Preface

People come to technical books with a vast array of different needs and requirements, arising from their differing educational backgrounds, professional orientations and career objectives. This is particularly evident in the field of semiconductors, which stands at the juncture of physics, chemistry, electronic engineering, material science and mathematics. No longer just an academic discipline, this field is at the heart of an ongoing revolution in communications, computation and electronic device applications, that innovate many fields and change modern life in myriad ways, large and small. Its profound impact and further potential command interest and attention from all corners of the earth, and from a wide variety of students and researchers.

The clear need to address a broadly diversified and variously motivated readership has weighed heavily in the authors' considerations. It poses a pedagogical problem faced by many teachers of intermediate level courses on semiconductor physics. Generally speaking, every student has previously studied about half of the course material. The difficulty lies in the fact that each student's exposure is likely to have been to a *different* half, depending on which lower level courses and teachers they have had, and where the emphasis lay. To accommodate readers with varied backgrounds we start from first principles and provide fully detailed explanations and proofs, assuming only that the reader is familiar with the Schrödinger equation. This intensively tutorial treatment of the electronic properties of semiconductors includes recent fundamental developments and is carried through to the physical principles of device operation, to meet the needs of readers interested in engineering aspects of semiconductors, as well as those interested in basic physics. Clarity of explanation and breadth of exposure relating to the electronic properties of semiconductors, from first principles to modern devices, are our principal objectives in this frankly pedagogical book. We offer full mathematical derivations to strengthen understanding and discuss the physical significance of results, avoiding reliance on 'hand waving arguments alone.

To support the reader's introduction to the physics of semiconductors, we provide a thorough grounding in the basic principles of solid state physics, assuming no prior knowledge of the field on the part of the reader. An elementary discussion of the crystal structure, chemical nature and macroscopic properties characterizing semiconductors is given in Chapter 1. Moreover, we also include an extensive appendix to guide the reader through group theory and its applications in connection with the symmetry properties of semiconductors, which are of major importance. Beside spatially homogeneous bulk semiconductors, we undertake a full exposition of inhomogeneous semiconductor junctions and heterostructures because of their crucial role in devices. To do this in a coherent way, the physics of bulk semiconductors is presented with emphasis on topics which are important for semiconductor junctions and devices. These include the band structure of ideal bulk semiconductors (Chapter 2), the localized states of bulk semiconductors with perturbations and the influence of external fields on band states (Chapter 3), the statistics of charge carriers in thermodynamic equilibrium (Chapter 4) as well as non-equilibrium processes in bulk semiconductors (Chapter 5). Such non-equilibrium processes can be treated from a macroscopic rather than a microscopic point of view, and we exploit this opportunity in the present volume. This means, in particular, that we do *not* trace back the characteristic transport, optical and other macroscopic parameters of semiconductors to the microscopic scattering mechanisms, but consider them as phenomenological quantities. In this connection, we forego a detailed treatment of lattice vibrations. This sacrifice is made in the present volume to accommodate the need for a discussion in depth of the physics of semiconductor $pn-$, hetero-, metal-, and insulator junctions. (Phonons will be treated jointly with the microscopic physics of transport, optical and screening properties of semiconductors in a second volume of this book, which will be written in the same tutorial manner as this one.) In regard to the physics of inhomogeneous semiconductor structures, we cover the properties of junctions in equilibrium (Chapter 6) as well as in the presence of external perturbations (Chapter 7). The latter topic is, of course, directly concerned with the physics of semiconductor devices. Throughout the book recent fundamental achievements in semiconductor physics are incorporated, for example, deep centers, clean semiconductor surfaces and semiconductor microstructures such as quantum wells and superlattices.

Reviewing the many meritorious books on semiconductors already in existence, we feel that there is a need for the particular choices of material and treatment we have made here, and that this book will serve well the needs of readers of varied backgrounds and interests. In its unified treatment of semiconductor physics and device operation from a common physical point of view, this volume offers physics-oriented readers a fuller expository exposure to device principles and recent device developments than is readily available in many other books on semiconductor physics; in addition, it offers device-oriented readers a more thorough grounding in the physical principles of semiconductors than is readily available in many semiconductor device books. Moreover, our treatment of the material is coherently structured and sufficiently deep that this book should also prove to be a valuable resource for researchers working on many advanced topics and devices involving electronic structure and processes in semiconductors. Moreover, it offers a thorough understanding of the field to newcomers to the point that they become capable of carrying out new research themselves in the areas treated here.

The book has emerged from lectures which the authors presented for physics students at the Humboldt-University of Berlin, Germany, and the State University of Sao Paulo, Brazil, and for physics and engineering physics students at the Stevens Institute of Technology in Hoboken, New Jersey, U.S.A. Part of the book has similarities with the german book "Grundlagen der Halbleiterphysik" ("Fundamentals of Semiconductor Physics") which was written by one of us (R. E.) together with A. Schenk. We are thankful to Dr. Schenk (now at ETH Zürich) for allowing us to use part of his work in the present volume. In writing this book we have had excellent support from many of our colleagues at our own and other Universities. We are particularly thankful to Prof. Dr. J. Auth (Humboldt-University Berlin), Prof. Dr. F. Bechstedt (Friedrich-Schiller University Jena), Prof. Dr. W. A. Harrison (Stanford University), Prof. Dr. M. Scheffler (Fritz-Haber Institut, Berlin), Prof. Dr. J. R. Leite, Prof. Dr. A. Fazzio, and Prof. Dr. J. L. Alves (State University Sao Paulo), as well as to Prof. Dr. H. L. Cui, Prof. Dr. G. Rothberg, Mr. G. Lichtner (Stevens Institute of Technology), and Prof. Dr. G. Gumbs (Hunter College, CUNY, New York), who read parts of the manuscript and contributed helpful suggestions and critical remarks. The technical assistance of Mrs. Hannelore Enderlein is gratefully acknowledged.

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