

**254**

## **Advances in Polymer Science**

*Editorial Board:*

A. Abe, Tokyo, Japan  
A.-C. Albertsson, Stockholm, Sweden  
G.W. Coates, Ithaca, NY, USA  
J. Genzer, Raleigh, NC, USA  
S. Kobayashi, Kyoto, Japan  
K.-S. Lee, Daejeon, South Korea  
L. Leibler, Paris, France  
T.E. Long, Blacksburg, VA, USA  
I. Manners, Bristol, UK  
M. Möller, Aachen, Germany  
O. Okay, Istanbul, Turkey  
B.Z. Tang, Hong Kong, China  
E.M. Terentjev, Cambridge, UK  
M.J. Vicent, Valencia, Spain  
B. Voit, Dresden, Germany  
U. Wiesner, Ithaca, NY, USA  
X. Zhang, Beijing, China

For further volumes:

<http://www.springer.com/series/12>

## **Aims and Scope**

The series *Advances in Polymer Science* presents critical reviews of the present and future trends in polymer and biopolymer science. It covers all areas of research in polymer and biopolymer science including chemistry, physical chemistry, physics, material science.

The thematic volumes are addressed to scientists, whether at universities or in industry, who wish to keep abreast of the important advances in the covered topics.

*Advances in Polymer Science* enjoys a longstanding tradition and good reputation in its community. Each volume is dedicated to a current topic, and each review critically surveys one aspect of that topic, to place it within the context of the volume. The volumes typically summarize the significant developments of the last 5 to 10 years and discuss them critically, presenting selected examples, explaining and illustrating the important principles, and bringing together many important references of primary literature. On that basis, future research directions in the area can be discussed. *Advances in Polymer Science* volumes thus are important references for every polymer scientist, as well as for other scientists interested in polymer science - as an introduction to a neighboring field, or as a compilation of detailed information for the specialist.

Review articles for the individual volumes are invited by the volume editors. Single contributions can be specially commissioned.

Readership: Polymer scientists, or scientists in related fields interested in polymer and biopolymer science, at universities or in industry, graduate students.

Special offer:

For all clients with a standing order we offer the electronic form of *Advances in Polymer Science* free of charge.

P.K. Dutta · Joydeep Dutta  
Editors

# Multifaceted Development and Application of Biopolymers for Biology, Biomedicine and Nanotechnology

With contributions by

A.K. Anal · S. Banerjee · A. Bhowmick · Y.M. Chabre ·  
J. Dutta · P.K. Dutta · J. Gopikrishna · M.K. Gupta ·  
C. Haldar · R. Jayakumar · R. Kaur · N. Kottari · R. Kumar ·  
P.P. Kundu · H.T. Lee · P. Maiti · S. Maya · D. Menon ·  
S.V. Nair · D. Narayanan · S.K. Pandey · D.K. Patel ·  
P. Pushp · R. Roy · M. Sabitha · R. Sharma · R. Srivastava ·  
A. Tuladhar

 Springer

*Editors*

P.K. Dutta  
MN National Institute of Technology  
Department of Chemistry  
Allahabad, Uttar Pradesh  
India

Joydeep Dutta  
Institute of Engineering & Technology,  
ITM University  
Department of Applied Sciences & Humanities  
Raipur, Chattrisgarh  
India

ISSN 0065-3195

ISBN 978-3-642-40122-0

DOI 10.1007/978-3-642-40123-7

Springer Heidelberg New York Dordrecht London

ISSN 1436-5030 (electronic)

ISBN 978-3-642-40123-7 (eBook)

Library of Congress Control Number: 2013949496

© Springer-Verlag Berlin Heidelberg 2013

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Springer is part of Springer Science+Business Media ([www.springer.com](http://www.springer.com))

# Preface

Polymers today have a very important role in the technological advancement of our society. Of the polymers, biopolymers are particularly attractive materials because they are generally nontoxic and biodegradable, thus combining excellent functional properties with environmental friendliness and prospects for sustainable development. Furthermore, the input materials used for the production of these polymers can be either renewable, based on agricultural plant or animal products, or synthetic. In this regard, synthetic biopolymers are more costly than natural biopolymers, but both “types” of biopolymers possess interesting properties that make them suitable for a wide repertoire of biomedical applications. In addition, multifunctional entities can be created through decoration of the polymer with specific molecules such as proteins, peptides, drugs, antibodies, biomimetic ligands, transfection agents, cells and various ligands. The advent of nanotechnology has given a new momentum towards the development of biopolymer-based nanomaterials, which can undoubtedly change the shape of our lives.

The present volume entitled “Multifaceted Development and Application of Biopolymers for Biology, Biomedicine and Nanotechnology” is an attempt to provide the scientific community and entrepreneurs with a thorough understanding and knowledge of the combination of nanotechnological, biotechnological, technological and medical aspects of the recent advances in biopolymer applications.

