Graduate Texts in Physics

The Physics of Semiconductors

An Introduction Including Nanophysics and Applications

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3. Auflage 2016. Buch. XXXIX, 989 S. Hardcover
ISBN 978 3 319 23879 1
Format (B x L): 15,5 x 23,5 cm
Gewicht: 1879 g

Weitere Fachgebiete > Physik, Astronomie > Thermodynamik > Festkörperphysik, Kondensierte Materie

Preface

Semiconductor electronics is commonplace in every household. Semiconductor devices have enabled economically reasonable fiber-based optical communication, optical storage, and high-frequency amplification and have recently revolutionized photography, display technology, and lighting. By now solar energy harvesting with photovoltaics contributes a significant portion to the energy mix. Along with these tremendous technological developments, semiconductors have changed the way we work, communicate, entertain, and think. The technological progress of semiconductor materials and devices is evolving continuously with a large worldwide effort in human and monetary capital. For students, semiconductors offer a rich and exciting field with a great tradition, offering diverse fundamental and applied topics [1] and a bright future.

This book introduces students to semiconductor physics and semiconductor devices. It brings them to the point where they can specialize and enter supervised laboratory research. It is based on the two-semester semiconductor physics course taught at Universität Leipzig in its Master of Science physics curriculum. Since the book can be followed with little or no pre-existing knowledge in solid-state physics and quantum mechanics, it is also suitable for undergraduate students. For the interested reader several additional topics are included in the book that can be covered in subsequent, more specialized courses. The material is selected to provide a balance between aspects of solid-state and semiconductor physics, the concepts of various semiconductor devices and modern applications in electronics and photonics.

The first semester contains the fundamentals of semiconductor physics (Part I, Chaps. 1–10) and selected topics from Part II (Chaps. 11–20). Besides important aspects of solid-state physics such as crystal structure, lattice vibrations, and band structure, semiconductor specifics such as technologically relevant materials and their properties, doping and electronic defects, recombination, surfaces, and hetero- and nanostructures are discussed. Semiconductors with electric polarization and magnetization are introduced. The emphasis is put on inorganic semiconductors, but a brief introduction to organic semiconductors is given in Chap. 17. Dielectric structures (Chap. 19) serve as mirrors, cavities, and microcavities and are a vital part of many semiconductor devices. Other chapters give introduction to carbon-based nanostructures and transparent conductive oxides (TCOs). The third part (Part III, Chaps. 21–24) is dedicated to semiconductor applications and devices that are taught in the second semester of the course. After a general and detailed discussion of various diode types, their applications in electrical circuits, photodetectors, solar cells, light-emitting diodes, and lasers are treated. Finally, bipolar and field-effect transistors including thin-film transistors are discussed.

In the present text of the third edition, a few errors and misprints of the second edition have been corrected. Several topics have been extended and are treated in more depth, e.g., double donors and double acceptors, negative-U centers, Boltzmann transport equation, ionic conductivity, hopping conductivity, impact ionization, thermopower, polarons, intra-band transitions, amorphous semiconductors, disorder effects, heteroepitaxy on mismatched, curved and patterned substrates, and noise. A chapter on semiconductor surfaces has been added.

The list of references has been augmented by almost 400 quotations with respect to the list in the second edition. All references now include title and complete page numbers. The references have been selected to (i) cover important historical and milestone papers, (ii) direct to reviews and topical books for further reading and (iii) give access to current literature and up-to-date research. In Fig. 1, the original papers within the more than 1800 references in this book are shown by year. Roughly three phases of semiconductor physics and technology can be seen. Before the realization of the first transistor in 1947, only a few publications are noteworthy. Then an intense phase of understanding the physics of semiconductors and developing semiconductor technology and devices based on bulk semiconductors (mostly Ge, Si, GaAs) followed. At the end of the 1970s, a new era began with the advent of quantum wells and heterostructures, and later nanostructures (nanotubes, nanowires, and quantum dots) and new materials (e.g., organic semiconductors, nitrides or graphene). Also several very recent references to emerging topics such as 2D materials, topological insulators or novel amorphous semiconductors are given.

