Edited by Challa S.S.R. Kumar,
Josef Hormes, Carola Leuschner

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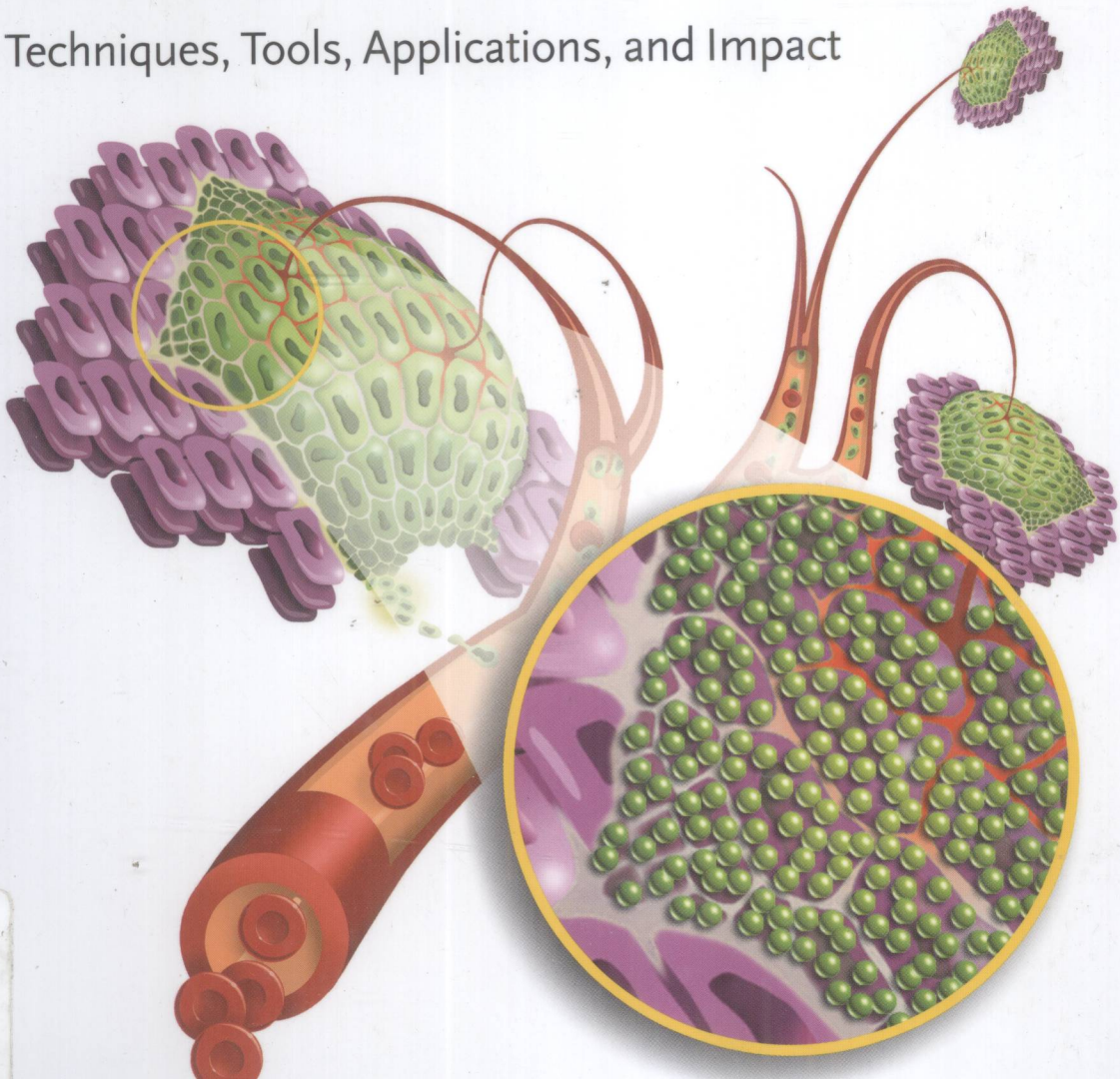
Nanofabrication Towards Biomedical Applications

Techniques, Tools, Applications, and Impact



Nanofabrication Towards Biomedical Applications

Techniques, Tools, Applications, and Impact

Edited by C. S. S. R. Kumar, J. Hormes, C. Leuschner

WILEY-VCH Verlag GmbH & Co. KGaA

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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 Die Deutsche Bibliothek
Die Deutsche Bibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data is available in the Internet at <http://dnb.ddb.de>.

Printed in the Federal Republic of Germany.

Printed on acid-free paper.