The chapter “Functionalized Nanoparticles and Chitosan-Based Functional Nanomaterials” summarizes the main advances in design and preparation of nanoparticles published over the last 10 years in terms of polymeric nanomaterials, emphasizing functionalized metal nanoparticles, carbon nanotubes, graphene, fullerene, liposomes, quantum dots and nanocomposites, and the current developing interest in functionalization of chitosan derivatives in the form of nanomaterials to provide new strategies for a wide range of applications. The chapter “Nanoparticles for Gene Delivery into Stem Cells and Embryos” describes the available nanoparticle-based gene delivery systems and their use in stem cells for maintaining self-renewal, pluripotency and/or targeted differentiation into specific cell types for cell-based therapy and/or gene therapy. The chapter also discusses and reviews the progress and future of nanoparticles for the generation of transgenic animals via

gene delivery into embryos – a research area that is yet to be fully explored. The chapter “Engineering of Polysaccharides via Nanotechnology” deals with various sources of chitosan and their physical, chemical and biological properties; synthesis of chitosan-based nanoparticles, nanospheres and nanogels; characterization; and biomedical applications. The chapter “Hydroxyapatite-Packed Chitosan-PMMA Nanocomposite: A Promising Material for Construction of Synthetic Bone” is focused on natural bone structure, polymer blends and recent advances in polymer/(nano)hydroxyapatite nanocomposites for application as synthetic bone. The chapter “Biodegradable Polymers for Potential Delivery Systems for Therapeutics” will provide support to research scientists and clinical physicians who are interested in the development and application of biodegradable polymeric nanoparticles as potential delivery systems for therapeutics. The chapter “Phytomedicine-Loaded Polymeric Nanomedicines: Potential Cancer Therapeutics” explains the design and development of nanoformulations and their application as potential anticancer agents. The chapter “Proteins and Carbohydrates as Polymeric Nanodrug Delivery Systems: Formulation, Properties and Toxicological Evaluation” embodies an in-depth discussion of various carbohydrate- and protein-based nanomedicines with respect to their formulation, properties of the nanoconstructs, manipulation and utilization of these properties towards developing a better drug delivery device and also the toxicological interactions of these nanocarriers with host physiological systems. The chapter “Biopolymeric Micro- and Nanoparticles: Preparation, Characterization and Industrial Applications” reviews the preparation, characterization and applications of biopolymeric micro- and nanoparticles. The chapter “Applications of Glyconanoparticles as Glycobiological Therapeutics and Diagnostics” provides an overview of the most recent syntheses and applications of glyconanoparticles in glycoscience that have deepened our understanding of multivalent carbohydrate–protein interactions. Together with sensitive detection devices, inhibitors of bacterial adhesion to host tissues, cancer vaccines and therapeutic systems (including photosensitizers for photodynamic therapies), these novel bionanomaterials are finding widespread relevance. The recent development of glyconanoparticle-based chemotherapeutic drug delivery agents is also addressed, together with their molecular imaging properties for MRI or X-ray contrast agents, as platforms for selective immunolabelling and imaging of cells, and as colorimetric devices in various bioassays.

Last but not least, we would like to thank all contributors for their generous support, the publisher for accepting our book and the administrative heads of both MNNIT Allahabad and IET Raipur, India, for their encouragement and cooperation, without which it would have been extremely difficult to complete this task in time.

Allahabad, India  
Raipur, India  
April 2013

P.K. Dutta  
Joydeep Dutta

# Contents

<b>Functionalized Nanoparticles and Chitosan-Based Functional Nanomaterials</b> .....	1
P.K. Dutta, Rohit Srivastava, and Joydeep Dutta	
<b>Nanoparticles for Gene Delivery into Stem Cells and Embryos</b> .....	51
Pallavi Pushp, Rajdeep Kaur, Hoon Taek Lee, and Mukesh Kumar Gupta	
<b>Engineering of Polysaccharides via Nanotechnology</b> .....	87
Joydeep Dutta	
<b>Hydroxyapatite-Packed Chitosan-PMMA Nanocomposite: A Promising Material for Construction of Synthetic Bone</b> .....	135
Arundhati Bhowmick, Subhash Banerjee, Ratnesh Kumar, and Patit Paban Kundu	
<b>Biodegradable Polymers for Potential Delivery Systems for Therapeutics</b> .....	169
Sanjeev K. Pandey, Chandana Haldar, Dinesh K. Patel, and Pralay Maiti	
<b>Phytomedicine-Loaded Polymeric Nanomedicines: Potential Cancer Therapeutics</b> .....	203
S. Maya, M. Sabitha, Shantikumar V. Nair, and R. Jayakumar	
<b>Proteins and Carbohydrates as Polymeric Nanodrug Delivery Systems: Formulation, Properties, and Toxicological Evaluation</b> .....	241
Dhanya Narayanan, J. Gopikrishna, Shantikumar V. Nair, and Deepthy Menon	

<b>Biopolymeric Micro- and Nanoparticles: Preparation, Characterization and Industrial Applications</b> .....	269
Anil Kumar Anal and Alisha Tuladhar	
<b>Applications of Glyconanoparticles as “Sweet” Glycobiological Therapeutics and Diagnostics</b> .....	297
Naresh Kottari, Yoann M. Chabre, Rishi Sharma, and René Roy	
<b>Index</b> .....	343