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Processing, Characterization and Applications

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《纳米科学与技术》丛书序

在新兴前沿领域的快速发展过程中，及时整理、归纳、出版前沿科学的系统性专著，一直是发达国家在国家层面上推动科学与技术发展的重要手段，是一个国家保持科学技术的领先权和引领作用的重要策略之一。

科学技术的发展和应用，离不开知识的传播：我们从事科学研究，得到了“数据”（论文），这只是“信息”。将相关的大量信息进行整理、分析，使之形成体系并付诸实践，才变成“知识”。信息和知识如果不能交流，就没有用处，所以需要“传播”（出版），这样才能被更多的人“应用”，被更有效地应用，被更准确地应用，知识才能产生更大的社会效益，国家才能在越来越高的水平上发展。所以，数据→信息→知识→传播→应用→效益→发展，这是科学技术推动社会发展的基本流程。其中，知识的传播，无疑具有桥梁的作用。

整个20世纪，我国在及时地编辑、归纳、出版各个领域的科学技术前沿的系列专著方面，已经大大地落后于科技发达国家，其中的原因有许多，我认为更主要的是缘于科学文化的习惯不同：中国科学家不习惯去花时间整理和梳理自己所从事的研究领域的知识，将其变成具有系统性的知识结构。所以，很多学科领域的第一本原创性“教科书”，大都来自欧美国家。当然，真正优秀的著作不仅需要花费时间和精力，更重要的是要有自己的学术思想以及对这个学科领域充分把握和高度概括的学术能力。

纳米科技已经成为21世纪前沿科学技术的代表领域之一，其对经济和社会发展所产生的潜在影响，已经成为全球关注的焦点。国际纯粹与应用化学联合会（IUPAC）会刊在2006年12月评论：“现在的发达国家如果不发展纳米科技，今后必将沦为第三世界发展中国家。”因此，世界各国，尤其是科技强国，都将发展纳米科技作为国家战略。

兴起于20世纪后期的纳米科技，给我国提供了与科技发达国家同步发展的良好机遇。目前，各国政府都在加大力度出版纳米科技领域的教材、专著以及科普读物。在我国，纳米科技领域尚没有一套能够系统、科学地展现纳米科学技术各个方面前沿进展的系统性专著。因此，国家纳米科学中心与科学出版社共同发起并组织出版《纳米科学与技术》，力求体现本领域出版读物的科学性、准确性和系统性，全面科学地阐述纳米科学技术前沿、基础和应用。本套丛书的出版以高质量、科学性、准确性、系统性、实用性为目标，将涵盖纳米科学技术的所有领域，全面介绍国内外纳米科学技术发展的前沿知识；并长期组织专家撰写、编辑出版下去，为我国

纳米科技各个相关基础学科和技术领域的科技工作者和研究生、本科生等，提供一套重要的参考资料。

这是我们努力实践"科学发展观"思想的一次创新，也是一件利国利民、对国家科学技术发展具有重要意义的大事。感谢科学出版社给我们提供的这个平台，这不仅有助于我国在科研一线工作的高水平科学家逐渐增强归纳、整理和传播知识的主动性（这也是科学研究回馈和服务社会的重要内涵之一），而且有助于培养我国各个领域的人士对前沿科学技术发展的敏感性和兴趣爱好，从而为提高全民科学素养作出贡献。

