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Book review

Nanoscale Materials and Devices for Electronics, Photonics and Solar Energy, A. Korkin, S. Goodnick, R. Nemanich. Springer International Publishing, Cham, Switzerland (2015). ISBN: 978-3-319-18632-0 (Print) 978-3-319-18633-7 (Online).

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The NGC2014 conference series book (the 6th Nano and Giga Forum) invited academic and industrial researchers to present tutorials and original research papers dedicated to solving scientific and technological problems in a number of areas relevant toward the continued progress in information and renewable energy technologies. The *Nano and Giga Challenges* (NGC) conference series has had a long tradition of tutorial lectures given by world-renowned researchers. As early as the first NGC forum in Moscow, Russia, in 2002, the organizers realized that publication of the lectures notes from NGC2002 would be a valuable legacy of the meeting and a significant educational resource and knowledge base for students, young researchers, and experts alike. The first NGC conference series book was published by *Elsevier* and named after the meeting itself – *Nano and Giga Challenges in Microelectronics* [1]. Subsequent books based on the tutorial lectures of the NGCM2004 [2], NGC2007 [3], NGC2009 [4], NGC2011 [5] and the most recent NGC2014 [6] conference, have been published by Springer in the *Nanostructure Science and Technology* series.

A subset of papers has been captured from the many exciting NGC2014 conference tutorials and presentations and organized into 8 chapters. Chapter 1 delves into the timely topic of ultra-low power devices by addressing the main trends, challenges, limits and possible solutions for strongly reducing the energy per binary switching event. After reviewing challenges to continue Moore's law and limits of logic switching, the discussion continues with novel materials and innovative device architectures for very low power CMOS (e.g. High K, SOI, and Multi-Gate), and then moves on to 'Beyond-CMOS' nanodevices for ultra-low power operation (e.g. Nanowires, Tunnel FETs, negative capacitance FETS, NEMS, etc. . .). Chapter 2 continues this bearing for novel "beyond-CMOS" devices with reviewing proposals targeted toward revolutionizing the current semiconductor technology with "pseudospintronic" devices which include the Bilayer pseudoSpin Field-Effect Transistor (BiSFET), the Bilayer pseudoSpin Junction Transistor (BiSJT), and potential applications of near-perfect Coulomb drag. These pseudospintronic devices are based on a completely different physics of switching compared to traditional CMOS, and have concepts employing possible room-temperature interlayer electron-hole exciton condensates in bilayer two-dimensional (2D) material systems for enhanced interlayer conduction and ultra-low switching voltages. The chapter's main focus is device performance *in the presence* of such electron-hole exciton condensates through Graphene-based pseudospintronic device simulations with quantum transport simulations for the essential physical properties, and SPICE-level circuit simulations, to demonstrate possible super low-power switching that could greatly exceed even the "end-of-roadmap" CMOS targets. In addition, the fabrication concerns of such novel devices are also discussed along with recent experimental progress.

More confirmation that graphene has become the object of many recent interesting experimental and theoretical studies on two-dimensional (2D) electron systems is brought forward in chapter 3 which covers Graphene based Photonics and Plasmonics. Included in this Chapter 3 is the discussion of the possibilities of tunability of the photonic band structure of graphene-based photonic crystals, plasmonic quantum generator, and surface plasmon amplification. A detailed microscopic theory of graphene monolayer and multilayers spectroscopy is also developed. The chapter begins by covering the dielectric function of graphene and graphene nanoribbons and discusses the universal optical absorption in graphene. This is followed by a discussion of 1D and 2D graphene-based photonic crystals after which the authors consider the localization of the electromagnetic waves on defects in the 1D and 2D photonic crystals. Also reviewed are the properties of plasmons and magnetoplasmons in graphene layers and graphene nanoribbons including THz graphene nanoribbon based spasers. The applications of graphene for photonics and optoelectronics are reviewed.

