

# Elementary Semiconductor Physics

Fundamentals of Semiconductor Physics Semiconductor Physics Semiconductor Physics and Applications Semiconductor Physics and Devices Semiconductor Devices Physics of Semiconductor Devices Introduction to Semiconductor Physics Fundamentals of Semiconductor Physics and Devices Introduction to Semiconductor Physics The Physics of Semiconductors Semiconductor Physics Physics of Semiconductor Devices Basic Semiconductor Physics Semiconductor Physical Electronics Introduction to Semiconductor Physics and Devices Fundamentals of Semiconductors Essentials of Semiconductor Physics Semiconductor Physics And Devices Introduction to Semiconductor Physics Semiconductor Physics: A Formula Handbook MIJOE JOSEPH Karlheinz Seeger M. Balkanski Donald A. Neamen Jasprit Singh Simon M. Sze Holger T. Grahn R. B. Adler Marius Grundmann Karlheinz Seeger J.-P. Colinge Chihiro Hamaguchi Sheng S. Li Mykhaylo Evstigneev Peter YU W. Tom Wenckebach Donald Neamen Richard B. Adler N.B. Singh

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semiconductors have made an enormous impact on 20 th century science and technology this is because components made from semiconductors have very favorable properties such as low energy consumption compactness and high reliability and so they now dominate electronics and radio engineering semiconductors are indispensable for space exploration where the requirements of small size low weight and low energy consumption are especially stringent this book uses quantum mechanical concepts and band theory to present the theory of semiconductors in a comprehensible term it also describes how basic semiconductor devices eg diodes transistors and lasers operate the book was written for senior high school and b e b tech students interested in semiconductor physics

it is a pleasure to take the opportunity to express my sincere gratitude to many colleagues who provided valuable hints for improvements even including lists of misprints which i hope have now been completely eliminated it is not possible to name all of them and so i will only mention the interesting discussions over so many years i had with professor hans w p $\ddot{u}$ tzl of the technical university of vienna on the occasion of our common weekly semiconductor seminar i am grateful to professor h j queisser and professor m cardona for helpful criticism special thanks are due to frau jitka fucik for typing and frau viktorie k $\ddot{u}$ ver for drawing services the cooperation with dr h k lotsch of springer verlag has been a pleasure vienna january 1982 k seeger contents 1 elementary properties of semiconductors i 1 1 insulator semiconductor semimetal metal 1 1 2 the positive hole 3 1 3 conduction processes compensation law of mass action 4 problems 8 2 energy band structure 10 2 1 single and periodically repeated potential well 10 2 2 energy bands by tight binding of electrons to atoms 17 2 3 the brillouin zone 21 2 4 constant energy surfaces 30 problems 33 3 semiconductor statistics 34 3 1 fermi statistics 35 3 2 occupation

probabilities of impurity levels 39 problems 45 4 charge and energy transport in a nondegenerate electron gas

the textbook combines a thorough theoretical treatment of the basic physics of semiconductors with applications to practical devices by putting special emphasis on the physical principles upon which these devices operate graduate students and lecturers in semiconductor physics condensed matter physics electromagnetic theory and quantum mechanics will find this a useful textbook and reference work jacket neamen's semiconductor physics and devices third edition deals with the electrical properties and characteristics of semiconductor materials and devices the goal of this book is to bring together quantum mechanics the quantum theory of solids semiconductor material physics and semiconductor device physics in a clear and understandable way

this introductory text designed for the first course in semiconductor physics presents a well balanced coverage of semiconductor physics and device operation and shows how devices are optimized for applications the text begins with an exploration of the basic physical processes upon which all semiconductor devices diodes transistor light emitters and detectors are based topics such as bandstructure effective masses holes doping carrier transport and lifetimes are discussed next the author focuses on the operation of the important semiconductor devices along with issues relating to the optimization of device performance issues such as how doping device dimensions and parasitic effects influence device operation are also included the book is appropriate for the following courses device physics semiconductor devices device electronics physics of semiconductor devices integrated circuit devices device electronics solid state devices

the third edition of the standard textbook and reference in the field of semiconductor devices this classic book has set the standard for advanced study and reference in the semiconductor device field now