我谨代表《纳米科学与技术》编委会，感谢为此付出辛勤劳动的作者、编委会委员和出版社的同仁们。

同时希望您，尊贵的读者，如获此书，开卷有益！

中国科学院院长
国家纳米科技指导协调委员会首席科学家
2011 年 3 月于北京

Preface

The goal in nanotechnology is to make high-performance nanodevices. For nanodevice fabrications, novel *bottom-up* approach, fabricating devices and systems by hierarchical assembly or controlled growth of nanoscale materials, has attracted tremendous interest. Because this bottom-up method allows single-crystalline nanostructure growth on a variety of substrates, the bottom-up method has been used to prepare high-quality nanomaterials even on amorphous glass, plastic, and graphene substrates. In the bottom-up approach, one-dimensional (1D) semiconductor nanostructures, including nanorods, nanowires, nanobelts, and nanotubes, are vital components for fabricating optoelectronic and photonic nanodevices. In particular, 1D semiconductor nanostructures such as nanowires, nanorods, and nanotubes open up significant opportunities for the fabrication of high-performance optoelectronic nanodevice. For the fabrication of high-efficiency optoelectronic devices including light-emitting diodes (LEDs) and solar cells, 1D heteroepitaxial nanostructures with well-defined crystalline interfaces must be essential building blocks since embedding quantum structures in individual nanostructures would enable novel physical properties such as quantum confinement to be exploited, such as the continuous tuning of spectral wavelength by varying the well thickness. Sophisticated optoelectronic nanodevices can be readily fabricated by composition and doping controls of semiconductor nanostructures. Furthermore, nanodevices based on vertically ordered 1D nanostructures permit extremely small size and ultrahigh density. Here, this book introduces the current status of semiconductor nanostructures for optoelectronic devices and outlines the processing and characterizations of semiconductor nanostructures and their optoelectronic device applications.

In Chaps. 1–6, current research activities related to the synthesis of 1D semiconductor nanostructures by various growth methods and their optoelectronic device applications are reviewed. Chapter 1 provides an overview of vapor–liquid–solid growth process, which has widely been employed for preparation of semiconductor nanowires. Using this technique, Si, Ge, GaAs, InP, GaP, ZnO, and GaN nanowires have been synthesized and several nanodevices including p–n junction semiconductor nanowire LEDs and solar cells have been fabricated. In Chaps. 2 and 3, catalyst-free metal-organic vapor phase epitaxy to prepare high purity semiconductor nanostructures is introduced. Here, the processes to control positions, conductivities, and compositions of nanostructures for fabricating coaxial nanostructure LEDs are also described. Chapter 4 describes synthesis methods and characteristics of AlN nanostructures for UV optoelectronic device applications. Chapter 5 reviews the research progress on the controlled synthesis of a wide variety of nanowire heterostructures such as branched heterostructures, which includes solution phase and template-based methods. Meanwhile, the semiconductor nanostructures can be hybridized with graphene, which has recently been attracting much attention as a novel nanomaterial system for flexible optoelectronic devices as details are described in Chap. 6.

In Chaps. 7 and 8, structural and optical characterizations of semiconductor nanomaterials and nanostructures are reviewed. Chapter 7 introduces research on structural properties of ZnO and GaN nanostructures using X-ray absorption fine structure. As described in Chap. 8, optical properties of semiconductor nanostructures were investigated using luminescence characterization techniques, which are nondestructive, nonintrusive, and sensitive to the presence of defects or impurities in nanomaterials.

The last three chapters describe nanodevice applications of 1D semiconductor nanostructures. In Chap. 9, lasing characteristics of single and assembled nanowires are reviewed. Chapter 10 introduces near-field optical evaluation and the use of nanorod quantum structures for nanophotonic devices such as a nanophotonic gate. Finally, Chap. 11 presents the overview of nanowire solar cell studies, and integration strategies for practical device applications.

This book entitled “Semiconductor Nanostructures for Optoelectronic Devices – Processing, Characterization and Applications” is being introduced to review the recent works in the field of 1D nanomaterials and their optoelectronic device applications. Each chapter is written by leading scientists in the relevant field. Thus, I hope that high-quality scientific and technical information is provided to students, scientists, and engineers who are, and will be, engaged in fabrications of semiconductor nanostructures and their optoelectronic device applications.

I extend my acknowledgment to Dr. Claus Ascheron of Springer-Verlag for his guidance and suggestions.

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