Typesetting Kühn & Weyh, Satz und Medien, Freiburg
Printing Strauss GmbH, Mörlenbach
Bookbinding Litges & Dopf Buchbinderei GmbH, Heppenheim

ISBN-13 978-3-527-31115-6
ISBN-10 3-527-31115-7

C. S. S. R. Kumar, J. Hormes, C. Leuschner (Eds.)
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Foreword

Nanobiotechnology: Hype, Hope and the Next Small Thing is the title of one of the chapters in this book. This title suggests that the applications of nanotechnology in biology and medicine are still in a somewhat uncertain future, but the contrary is also true: there are already several products, such as zinc oxide nanoparticles in sun cream or nano-silver as a coating material for home appliances to destroy bacteria and prevent them from spreading, that are available on the market. Other, even more exciting applications are in the testing phase, for example, using magnetic nanoparticles for a targeted hyperthermia treatment of brain cancer. There are of course also applications that might become reality in the far future – though there are always surprises possible in nanotechnology, e.g., implantable pumps the size of a molecule that deliver medicines with a precise dose when and where needed, or the possibility to remove a damaged part of a cell and replacing it with a biological machine. These applications are some of the goals stated in the National Institute of Health roadmap for nanomedicine, which was established in spring 2003. This initiative is again part of a larger US National Nanotechnology Initiative (NNI), for which the President's budget will provide about $1 bn for 2005 for projects coordinated by at least ten different federal agencies.

The book aptly named *Nanofabrication Towards Biomedical Applications* is timely as the contributions are all written by experts in their field, summarizing the present status of influence of nanotechnology in biology, biotechnology, medicine, education, economy, society and industry. I am particularly impressed with the judicious combination of chapters covering technical aspects of the various fields of nanobiology and nanomedicine from synthesis and characterization of nanosystems to practical applications, and the societal and educational impact of the emerging new technologies. Thus, this book gives an excellent overview for non-specialists by providing an up-to-date review of the existing literature in addition to providing new insights for interested scientists, giving a jump-start into this emerging research area. I hope this book will stimulate many scientists to start research in these exciting and important directions. I am particularly pleased to recognize the efforts of

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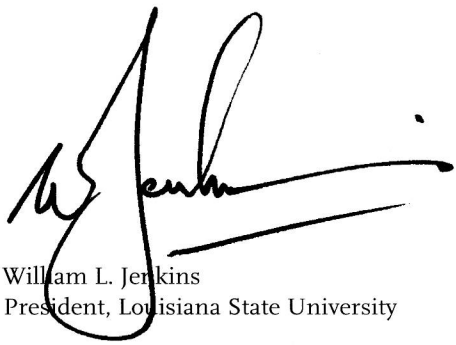
ISBN 3-527-31115-7

the Center for Advanced Microstructures and Devices (CAMD) and of the Pennington Biomedical Research Center (PBRC) in taking a lead to spread the influence of biomedical nanotechnology, and I am convinced that the book will be a valuable tool in the hands of all those interested in discovering new paths and opportunities in this fascinating new field.



William L. Jenkins
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Preface

Within a short span of a decade nanotechnology has evolved into a truly interdisciplinary technology touching every traditional scientific discipline. The effect of nanotechnology on biomedical fields has been somewhat slower and is just beginning to gain importance as seen from a recent search on research publications. Of the total number of nanotechnology related publications which are approximately 2500 in the year 2002-2004, only about 10% of them were related to biomedical sciences. Even though, the effect of nanotechnology on biomedical field is slow, it is bound to gain momentum in the years to come as all biological systems embody nanotechnological principles. Slowly but surely, nanomaterials and nanodevices are being developed that have design features on a molecular scale and have the potential to interact directly with cells and macromolecules. The nanoscientific tools that are currently well understood and those that will be developed in future are likely to have an enormous impact on biology, biotechnology and medicine. Similarly, understanding of biology with the help of nanotechnology will enable the production of biomimetic materials with nanoscale architecture. The comparable size scale of nanomaterials and biological materials, such as antibodies and proteins, facilitates the use of these materials for biological and medical applications. Also, in recent years the biomedical community has discovered that the distinctive physical characteristics and novel properties of nanoparticles such as their extraordinarily high surface area to volume ratio, tunable optical emission, magnetic behavior, and others can be exploited for uses ranging from drug delivery to biosensors.

