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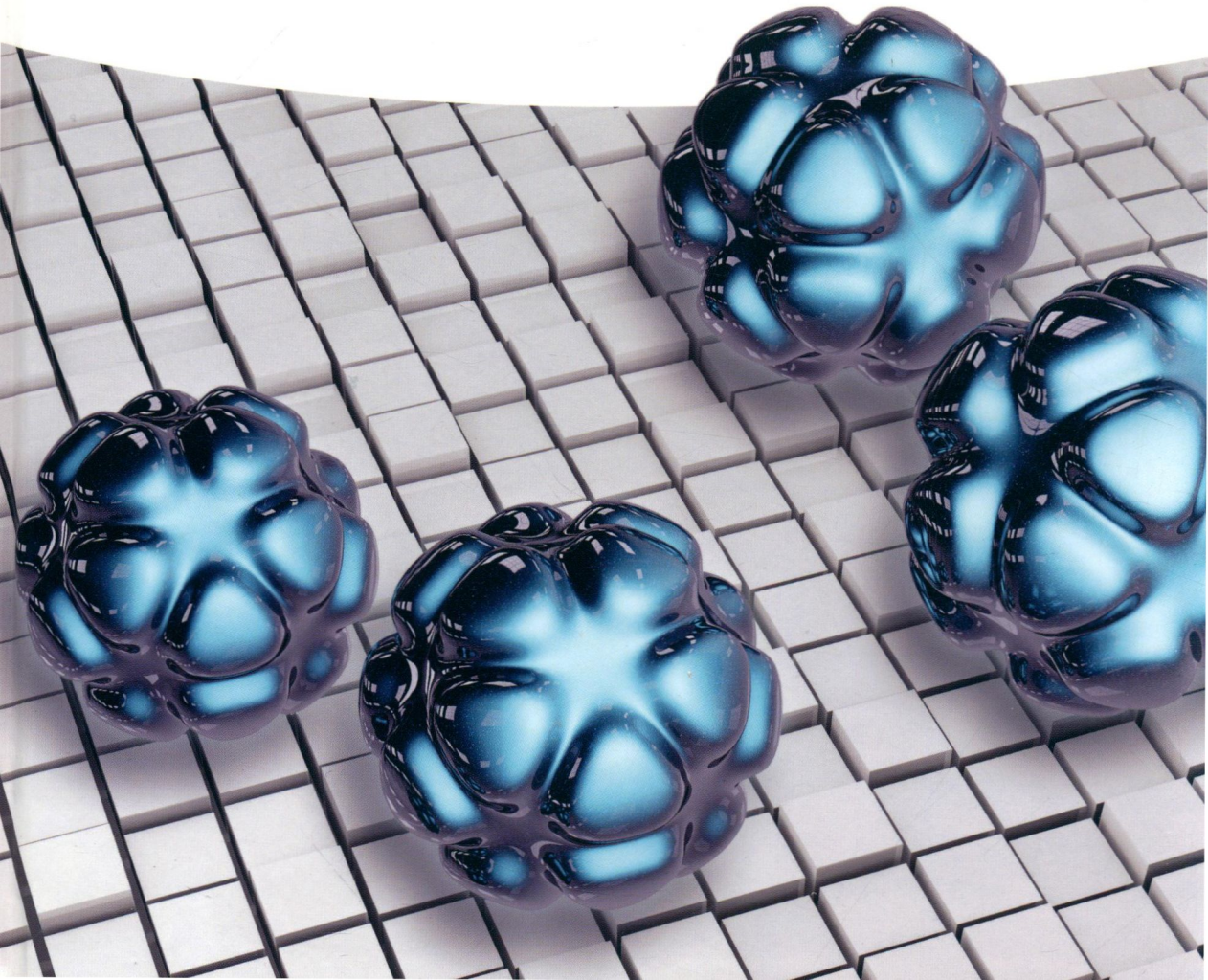
Edited by Quan Li

Functional Organic and Hybrid Nanostructured Materials

Fabrication, Properties, and Applications



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The first book to explore the potential of tunable functionalities in organic and hybrid nanostructured materials in a unified manner.

