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Abstract

The importance of nanoelectronics is enormous given the constant demand for enhancement in performance of electronic and computing devices. While Moore's law predicted the exponential increase in the power of processing units, the associated device level physics have brought about a new set of interdisciplinary challenges. Miniaturization of transistors has been the key to the unprecedented growth of microelectronics and its gradual transition to lower length scales. However, system sizes at the nanoscale being comparable to the mean free paths of the charge carriers (*electrons*), additional considerations in the transport processes need to be accounted for to obtain a thorough understanding of the operation of these molecular scale devices. The fundamental operating principles though similar, issues related to ballistic transport and wave nature of electrons, effects of tunneling etc., become significant at such small system dimensions.

Disciplines

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Comments

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Book Review

Nanoelectronic Devices, by Byung-Gook Park, Sung Woo Huang, and Young June Park, Pan Stanford Textbook Series on Nanotechnology—Volume 1, Singapore, 2012.

REVIEWED BY GANESH BALASUBRAMANIAN[1]

The importance of nanoelectronics is enormous given the constant demand for enhancement in performance of electronic and computing devices. While Moore's law predicted the exponential increase in the power of processing units, the associated device level physics have brought about a new set of interdisciplinary challenges. Miniaturization of transistors has been the key to the unprecedented growth of microelectronics and its gradual transition to lower length scales. However, system sizes at the nanoscale being comparable to the mean free paths of the charge carriers (*electrons*), additional considerations in the transport processes need to be accounted for to obtain a thorough understanding of the operation of these molecular scale devices. The fundamental operating principles though similar, issues related to ballistic transport and wave nature of electrons, effects of tunneling etc., become significant at such small system dimensions.

Nanoelectronic Devices is a unique book that integrates the basic concepts of nanoscale physics with advanced engineering ideas to discuss the different aspects of device design and functioning. The book can be broadly classified into two parts: the first section provides an overview of quantum mechanics, electronic transport, and basic operational principles. The authors make a dedicated attempt to offer sufficient background in physics to set the stage for the later chapters. The content is brief and targeted towards providing a crash course in quantum physics and electronics, so knowledge of solid-state physics is definitely a prerequisite for comprehensive understanding of the nanoelectronics subject matter. The second part focuses on in-depth description of quantum devices. Discussions on electron transport in quantum wells as well as for 1D motion in quantum wires and 0D processes in quantum dots are sufficiently expanded to provide a good platform for graduate education and research.

Chapter 1 begins with basics of quantum mechanics, wave nature of electrons, Schrödinger equation, and extends to the concepts of energy bands and wave vectors. The origins of the semiclassical equation of electron motion are suitably described followed by discussions of confinement effects and tunneling. Chapter 2 introduces semiconductors and fundamentals of carrier transport, Fermi-Dirac distribution and continues to the relevance of generation, diffusion, recombination, and continuity in molecular scale electronics. The chapter concludes with introduction followed by details of *p-n* junctions and a brief overview of heterojunctions. Chapter 3 entitled *MOS Structure and CMOS Devices* exposes the readers to metal-oxide-semiconductors (MOS) and associated devices, MOSFET, and CMOS. The structure, operational principles, governing equations for carrier transport as well as the associated circuitry are explained extensively.

The second part of the book provides exhaustive analyses of the functioning and underlying physics of the different quantum devices. Chapter 4: *Quantum Well Devices*, introduces the MOSFET scaling theory and familiarizes the readers with the challenges involved in scaling issues with device miniaturization. The strategies discussed here to overcome these scientific problems for nanoelectronic systems illustrate the vast experience of the authors in the related research, as well their multidisciplinary vision about the subject. The next chapter describes the phenomenon of ballistic electron transport in 1D systems such as nanowires. Such devices have received widespread attention from the scientific community over the last decade because of their ability to control the direction of carrier transport. The authors extend the discussion further to 0D devices in Chapter 6, *Quantum Dot Devices*, and explain the working of single electron transistors. An interesting aspect of these chapters is that they provide a strong theoretical base for the advanced engineering concepts with the discussions on modeling the transport through these devices.

The last chapter seems to be inspired with current research advances in molecular sensing. Chapter 7 on MOSFET based molecular sensors broadens the discussions of carrier motion and device physics to solution chemistry and biomolecular detection. Atomic charges play a significant role in molecular interactions within electrolytes, ionic solutions, and aqueous systems containing biological molecules. Hence, such a chapter provides a timely exposure for readers on fundamental issues related to mechanobiology, biomedical sciences, and sensing. Again, the intrinsic attitude of the authors towards interdisciplinary science and engineering is reflected from their enthusiasm to present such contemporary topics in this book.

The authors have done a good job of correlating physics with engineering principles, which is noteworthy. The book is well organized with concise set of bibliographical references for further reading. The appendices and the color figures at the end of the book enhance the quality and usefulness of the material presented. The color illustrations offer improved visual comprehension of the device operations. The topics are coherent and meticulously described given how difficult it is to explain such advanced concepts. This book, which encourages readers to learn the fundamentals of physics before venturing into device design and application, is a great resource for both graduate students and researchers although adapting it for problem-based teaching might require some effort especially due to the lack of solved numerical examples.

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