the application of rate equations and Maxwell's equations to opto electronic devices

Quasi-hydrodynamic Semiconductor Equations Ansgar Jüngel, 2001-02-01 This book presents a hierarchy of macroscopic models for semiconductor devices studying three classes of models in detail

isentropic drift diffusion equations energy transport models and quantum hydrodynamic equations The derivation of each including physical discussions is shown Numerical simulations for modern semiconductor devices are performed showing the particular features of each The author develops modern analytical techniques such as positive solution methods local energy methods for free boundary problems and entropy methods

Transport Equations for Semiconductors Ansgar

Jüngel,2009-04-20 Semiconductor devices are ubiquitous in the modern computer and telecommunications industry A precise knowledge of the transport equations for electron flow in semiconductors when a voltage is applied is therefore of paramount importance for further technological breakthroughs In the present work the author tackles their derivation in a systematic and rigorous way depending on certain key parameters such as the number of free electrons in the device the mean free path of the carriers the device dimensions and the ambient temperature Accordingly a hierarchy of models is examined which is reflected in the structure of the book first the microscopic and macroscopic semi classical approaches followed by their quantum mechanical counterparts

Analysis and Simulation of Semiconductor Devices S. Selberherr,2012-12-06

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

Physics of Semiconductor Devices J.-P. Colinge,C.A. Colinge,2005-10-03

Physics of Semiconductor Devices covers both basic classic topics such as energy band theory and the gradual channel model of the MOSFET as well as advanced concepts and devices such as MOSFET short channel effects low dimensional devices and single electron transistors Concepts are introduced to the reader in a simple way often using comparisons to everyday life experiences such as simple fluid mechanics They are then explained in depth and mathematical developments are fully described Physics of Semiconductor Devices contains a list of problems that can be used as homework assignments or can be solved in class to exemplify the theory Many of these problems make use of Matlab and are aimed at illustrating theoretical concepts in a graphical manner

Semiconductor Equations Book Review: Unveiling the Magic of Language

In an electronic digital era where connections and knowledge reign supreme, the enchanting power of language has become apparent than ever. Its capability to stir emotions, provoke thought, and instigate transformation is truly remarkable. This extraordinary book, aptly titled "**Semiconductor Equations**," written by a highly acclaimed author, immerses readers in a captivating exploration of the significance of language and its profound impact on our existence. Throughout this critique, we will delve into the book's central themes, evaluate its unique writing style, and assess its overall influence on its readership.

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