The highly experienced editor and a team of leading experts review the promising and enabling aspects of this exciting materials class, covering the design, synthesis and/or fabrication, properties and applications. The broad topical scope includes organic polymers, liquid crystals, gels, stimuli-responsive surfaces, hybrid membranes, metallic, semiconducting and carbon nanomaterials, thermoelectric materials, metal-organic frameworks, luminescent and photochromic materials, and chiral and self-healing materials.

For materials scientists, nanotechnologists as well as organic, inorganic, solid state and polymer chemists.

Quan Li *is Director of Organic Synthesis and Advanced Materials Laboratory at Liquid Crystal Institute of Kent State University, where he is also Adjunct Professor in the Chemical Physics Interdisciplinary Program. He, as a Principal Investigator and Project Director, has directed the cutting edge research projects funded by U.S. Air Force Office of Scientific Research, U.S. Air Force Research Laboratory, U.S. Army Research Office, U.S. Department of Defense Multidisciplinary University Research Initiative, U.S. National Science Foundation, U.S. National Aeronautics and Space Administration, U.S. Department of Energy, Ohio Board of Regents under Its Research Challenge Program, Ohio Third Frontier, Samsung Electronics, etc. He received his Ph.D. in Organic Chemistry from the Chinese Academy of Sciences (CAS) in Shanghai, where he was promoted to the youngest Full Professor of Organic Chemistry and Medicinal Chemistry in February of 1998. He was a recipient of CAS One-Hundred Talents Award (BeiRenJiHua) in 1999. He was Alexander von Humboldt Fellow in Germany. He has won Kent State University Outstanding Research and Scholarship Award. He has also been honored as Guest Professor and Chair Professor by several Universities.*

ISBN 978-3-527-34254-9

www.wiley-vch.de

Li (Ed.)

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Cover fotoliaxrender

Library of Congress Card No.:
applied for

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available on the Internet at <http://dnb.d-nb.de>.

Print ISBN: 978-3-527-34254-9
ePDF ISBN: 978-3-527-80735-2
ePub ISBN: 978-3-527-80737-6
Mobi ISBN: 978-3-527-80738-3
oBook ISBN: 978-3-527-80736-9

Cover Design Bluesea Design, McLeese Lake, Canada
Typesetting Spi Global, Chennai, India
Printing and Binding C.O.S. Printers Pte Ltd Singapore

Printed on acid-free paper

10 9 8 7 6 5 4 3 2 1

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Preface

Historically, materials have defined ancient human civilizations, such as the Stone Age, Bronze Age, and Iron Age. During those ancient times, our ancestors had mastered the art of fabricating and using materials in the bulk state. However, during the last several decades, scientists and engineers have been greatly inspired by the ingenuity of Nature in the development of elegant multifunctional, strong, and durable hierarchical materials starting from nanometer length scale to macroscale by using a limited number of available building blocks under very mild processing conditions. Consequently, nature-inspired approaches have yielded some of the most remarkable functional materials, which have driven the forward march of societies and technologies alike. Meanwhile, the advent of sophisticated synthetic methods has facilitated the development of nanostructured organic applied materials with a multitude of promising attributes and performances. As a result, molecular, supramolecular, and macromolecular organic functional materials with controllable hierarchically ordered structures and versatile functionality have found a variety of applications. Though parallel improvements of organic and inorganic materials are now in full swing, it has been realized that the confluence of both organic and inorganic building blocks yields much superior "hybrid" materials that often exhibit unique and unprecedented phenomena and properties leading to a fertile materials paradigm. In this endeavor, self-assembly and nanotechnology provide additional thrust in prescribing both organic and hybrid materials with tunable desired properties and functions. Furthermore, hybrid materials in most instances owe their exciting characteristics to the underlying well-defined nanostructures. Since the distinct components of hybrid materials can be independently designed, it offers a flexible route in the fabrication of appropriate materials with specific and variable functionalities from a rich and diverse pool of building blocks. Accordingly, a plethora of soft, hard, responsive, and smart organic and hybrid materials has recently been developed toward fulfilling societal and industrial demands. In taking stock of the state of affairs, this reference book covers the design, synthesis and/or fabrication, properties, and applications of contemporary and emerging organic and hybrid materials. Development of recent approaches to realize functional organic and hybrid materials has been highlighted. Topics as diverse as nanostructured metallic, semiconducting and carbon nanomaterials, photochromic and photoresponsive materials, stimuli-responsive host–guest materials and surfaces, ion-driven