completely updated and reorganized to reflect the tremendous advances in device concepts and performance this third edition remains the most detailed and exhaustive single source of information on the most important semiconductor devices it gives readers immediate access to detailed descriptions of the underlying physics and performance characteristics of all major bipolar field effect microwave photonic and sensor devices designed for graduate textbook adoptions and reference needs this new edition includes a complete update of the latest developments new devices such as three dimensional mosfets modfets resonant tunneling diodes semiconductor sensors quantum cascade lasers single electron transistors real space transfer devices and more materials completely reorganized problem sets at the end of each chapter all figures reproduced at the highest quality physics of semiconductor devices third edition offers engineers research scientists faculty and students a practical basis for understanding the most important devices in use today and for evaluating future device performance and limitations a solutions manual is available from the editorial department

this book covers the physics of semiconductors on an introductory level assuming that the reader already has some knowledge of condensed matter physics crystal structure band structure carrier transport phonons scattering processes and optical properties are presented for typical semiconductors such as silicon but iii v and ii vi compounds are also included in view of the increasing importance of wide gap semiconductors the electronic and optical properties of these materials are dealt with too

this book is an introduction to the principles of semiconductor physics linking its scientific aspects with practical applications it is addressed to both readers who wish to learn semiconductor physics and those seeking to understand semiconductor devices it is particularly well suited for those who want to do both semiconductor physics provides material for a comprehensive upper level undergraduate and graduate course on the subject guiding readers to the point where they can choose a special topic and begin

supervised research the textbook provides a balance between essential aspects of solid state and semiconductor physics on the one hand and the principles of various semiconductor devices and their applications in electronic and photonic devices on the other it highlights many practical aspects of semiconductors such as alloys strain heterostructures nanostructures that are necessary in modern semiconductor research but typically omitted in textbooks for the interested reader some additional advanced topics are included such as bragg mirrors resonators polarized and magnetic semiconductors are included also supplied are explicit formulas in mathematica format for many results to support better understanding semiconductor physics requires little or no prior knowledge of solid state physics and aims to supply the clear and applied focus lacking in competing literature

this book has been designed primarily as a text book for a three semester three hour per week senior or graduate course in semiconductor physics for students in electrical engineering and physics it may be supplemented by a solid state physics course prerequisites are courses in electrodynamics and for some of the chapters basic quantum mechanics emphasis has been laid on physical rather than technological aspects semiconductor physics is in fact an excellent and demanding training ground for a future physicist or electrical engineer giving him an opportunity to practice a large variety of physical laws he was introduced to in the more fundamental courses a detailed treatment of the transport and optical properties of semiconductor is given it was decided to omit the usual description of the material properties of certain semiconductors and instead to include them in between equations in mathematical derivations which i hope will make life simpler for a non theoretician in view of the many thousands of papers which appear every year in the field of semiconductor physics and which are distributed among more than 30 journals it would have been impossible for a single person to write comprehensive book unless there had not been some excellent review articles on special topics published in the series solid state physics festkörper probleme advances in solid state physics semiconductors and semimetals and progress in semiconductors

and i have leaned heavily on such review articles

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

this textbook presents a detailed description of basic semiconductor physics covering a wide range of important phenomena in semiconductors from simple to advanced it introduces and explains four different methods of energy band calculations in the full band region and covers fundamental topics such as the effective mass approximation and electron motion in a periodic potential the boltzmann transport equation and deformation potentials used for the analysis of transport properties the text also examines experimental and theoretical analyses of cyclotron resonance in detail and reviews essential optical and transport properties while covering optical transitions electron phonon interaction and electron mobility it presents numerical calculations of scattering rate relaxation time and mobility for typical semiconductors with bulk quantum well and hemt structures including wideband gap materials such as gan and sic in addition to iv and iii v semiconductors the updated fourth edition includes coverage of new topics such as surface modulated superlattices wannier stark effect bloch oscillation wide band gap semiconductors and photonic crystals featuring full color diagrams calculated with updated physical parameters as well as chapter end problems and solutions this tried and tested textbook on the basics of semiconductors physics is the cornerstone to any graduate or upper level undergraduate course on the subject

semiconductor physical electronics second edition provides comprehensive coverage of fundamental semiconductor physics that is essential to an understanding of the physical and operational principles of a wide variety of semiconductor electronic and optoelectronic devices this text presents a unified and balanced treatment of the physics characterization and applications of semiconductor materials and devices for physicists and material scientists who need further exposure to semiconductor and photonic devices and for device engineers who need additional background on the underlying physical principles this updated and revised second edition reflects advances in semiconductor technologies over the past decade including many new semiconductor devices that have emerged and entered into the marketplace it is suitable for graduate students in electrical engineering materials science physics and chemical engineering and as a general reference for processing and device engineers working in the semiconductor industry

