SpringerBriefs in Molecular Science

Biometals

Series Editor

Larry L. Barton

For further volumes:
http://www.springer.com/series/10046

Anil K. Suresh

Metallic Nanocrystallites and their Interaction with Microbial Systems

Springer

Anil K. Suresh
Department of Molecular Medicine
Beckman Research Institute
City of Hope
Flower Avenue 1710
Duarte, CA 91010
USA

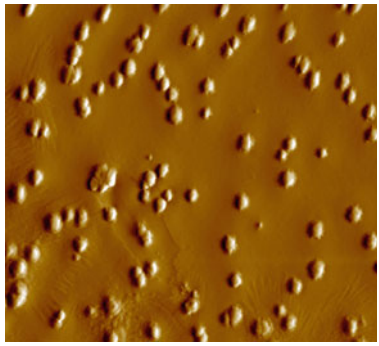
ISSN 2191-5407
ISBN 978-94-007-4230-7
DOI 10.1007/978-94-007-4231-4
Springer Dordrecht Heidelberg New York London

e-ISSN 2191-5415
e-ISBN 978-94-007-4231-4

Library of Congress Control Number: 2012933319

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)



Give me a place to stand, and I will move the Earth

—Archimedes

I dedicate this book to my beloved Ph.D. mentor, Dr. M. I. Khan, my parents, my wife, my brothers, and my lovely little angel daughter Akanksha

Preface

Nanoscience and nanotechnology are a fast growing and dynamic areas, which include novel class of materials that are being developed for various applications. Nanotechnology has immense potential in almost every field of science and technology, primarily due to their size and/or shape dependent intrinsic physicochemical, optoelectronic, catalytic and biological properties and greater surface area. As some may know, modern nanotechnology originated in the year 1959 after an oral presentation given by Dr. Richard Feynman, "*There's plenty of room at the bottom*." The impetus for modern nanotechnology was provided by interfacing nanoscience with biology, medicine, electronics and advanced analytical tools. Researchers and industrialists believe that one day nanotechnology will likely impact the perspective of things being looked at, and will drastically revolutionize the industries and pharmaceutical companies with great emphasis on human health, environment safety and sustainability. Nanotechnology has already begun to improve many facets of science and technology, and researchers are revisiting several useful aspects with a nanoperspective to understand how similar things could work at the nanoscale. This phenomenon is likely to revolutionize pharmaceutical sciences, and many drugs are being reconsidered for possible deliveries using smart multifunctional nanomaterials.

This book emphasizes two distinct but interrelated and novel aspects with respect to nanoparticles: ecologically benign and cost effective production of nanoparticles, and issues related to safety concerns of nanoparticles on the biotic environment. Nanoparticles in distinct forms are extensively used in various consumer products as additives and therefore are required in huge quantities. In that respect it has become highly imperative to be able to produce nanoparticles at the mega scale, using both ecologically friendly and economic procedures. Also, as the nanoparticles are getting implemented more and more widely, they are released into the environment in one form or another, following it a host for new potential health issues. To prevent this risk, one must look at the proper development and use of these nanomaterials and the fate, transport and impacts of such engineered nanostructures on the environment must be addressed. Interactions between the nanoparticles and microorganisms in the environment are

unavoidable, but the pandemic consequences of such interactions are beginning to be investigated. This book will also illustrate how naturally occurring microorganisms and manmade nanoparticles interact, and the consequences of such interaction, using suitable examples from our studies published in several peer reviewed International Journals. Because of its uniqueness in content and scope, I am positive that this volume will be helpful not only to the scientific and industrial community but it will also attract the attention of students and researchers in different areas of sciences such as microbiology, biotechnology, nanotechnology, toxicology, materials science, biomedical engineering, cell and molecular biology etc. The several objectives of this brief are to introduce nanobiotechnology along with the fast emerging "green biosynthesis" for their manufacture, and to let the readers aware on the potential interactions of engineered nanoparticles with microorganisms. Impacts of noble metal and metal oxide nanoparticles such as gold, silver and cerium oxide on the growth and viability of several Gram-negative and Gram-positive bacteria will be presented. Differences in the interactions using different forms of nanomaterials, nanoparticles synthesis methodology, surface coatings, and the various analytical assays used to determine the bactericidal activity will be described. Mechanistic insights on the relationship between the bacterial growth inhibition, reactive oxygen species generation and up and/or down regulation of transcriptional stress responsive genes will also be discussed. Finally, how we made use of the emerging advance imaging techniques such as transmission electron and atomic force microscopes that will shed impacts towards a better understanding on the overall microbial–nanoparticle interactions will be discussed.