Related to the trend for ultra-low power consumption devices, is the emergent understanding that the sustainable development of human society requires use of new alternate sources of energy to natural gas and oil. Chapter 4 pivots us toward this end through the topic of Materials Challenges for Concentrated Solar Power (CSP). Electrical power generating plants which are driven by concentrating solar power (CSP) have been attracting increasing interest to understanding and improving the current state of CSP technology. A CSP system converts solar to thermal to electrical energy. This chapter 4 covers a number of CSP challenges that have already been met, along with new innovations in solar collectors, heat transfer fluid materials, and thermal energy storage.

After this visit to the 'Giga' world of CSP, Chapter 5 brings us back toward and beyond the 'Nano' including quantum dots

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with the topic of Atomistic Simulations of Electronic and Optical Properties of Semiconductor Nanostructures. There is currently increasing interest in self-assembled quantum dots (SADs), quantum wires, and colloidal nanocrystals (CNCs) due to their potential application in photonic devices, including lasers, detectors, amplifiers and solar cells along with an importance for optical memories, sources of single photons and entangled photon pairs. Thus, the electronic and optical properties of these systems are of great importance. However, the nature of these systems, such as SADS, can preclude the use of ab-initio techniques. Chapter 5 presents a tight-binding based multi-million atom computational platform to assist with the calculation/simulation of the electronic and optical properties of these interesting systems.

Chapter 6 has us progressing in a survey toward the nanosized with a look at solid-state devices having features similar in size to single molecules which have become a reality in recent years. These include such devices as solid state nanopores, carbon nanotube field-effect transistors, nanoscale detectors of single molecule redox chemistry, and tunnel junctions; all of which herald a revolution in electronics, combining the computing potential of CMOS with the diversity of chemistry. Chapter 6 considers the electrochemical requirements needed for stable operation of such devices and also reviews sources of noise, and how correlations in noise generated by nanoscale sensors can be used to carry out single molecule spectroscopy. The purpose of this chapter is not to review this new field, although it does describe some devices by way of examples. Rather, the primary aim is to introduce the physical chemistry aspects of these devices that may not be familiar to the general semiconductor physics audience, and to outline some important, and likely under-appreciated aspects, of fluctuations at the nanoscale.

Chapter 7 also has a signal aspect to it by way of reviewing recent advances in terahertz-wave generation using graphene and compound semiconductor nano-heterostructures. One of the key tasks of modern microelectronics has been the development of compact, tunable and coherent sources and detectors operating in the terahertz (THz) regime. This chapter discusses some of the unique properties of graphene, such as Plasmons with high velocity, peculiar transport properties owing to the massless and gapless energy spectrum, and a negative-dynamic conductivity in the THz spectral range, which may enable new types of THz lasers.

Finally, Chapter 8 goes beyond the diffraction limit to explore optics at the deep nanoscale with the topic Optics of hybrid nanomaterials in the strong coupling regime. Advances in materials fabrication techniques along with modern experimental equipment have fueled the rapid surge of nano-optics in recent years and an emphasis on plasmonic materials in these applications has been due to several intriguing properties of nanoscale structures comprised of noble metals: their unique ability to resonantly scatter incident electromagnetic radiation in the visible part of the spectrum and extreme light concentration. Despite much progress, the research in optics of hybrid nanomaterials far from complete. Chapter 8 reviews the current progress in this research area emphasizing important goals and underlining open questions with a focus toward the theoretical modeling of linear and nonlinear optical properties of hybrid systems.

In summary, the NGC2014 conference book from the *Nanostructure Science and Technology* series is of great value for both "newcomers" and seasoned experts to the topics covered. This year's conference material was particular relevant toward progress in information and renewable energy technologies with the presented material continuing the long '*Nano and Giga Challenges in Microelectronics*' tradition of high quality tutorial lectures given by world-renowned researchers and will give the reader a taste of this unique and popular conference series.

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