this classroom tested textbook provides a self contained one semester course in semiconductor physics and devices that is ideal preparation for students to enter burgeoning quantum industries unlike other textbooks on semiconductor device physics it provides a brief but comprehensive introduction to quantum physics and statistical physics with derivations and explanations of the key facts that are suitable for second year undergraduates rather than simply postulating the main results the book is structured into three parts each of which can be covered in around ten lectures the first part covers fundamental background material such as quantum and statistical physics and elements of crystallography and band theory of solids since this provides a vital foundation for the rest of the text concepts are explained and derived in more detail than in comparable texts for example the concepts of measurement and collapse of the wave function which are typically omitted are presented in this text in language accessible to second year students the second part covers semiconductors in and out of equilibrium and gives details which are not commonly presented such as a derivation of the density of states using

dimensional analysis and calculation of the concentration of ionized impurities from the grand canonical distribution special attention is paid to the solution of Poisson's equation a topic that is feared by many undergraduates but is brought back down to earth by techniques and analogies from first year physics finally in the third part the material in parts 2 and 3 is applied to describe simple semiconductor devices including the MOSFET the Schottky and PN junction diodes and optoelectronic devices with a wide range of exercises this textbook is readily adoptable for an undergraduate course on semiconductor physics devices and with its emphasis on consolidating and applying knowledge of fundamental physics it will leave students in engineering and the physical sciences well prepared for a future where quantum industries proliferate

excellent bridge between general solid state physics textbook and research articles packed with providing detailed explanations of the electronic vibrational transport and optical properties of semiconductors the most striking feature of the book is its modern outlook provides a wonderful foundation the most wonderful feature is its efficient style of exposition an excellent book physics today presents the theoretical derivations carefully and in detail and gives thorough discussions of the experimental results it presents this makes it an excellent textbook both for learners and for more experienced researchers wishing to check facts i have enjoyed reading it and strongly recommend it as a text for anyone working with semiconductors i know of no better text i am sure most semiconductor physicists will find this book useful and i recommend it to them contemporary physics offers much new material an extensive appendix about the important and by now well established deep center known as the dx center additional problems and the solutions to over fifty of the problems at the end of the various chapters

provides a modern introduction to semiconductor physics presenting the basic information necessary to understand semiconductors along with some of the latest theories and developments based on the author's undergraduate course this book bridges the gap between basic subjects such as quantum mechanics and

maxwell's equations and the fundamental processes determining the behaviour of semiconductors following a quantum mechanics approach this text is predominantly aimed at scientists rather than engineers and forms the basis for the understanding of modern mesoscopic physics in semiconductors and quantum devices like resonant tunneling diodes rather than attempting to comprehensively cover all aspects of semiconductor physics this text aims to cover the most important and interesting aspects of this subject to scientists starting with the development of semiconductor physics from basic quantum mechanics the text moves on to cover band structure and effective mass theory before covering electron phonon coupling and charge transport it concludes with a chapter on optical transitions students will need some knowledge of quantum mechanics and solid state although this is covered to some extent in the book features concise introduction to the basics of semiconductor physics bridges the gap between fundamental subjects such as quantum mechanics and maxwell's equations and the processes determining the behaviour of semiconductors describes semiconductor theory from a full quantum mechanical approach an accessible introduction avoiding reliance on group theory contents preface notation conventions introduction electrons nuclei and hamiltonians band structure the  $k$   $p$  approximation effective mass theory the crystal lattice electron phonon coupling charge transport optical transitions band electrons in an optical field appendix a the hydrogen atom appendix b the harmonic oscillator appendix c perturbation theory appendix d tensors in cubic crystals appendix e the classical limit appendix f some fourier transforms appendix g exercises bibliography

provides a basis for understanding the characteristics operation and limitations of semiconductor devices this title deals with the electrical properties and characteristics of semiconductor materials and devices it intends to bring together quantum mechanics the quantum theory of solids and semiconductor material physics

semiconductor physics a formula handbook is an indispensable guide that distills the complex principles

of semiconductor physics into clear and concise formulas covering essential topics such as band theory carrier transport semiconductor devices and optoelectronic phenomena this handbook provides quick access to key equations and principles needed for understanding semiconductor behavior and designing electronic and optoelectronic devices whether you re a student researcher or industry professional in the field of electrical engineering or materials science this book serves as a valuable reference for mastering the fundamental aspects of semiconductor physics and its applications in modern technology

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