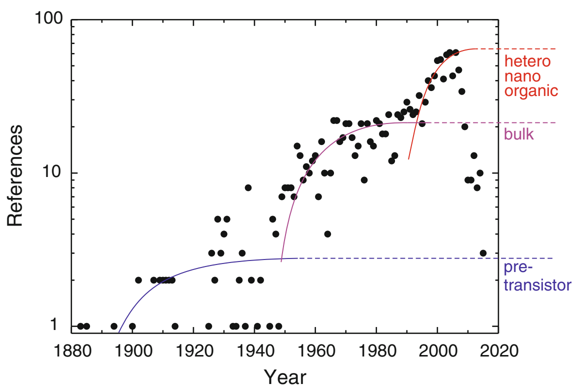

Fig. 1 Histogram of references in this book

I would like to thank many colleagues for their various contributions to this book, in alphabetical order (if no affiliation is given, at the time at Universität Leipzig): Gabriele Benndorf, Klaus Bente, Rolf Böttcher, Matthias Brandt, Christian Czekalla, Christof Peter Dietrich, Pablo Esquinazi, Heiko Frenzel, Volker Gottschalch, Helena Franke (née Hilmer), Axel Hoffmann (TU Berlin), Alois Krost† (Otto-von-Guericke Universität Magdeburg), Michael Lorenz, Stefan Müller, Thomas Nobis, Rainer Pickenhain, Hans-Joachim Queisser (Max-Planck-Institut für Festkörperforschung, Stuttgart), Bernd Rauschenbach (Leibniz-Institut für Oberflächenmodifizierung, Leipzig), Bernd Rheinländer, Heidemarie Schmidt, Mathias Schmidt, Rüdiger Schmidt-Grund, Matthias Schubert, Jan Sellmann, Oliver Stier (TU Berlin), Chris Sturm, Florian Tendille (CNRS-CRHEA), Gerald Wagner, Eicke Weber (UC Berkeley), Holger von Wenckstern, Michael Ziese, and Gregor Zimmermann. This book has benefitted from their comments, proof reading, experimental data, and graphic material. Also, numerous helpful comments from my students on my lectures and previous editions of this book are gratefully acknowledged.

I am also indebted to many other colleagues, in particular to (in alphabetical order) Gerhard Abstreiter, Zhores Alferov, Martin Allen, Levon Asryan, Günther Bauer, Manfred Bayer, Friedhelm Bechstedt, Dieter Bimberg, Otto Breitenstein, Len Brillson, Fernando Briones, Immanuel Broser†, Jean-Michel Chauveau, Jürgen Christen, Philippe De Mierry, Steve Durbin, Laurence Eaves, Klaus Ellmer, Guy Feuillet, Elvira Fortunato, Ulrich Gösele†, Alfred Forchel, Manus Hayne, Frank Heinrichsdorff, Fritz Henneberger†, Detlev Heitmann, Robert Heitz†, Evamarie Hey-Hawkins, Detlef Hommel, Evgeni Kaidashev, Eli Kapon, Nils Kirstaedter, Claus Klingshirn, Fred Koch†, Jörg Kotthaus, Nikolai Ledentsov, Peter Littlewood, Dave Look, Axel Lorke, Anupam Madhukar, Ingrid Mertig, Bruno Meyer†, David Mowbray, Hisao Nakashima, Jörg Neugebauer, Michael Oestreich, Louis Piper, Mats-Erik Pistol, Fred Pollak†, Volker Riede, Bernd Rosenow, Hiroyuki Sakaki, Lars Samuelson, Darrell Schlom, Vitali Shchukin, Maurice Skolnick, Robert Suris, Volker Türck, Konrad Unger†, Victor Ustinov, Leonid Vorob'jev, Richard Warburton, Alexander Weber, Peter Werner, Wolf Widdra, Ulrike Woggon, Roland Zimmermann, Arthur Zrenner, Alex Zunger, and Jesús Zúñiga-Pérez, with whom I have worked closely, had enjoyable discussions with and who have posed questions that stimulated me. It is my distinct privilege and joy that this list becomes longer as I pursue studies in semiconductor physics but sadly the number of †-symbols increases too rapidly from edition to edition.

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http://www.springer.com/978-3-319-23879-1

The Physics of Semiconductors
An Introduction Including Nanophysics and Applications
Grundmann, M.
2016, XXXIX, 989 p. 855 illus., 200 illus. in color.,
Hardcover
ISBN: 978-3-319-23879-1