Viewing from the point of biomedical researchers, it is very difficult to fathom out relevant literature and suitable information on nanotechnological tools that would have profound impact on biomedical research as most of the literature is published in physico-chemical journals. It is our endeavor to support the biomedical community by providing the required information on nanotechnology under one umbrella. We are pleased to introduce to our readers a book that covers various facets of nanofabrication which we hope will help biologists and medical researchers. The book covers not only the scientific aspects of nanofabrication tools for biomedical research but also the implications of this new area of research on education, industry and society at large. Our aim is to provide as comprehensive perspective as possible to our readers who are interested in learning, practicing and teaching nanotechnological tools for biomedical fields. We, therefore, designed the contents of the

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book to have four major sections: (1) Synthetic aspects of nanomaterials, (2) Characterization techniques for nanomaterials (3) Application of nanotechnological tools in biomedical field and (4) Educational, economical and societal implications.

The first section of the book provides information about the fabrication tools for nanomaterials. Fabrication of nanomaterials is by now a very well developed area of research and it is impossible to cover all aspects. Traditionally, synthetic approaches to nanomaterials have been divided into two categories: "top-down" and "bottom-up". "Top-down" practitioners attempt to stretch existing technology to engineer devices with ever-smaller design features. "Bottom-up" researchers attempt to build nanomaterials and devices one molecule/atom at a time, much in the way that living organisms synthesize macromolecules. Therefore, in this volume we made an attempt to explore wet chemical methods for fabrication of metallic nanoparticles, synthetic approaches to carbon nanotubes, and approaches to building of nanostructured materials from low-dimensional building blocks. A fascinating account of biomimetic approaches to building materials from nanostructures is dealt in two chapters – "Nanostructured collagen mimics in tissue engineering" and "Molecular biomimetics: Building materials the nature's way, one molecule at a time". We hope to cover other synthetic aspects in subsequent volumes.

The second section of the book covers tools that are currently available for characterization of nanomaterials and is anticipated to give biomedical researchers an opportunity to learn not only basics of some of the very important techniques such as X-ray absorption spectroscopy and X-ray diffraction, transmission electron microscopy, or electron diffraction, but also help in developing an understanding of how these techniques can be utilized to enhance their own research. Also included in this section is a chapter entitled, "Single-molecule detection and manipulation in nanotechnology and biology" which we hope provides our readers up-to-date information about the opportunities that currently exist and future perspectives on tools for visualizing the world at the molecular and nanoscopic level. "Nanotechnologies for Cellular and Molecular Imaging by MRI" is one of the chapters that is anticipated to give our readers an insight into diagnosis and characterization of atherosclerotic plaques. In this section again, there are many more characterization tools and novel detection methods that have been deliberately left behind to be covered in subsequent volumes.

The third section offers examples of how nanotechnological tools are being utilized in biomedical research. While the chapter entitled, "Nanoparticles for Cancer drug delivery" provides a state-of-the-art information on various types of nanoparticles that are currently under development for cancer therapy, a more specific approach using metal nanoshells is described in the chapter-diagnostic and therapeutic application of metal nanoshells. This particular section introduces our readers to other important areas of biomedical research such as gene delivery, and biological agent decontamination that were positively affected by nanotechnology. We do realize that there are many more applications and subject areas in biomedical research that continue to be impacted by nanotechnology. It is impossible to cover all of them in one book, but we hope to be able to cover as many examples as possi-

ble by following up with further volumes dedicated to nanofabrication for biomedical applications, which are currently being planned.

The final section and the most important one in our opinion brings out the impact of biomedical nanotechnology on education, society and industry. There is no doubt that nanotechnology is going to significantly affect these important facets of our lives and it is our mission to ensure that researchers working in the area of biomedical nanotechnology become aware of these implications as early as possible. While the chapter, "too small to see" enlightens the readers on how educators are trying to grapple with a situation to educate the new generation about nanotechnology, the chapter aptly titled as "nanobiomedical technology: financial, legal, clinical, political, ethical and societal challenges to implementation" introduces to the reader various global challenges to the implementation of this new technology.

A book series of this magnitude is impossible without the unwavering support from the authors who have taken time of their busy schedule to submit their manuscripts on time and we are indebted to them. We gratefully acknowledge the support from Wiley VCH, in particular to Martin Ottmar, who has been working closely with us to make this first volume of the book series a reality. The Center for Advanced Microstructures and Devices and the Pennington Biomedical Research Center are two unique institutions in Louisiana, USA, who have been providing innumerable opportunities to their employees to excel and we cherish this support and encouragement. Finally, we are indebted to our families for their trust and support in addition to bearing our long absences from our family chores.

Baton Rouge, November 2004
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ISBN 3-527-31115-7

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ISBN 3-527-31115-7