Preface

This book bridges the gap between elementary quantum transport books and more rigorous graduate-level material on the quantum field theory of many-body systems. The book presents a simple, intuitive understanding of Green's function theory and its application for the analysis of nanoelectronic devices. It attempts to explain the underlying physics with a consistent theoretical footing. This book targets graduate-level students and researchers in electronics and physics. One of the stimulating factors for the writing of this book was the many requests I received from scientists and students who wanted to receive a copy of my dissertation, where I addressed a similar topic. This book, however, includes more materials on the underlying principles, numerical techniques, and applications. It is my hope that the inclusion of these elements will help young scientists to contribute something new to the frontiers of nanoelectronics.

In this book after a short introduction in Chap. 1, the postulates of quantum mechanics are briefly presented in Chap. 2. As electrons in solids experience various scattering mechanisms, an accurate study of electron transport in solid state devices requires the knowledge and techniques of many-body theory. Chapters 3 and 4, respectively, review the basic principles of many-body systems and band theory of electrons in solids. With the aid of statical mechanics, which is discussed in Chap. 5, we relate microscopic and macroscopic quantities in many-body systems and study systems both under equilibrium and non-equilibrium condition. Next, the Green's function formalism is presented in Chap. 6. As the exact solution of the Green's function for a realistic system cannot be obtained, approximation methods are needed. Such approximations and the related methods are discussed in the rest of this chapter. After building a solid theoretical foundation, numerical methods for calculating Green's functions are presented in Chap. 7. All the elements of the kinetic equations, which are the device Hamiltonian, contact self-energies, and scattering self-energies are carefully studied and efficient methods for evaluation are explained. Finally, these methods are applied to the study of electron, spin, and phonon transport in nanoribbons in Chap. 8. Additionally, device characteristics of tunneling transistors and photo-detectors are investigated using the outlined methodologies.

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