Self-Assembled Nanostructures

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Self-Assembled Nanostructures
Jin Z. Zhang, Zhong-lin Wang, Jun Liu, Shaowei Chen, and Gang-yu Liu

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Self-Assembled Nanostructures

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Scope of the Series

“Nanostructure Science and Technology”

Nanostructure science and technology now forms a common thread that runs through all physical and materials sciences and is emerging in industrial applications as nanotechnology. The breadth of the subject material is demonstrated by the fact that it covers and intertwines many of the traditional areas of physics, chemistry, biology, and medicine. Within each main topic in this field there can be many subfields. For example, the electrical properties of nanostructured materials is a topic that can cover electron transport in semiconductor quantum dots, self-assembled molecular nanostructures, carbon nanotubes, chemically tailored hybrid magnetic-semiconductor nanostructures, colloidal quantum dots, nanostructured superconductors, nanocrystalline electronic junctions, etc. Obviously no one book can cope with such a diversity of subject matter. The nanostructured material system is, however, of increasing significance in our technology-dominated economy and this suggests the need for a series of books to cover recent developments.

The scope of the new series is designed to cover as much of the subject matter as possible—from physics and chemistry to biology and medicine, and from basic science to applications. At present, the most significant subject areas are concentrated in basic science and mainly within physics and chemistry, but as time goes by more importance will inevitably be given to subjects in applied science and will also include biology and medicine. The series will naturally accommodate this flow of developments in the science and technology of nanostructures and maintain its topicality by virtue of its broad emphasis. It is important that emerging areas in the biological and medical sciences, for example, not be ignored as, despite their diversity, developments in this field are often interlinked. The series will maintain the required cohesiveness from a judicious mix of edited volumes and monographs that, while covering subfields in depth, will also contain more general and interdisciplinary texts.

Thus the series is planned to cover in a coherent fashion the developments in basic research from the distinct viewpoints of physics, chemistry, biology, and

materials science and also the engineering technologies emerging from this research. Each volume will also reflect this flow from science to technology. As time goes by, the earlier series volumes will then serve as reference texts to subsequent volumes.

David J. Lockwood
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Ottawa, Canada

Foreword

Self Assembled Nanostructures by J. Z. Zhang, Z .L. Wang, J. Liu, S. Chen, and G.-Y. Liu is an exhaustive compilation of the different active areas in nanoscience today. The authors should be congratulated for their great efforts in writing such an extensive volume. They have amassed ten chapters on the different aspects of nanoscience covering topics such as synthesis, natural nanomaterials, nanocrystal self-assembly, structure characterization, lithographic techniques, chemical and photochemical reactivity, optical electronic dynamic properties of both semiconductor and metallic nanoparticles, and their electrochemical properties.

This book is valuable because of both its breadth and its focus. The chapters cover a wide span of topics relevant to the field of nanoscience with a focus on self-assembly. At the same time, the authors have commendably integrated their efforts and produced a very readable book.

The authors recognize that this important technique is crucial to furthering progress in nanoscience since our potential ability to employ nanoparticles in useful technological applications depends, in large part, on our ability to self-assemble them correctly.

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Preface

Nanostructured materials, or nanomaterials, refer to materials that have relevant dimensions on the nanometer length scales and reside in the mesoscopic regime between isolated atoms or molecules and bulk matter. These materials have unique physical and chemical properties that are distinctly different from bulk materials. Their size-dependent properties, their sensitivity to surface phenomena, and how they are spatially arranged present a significant challenge to our fundamental understanding of how these materials should behave. Intense interest in nanostructured materials is also fueled by tremendous economic and technological benefits anticipated from nanotechnology and nanodevices. Nanomaterials have demonstrated great potentials for applications in optoelectronics, photovoltaics, photocatalysis, microelectronics, sensors, and detectors. The advance in these areas will affect our daily life from how we design a faster computer, to how we use and conserve energy, preserve the environment, and how we diagnose and treat disease.

The research and development in nanomaterials involve three key aspects: assembly and synthesis of the nanomaterials, characterization of their properties, and exploration or implementation of their applications. Several books on the general subject of nanomaterials have appeared in the last few years. Most of these books have focused on the theoretical and physical aspects of nanomaterials and are written for professionals or experts in the field. To our best knowledge, there have been no introductory-level books that provide a systematic coverage of the basics of nanomaterials that covers the three important aspects of materials assembly and synthesis, characterization, and application. This book is designed to bridge that gap and offers several unique features. First, it is written as an introduction to and survey of nanomaterials with a careful balance between basics and advanced topics. Thus, it is suitable for both beginners and experts, including graduate and upper-level undergraduate students. Second, it strives to balance the chemistry aspects of nanomaterials with physical principles. Third, the book highlights nanomaterial based architectures including assembled or self-assembled systems rather than only isolated nanoparticles. Finally, the book provides an in-depth discussion of important examples of applications, or potential applications of nanoarchitectures, ranging from physical to chemical and biological systems.

The book is organized as follows. Chapter 1 provides an introduction to the field of nanomaterials. It covers some of the key historic developments, novel

properties, and basic physical principles of nanomaterials. Chapter 2 deals primarily with molecular self-assembly or synthetic self-assembled nanostructures, including Langmuir–Blodgett films, surfactant directed nanoporous materials, and molecularly directed films and composites. Chapter 3 presents a survey of naturally self-assembled nanostructures important in biology and biomedical sciences, for example, bone tissues, natural laminated composites in sea shells, and cell membranes. Issues discussed include molecularly directed nucleation and growth, hierarchical ordering, and functional selectivity. A discussion of nanocrystal self-assembly is presented in Chapter 4, including different synthetic methods for making nanocrystals with emphasis on wet chemistry methods. Assembly and fabrication into desired two-dimensional and three-dimensional structures and magnetic properties are also covered. Chapter 5 deals with characterizations of structure and chemical functionality of nanoarchitectures using different microscopy techniques. Chapter 6 focuses on lithography-engineered nanoarchitecture and nanofabrication, with emphasis on structure and chemical characterization of nanoarchitectures. Chemical reactivity of nanoarchitectures is the subject of Chapter 7, as illustrated with various chemical reactions conducted involving nanomaterials, including redox reactions involved in catalysis, photocatalysis, photoelectrochemistry, molecular recognition, and specific surface interaction. Chapter 8 deals specifically with optical and electronic functionality of nanoarchitectures, with focus on optical and electronic properties of semiconductor nanomaterials studied using frequency and time-resolved optical techniques. Optical and dynamic properties of metal nanomaterials are the subject of Chapter 9. Chapter 10 concentrates on electrochemical and transport properties of nanoarchitectures studied using electrochemical as well as electrical techniques. The scientific and technological impacts of nanoarchitectures are covered in many of the chapters. Several key application examples of nanoarchitectures, including nanoelectronics, solar cells, photocatalysis, photoelectrochemistry, light emitting diodes, lasers, detectors, sensors, and bioimaging are considered.

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