nanostructures, columnar liquid-crystalline superstructures, organic polymers, supramolecular polymers, polymer nanocomposites, metal-organic frameworks, and proton exchange membranes are covered. Authoritative accounts with emphasis on the optical, electronic, optoelectric, charge-transport, sensing, catalytic, electrochemical, thermoelectric, optoacoustic, and energy-conversion properties of organic and hybrid nanostructured materials and their future prospects have been collated in this book by active and leading experts.

The sheer vastness of this field does not permit exhaustive coverage of all aspects of research and development in one book; rather, this book focuses on the recent developments in the most fascinating and vibrant themes on functional organic and hybrid nanostructured materials encompassing their fabrication, properties, and applications. The chapters included deal with the following topics: Controllable Self-Assembly of One-Dimensional Nanocrystals (Chapter 1), Self-Assembled Graphene Nanostructures and Their Applications (Chapter 2), Photochromic Organic and Hybrid Self-Organized Nanostructured Materials: From Design to Applications (Chapter 3), Photoresponsive Host–Guest Nanostructured Supramolecular Systems (Chapter 4), π-Electronic Ion-Pairing Assemblies Providing Nanostructured Materials (Chapter 5), Stimuli-Responsive Nanostructured Surfaces for Biomedical Applications (Chapter 6), Stimuli-Directed Self-Organized One-Dimensional Organic Semiconducting Nanostructures for Optoelectronic Applications (Chapter 7), Stimuli-Directed Helical Axis Switching in Chiral Liquid Crystal Nanostructures (Chapter 8), Electrically Driven Self-Organized Chiral Liquid-Crystalline Nanostructures: Organic Molecular Photonic Crystal with Tunable Bandgap (Chapter 9), Nanostructured Organic–Inorganic Hybrid Membranes for High-Temperature Proton Exchange Membrane Fuel Cells (Chapter 10), Two-Dimensional Organic and Hybrid Porous Frameworks as Novel Electronic Material Systems: Electronic Properties and Advanced Energy Conversion Functions (Chapter 11), Organic/Inorganic Hybrid Nanostructured Materials for Thermoelectric Energy Conversion (Chapter 12), Hybrid Organic–Nitride Semiconductor Nanostructures for Biosensor Applications (Chapter 13), Polymer-Nanomaterial Composites for Optoacoustic Conversion (Chapter 14), Functional Nanostructured Conjugated Polymers (Chapter 15), and Nanostructured Self-Organized Heliconical Nematic Liquid Crystals: Twist Bend Nematic Phase (Chapter 16). Each Chapter with its independent standing describes the fabrication, properties, and applications of a particular class of materials and culminates with a brief forecast to the future. Overall, this book offers an advanced but accessible coverage of functional organic and hybrid nanostructured materials for undergraduate and graduate students, as well as the researchers at all levels in both academia and industries in the fields of materials science and materials engineering, nanoscience and nanotechnology, macromolecular and supramolecular science, organic chemistry, inorganic chemistry, physical chemistry, liquid crystals, soft materials, metal-organic and covalent organic frameworks, photonics, optoelectronics, biosensing, surface and interface, energy harvesting, storage and conversion, and metal-organic and covalent organic frameworks. It is hoped that readers will find the book useful and of benefit both as summaries of recent developments in this field and as

tutorials of fundamental concepts for beginners. Additionally, it is anticipated to be thought-provoking toward the inception of new ideas to stimulate future developments in this enabling and interdisciplinary research frontier.

Finally, I would like to express my gratitude to Martin Preuss at Wiley-VCH for inviting me to bring this exciting field of research to a wider audience, and to all our distinguished contributors for their dedicated efforts. Also, I am indebted to my wife Changshu and my sons Daniel and Songqiao for their affectionate support and sacrifices.

June 2017

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Kent, Ohio

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