Overall, the book contains five chapters. Chapter 1 includes the basic and general introduction to nanoscience and nanotechnology, properties of nanoparticles, synthesis methodologies employed to produce various nanoparticles, physical characterizations of nanoparticles, and the applications of nanoparticles, with emphasis on biological and medicinal applications. Chapter 2 details the microbial based biofabrication of nanoparticles, mechanism involved behind biofabrication, and the advantages of biosynthesis over the existing conventional chemical and physical routes of synthesis. Moreover, the reliability of biosynthesis technique with detailed description on the biosynthesis with suitable example, thorough physical characterizations of the synthesized particles so as to assess their morphology, crystallinity, surface characteristics based on advanced analytical tools will be presented. Chapter 3 discusses the bactericidal properties of engineered metal nanoparticles and analysis the comparative toxicity assessments of engineered silver nanoparticles on bacteria and discusses the toxicity assessments of nanoparticles, deemed reasons for nanoparticles being considered toxic and the necessity to address the potential toxicity of nanoparticles. It then proceeds to describes the external factors that might govern nanoparticles mediated toxicity and the proposed mechanisms behind the toxicity. Additionally, it discusses the details of the various techniques used to evaluate bactericidal activity, their advantages and limitations along with the influence of size, shape, surface coatings of nanoparticles on the toxicity and the mechanistic of bacteria-nanoparticle

interactions. Chapter 4 focuses on the biocompatibility and inertness of gold nanocrystallites and analyses the inert nature of gold nanoparticles along with its biosynthesis and physical characterizations. Last but not least, Chap. 5 examines the antibacterial properties of engineered metal oxide nanocrystallites and the stress mechanism involved. As an example, it describes our work on the effects of engineered cerium oxide nanoparticles on the growth and viability of several Gram-negative and Gram-positive bacterial strains. It then discusses the relation between the growth inhibition, reactive oxygen species generation and up and or down regulation of transcriptional stress genome. Finally, it analyses the use of advanced analytical tools like the transmission electron microscopy to evaluate the bacterial response mechanisms.

I am pleased that I have been invited to write this book published by Dr. Sonia Ojo, senior publishing editor at Springer within the Springer Briefs in Biometals series by Prof. Larry Barton. To all I wish a happy reading!

Duarte, 12 December 2011 Anil K. Suresh

Acknowledgments

Much to my extreme delight, I would like to evince my gratitude and indebtedness to my beloved Ph.D. mentor *late. Dr. M. I. Khan*, a truly remarkable scientist who introduced me to this fascinating realm of Nanobioscience and Nanobiotechnology. His invaluable guidance, constant inspiration, and unending support have always been contagious and motivational throughout my Ph.D. pursuit. His scientific temperament, innovative approach, dedication towards his profession and his down to earth nature has inspired me highly. Although this eulogy does not give him justice, I preserve an everlasting gratitude for him.

I heartedly thank *Prof. Jay Nadeau* at McGill University, Canada and *Prof. Yves-Alain Peter* at Ecole Polytechnique in Montreal, Canada, for their mentorship during my first postdoctoral training. Special thanks to them for giving me the opportunity to let me explore my research expertise on nanomaterials on further implementation in cell imaging and drug delivery systems. They often used to organize family get-together and fun-filled extracurricular activities (kayaking, canoeing, skiing, rock climbing, and ropes courses). It was a very friendly environment and I learned a lot from them.

I wish to express my sincere gratitude and heartfelt thanks to *Dr. Mitchel Doktycz* and *Dr. Dale Pelletier* at Oak Ridge National Laboratory, USA. With them I pursued my second postdoctoral training. I am grateful for their mentorship, motivation, subtle guidance, fruitful discussions, never ending support, and constant help. The trust and freedom they gave me to implement my own research ideas have been crucial to achieve this feat. Working with them has always made me feel relaxed and has enabled me to progress in a lively and cool environment. I will never been able to thank them enough. They are like godfathers to me.

I would also like to use this opportunity to express my sincere thanks to *Prof. Jacob Berlin*, not only for giving me the opportunity to work as a Staff Scientist in his Laboratory at the Department of Molecular Medicine, Beckman Research Institute at City of Hope, USA but also for introducing me to my dream area of research: *Cancer Therapeutics and Clinical Medicine*.

I sincerely acknowledge and I am very much thankful to my research collaborators and colleagues *Dr. Tommy Phelps, Dr. Wei Wang, Dr. Aloke Kumar,*

Dr. Ji-Won Moon, Dr. Baohua Gu and Prof. David Allison, at the Oak Ridge National Laboratory for their valuable help in generating data and editing manuscripts, for our fruitful discussions, and for showing me their constant support, inspiration and motivation throughout my stay at ORNL.

I would also like to thank all my lab mates and colleagues I worked with throughout my research period at National Chemical Laboratory in India; at the McGill University in Canada; at the Oak Ridge National Laboratory in the USA and presently here at City of Hope in the USA, for their constant support and help whenever it was required.

It gives me immense pleasure to thank *Amma, Daddy*, and my *lovely brothers Sunil* and *Vinil*, for their love, unfailing support, tremendous patience, trust and encouragement shown in their own special way during my long period of studies. They have been a constant source of strength and inspiration for me. My due thanks to them for their love, support and faith in me. Also thanks my *sister-in-laws*, who recently joined our family, for their support.

I would also like to thank my *wife, Arundhati*, for her care, understanding, love and for everything she does for me.

I am ever grateful to the *Almighty God*, the Creator and the Guardian, and to whom I owe my very existence; because of his blessings, wisdom and perseverance that he has been bestowing upon me at all times. I bow to the divine strength and hope that his blessings will dwell throughout my life.

Last but not least, thanks to my *daughter Akanksha*, lovely little angel, whose cute smiles and funny acts soothed the pain I experienced while achieving every feat of my life.

Contents