NanoScience and Technology

Low Dimensional Semiconductor Structures

Characterization, Modeling and Applications

Bearbeitet von
Hilmi Ünlü, Norman J. M. Horing

1. Auflage 2012. Buch. xiv, 162 S. Hardcover
ISBN 978 3 642 28423 6
Format (B x L): 15,5 x 23,5 cm
Gewicht: 432 g

Preface

The modern world has witnessed the exceptionally rapid development of both our theoretical understanding and the technological advancement of semiconductor devices, following the invention of the first transistor in 1949. Improved techniques for growing semiconductor thin films of differing structural and electronic properties, even with layer thickness approaching atomic dimensions, have provided new opportunities for basic scientific studies and device applications. Such new fabrication technologies have made it possible to reduce device dimensions to the point where quantum size effects play a significant role in any realistic description of device operation and are required to reliably predict their performance in electronic and optical applications. Contemporary transistors operate much faster than conventional ones and have led to a many-thousand-fold increase in speed, which is crucial to the electronic and optical communication and computer industries.

Today's electronic and optical communications and information technology is still silicon- semiconductor-based and can, thus far, meet the current needs by either increasing the production rate or by developing new production technologies. As a result of intensive research and development activities, the size of the existing silicon semiconductor devices is expected to be about 10–20 nm in the year 2020. Accordingly, a new technology is needed for the production of electronic and optoelectronic devices that are smaller in size and volume and faster in speed. This will involve many new scientific and technological problems requiring solution before such a new technology is actually put into use to meet consumers' needs for better and faster electronics- and computer-based communications. In order to overcome these problems, the world's leading scientists and engineers have been carrying out intensive research on low dimensional/nanoscience and nanotechnology to create future information and communication technologies. Nanoscience and nanotechnology refer to the comprehensive interdisciplinary body of knowledge on the nanometer size scale involving the science (physics, chemistry, biology, and materials science) and engineering (electronics, computer, mechanical, chemical, construction, textiles, environment, etc.) fields.

Low dimensional/nanoscience and nanotechnology was put forward as a concept by Richard Feynman in a seminar called "There is plenty of room at the bottom",

which he gave at an American Physical Society meeting at the California Institute of Technology (Caltech) on December 29, 1959. The meaning of the word "nano" is small, and 1 nm is equal to one billionth of a meter (1 nm = 1/1,000,000,000 m). The physical and chemical properties of materials on that scale depend upon size and may be controlled using it. Indeed, the production of new low-dimensional materials is possible at the nanoscale. Feynman described a process to manipulate atoms and molecules to organize and operate devices and/or systems at lower dimensions, as needed. He also noted that scaling issues can arise due to possible changing of the magnitudes of physical phenomena, such as surface tension, van der Waals attraction, etc.

Since that first proposal of nanotechnology by Feynman in 1959, intensive research and development activities have gained momentum in the last 30 years. Nanotechnology and nanoscience had two major developments in the early 1980s: (1) cluster science and the discovery of the scanning tunneling microscope (STM), which led to the discovery of fullerenes in 1985 and carbon nanotubes just a few years later, and (2) further major developments in the area of the synthesis and properties of semiconductor nanocrystals, such as metal-oxide nanoparticles and quantum dots. Rapid development continued in the area of structural characterization of materials. The discovery of atomic force microscopy (AFM) took place just 6 years after the STM was invented.

In recent years, a truly extraordinary volume of research has been carried out all over the world on low-dimensional semiconductors, metals, ceramics, polymers, and composites containing nanostructured materials for applications in health/disease, pharmacology, energy, agriculture/food, electronics and communication, information processing and storage using the multiple functionality of the recently developed nanomaterials. This has spurred new industry in various fields, including defense technology. Newly created and improved technologies, including electronic communications, have intensified scientific research and technological development involving structures composed of atoms and molecules, as well as biological structures. Indeed, some recent scientific studies have been carried out on colloidal quantum dots. Since quantum dots have carriers confined in all directions (zero dimensions), they have a sharper density of states than that of higher dimensional (two- and three-dimensional) structures. Correspondingly, quantum dots have superior charge transport and optical properties and, consequently, much intensive research has been done to use them in making diode lasers, transistors, and biological sensors.

It was a great pleasure to host the International Conference on Nanomaterials and Nanosystems (NanoMats2009; http://www.nanomats.itu.edu.tr) and the Fourth National Conference on Nanoscience and Nanotechnology (NanoTr4; http://www.nanotr4.itu.edu.tr) at İstanbul Technical University, İstanbul, Turkey. In these conferences, all aspects of low dimensional/nanoscience and nanotechnology were addressed. The NanoMats2009 conference was endorsed by the European Materials Research Society (E-MRS; http://www.emrs-strasbourg.com/) and was organized in collaboration with scientists from İstanbul Technical University, İstanbul University, Stevens Institute of Technology, and the University of Essex. Both

NanoMats2009 and NanoTr4 have successfully brought together researchers from over a dozen countries in the areas of physics, chemistry, biology, materials science, and engineering to review the current status of the field. The participants of both NanoMats2009 and NanoTr4 had the opportunity to learn about the latest results and cutting-edge advances in all major areas of nanomaterials and nanosystems from leading international academic and industrial experts in the field. In NanoMats2009, 2 Plenary Lectures, 26 Invited Oral Presentations, 60 Oral Presentations, and 126 Poster presentations took place at the conference. Similar remarks pertain to NanoTr4. Participants addressed fundamental issues and solutions in nanomaterials and nanosystems involving a wide range of problems, sharing new ideas and results to delineate outstanding problems and guiding future research.

The focus of the conference presentations was concentrated on fundamental phenomena at the nanoscale, including in its scope the synthesis, properties, characterization and modeling of nanomaterials, nanotechnologies involving nanodevices and nanosystems, imaging, measuring, modeling, and manipulating low-dimensional matter at the nanoscale. The topics covered at the NanoMats2009 and NanoTr4 conferences are of vital importance in a wide range of modern technologies employed in most industries, communication, healthcare, energy conservation, biology, food, environment, and education, and thus will have a broad impact on our society. NanoMats2009 and NanoTr4 also had a strong educational and student outreach component that provided opportunities for young investigators to present their research findings and to learn about the most recent developments in this rapidly moving field. On the one hand, this was intended to facilitate fruitful and constructive discussions among the participants, leading to future collaborations between them. On the other hand, the strength of the educational component has led us to feel that its tutorial benefit to the larger body of students and uninitiated is best enhanced by publication in book form, rather than as a superficial conference proceedings of very short research reports. Nevertheless, the cutting-edge conference research papers selected for inclusion here are certainly of interest to all workers in the field.

This book covers a broad range of selected papers presented at NanoMats2009 and NanoTr4. On behalf of the Organizing Committee, we would like to thank all of the participants for their contributions to both NanoMats2009 and NanoTr4 with oral and/or poster presentations, as well as all other attending participants.

Istanbul — Hilmi Ünlü
Hoboken, NJ — Norman J. Horing