Green Synthesis of Nanomaterials

Biological and Environmental Applications

Edited by
Archana Chakravarty
Preeti Singh
Saiqa Ikram
R. N. Yadava

WILEY

Green Synthesis of Nanomaterials

Green Synthesis of Nanomaterials

Biological and Environmental Applications

Edited by

Archana Chakravarty
Jamia Millia Islamia; Central University
New Delhi
India

Preeti Singh
Institute of Chemical Technology
Mumbai
India

Saiqa Ikram
Jamia Millia Islamia; Central University
New Delhi
India

R.N. Yadava
Purnea University Bihar,
Bihar
India

WILEY

Published by John Wiley & Sons, Inc., Hoboken, New Jersey.
Published simultaneously in Canada.

Library of Congress Cataloging-in-Publication Data applied for:

ISBN: HB: 9781119900900, ePDF: 9781119900917, epub: 9781119900924

Cover Design: Wiley
Cover Image(s): © Konstantinos Zouganelis/Getty Images

Set in 9.5/12.5pt STIXTwoText by Straive, Pondicherry, India

Contents

List of Contributors

Rohana Abu
Faculty of Chemical and Process Engineering Technology
Universiti Malaysia Pahang Al-Sultan Abdullah. Persiaran Tun Kalil Yaakob, Gambang Kuantan, Pahang
Malaysia

Khairatun Najwa Mohd Amin
Faculty of Chemical and Process Engineering Technology
Universiti Malaysia Pahang Al-Sultan Abdullah. Persiaran Tun Kalil Yaakob, Gambang Kuantan, Pahang
Malaysia

Isha Arora
Department of Chemistry
Amity Institute of Applied Sciences, Amity University
Noida, UP
India

Deepak Kumar Bhartiya
Department of Zoology
Government Degree College
Dhadha Bujurg-Hata
Kushinagar, UP
India

Archana Chakravarty
Department of Chemistry
Jamia Millia Islamia
New Delhi, Delhi
India

Aayushi Chanderiya
Department of Chemistry
Dr. Harisingh Gour University
Sagar, MP
India

Amrish Chandra
Amity Institute of Pharmacy
Amity University
Noida, UP
India

Vinita Chaturvedi
Biochemistry Division
Central Drug Research Institute
CSIR Lucknow, UP
India

Ritu Rani Chaudhary
Department of Chemistry
B.S.A. College
Mathura, UP
India

Shivani Chaudhary
Department of Chemistry
Dr. Bhimrao Ambedkar University
Agra, UP
India

Neeru Dabas
Department of Chemistry
Amity School of Applied Science
Amity University
Gurugram, HR
India

Ratnesh Das
Department of Chemistry
Dr. Harisingh Gour Central
University
Sagar, MP
India

Rimon Ranjit Das
Department of Physics
Amity Institute of Applied
Sciences, Amity University
Noida, UP
India

Nowsheenah Farooq
Bioinorganic Lab
Department of Chemistry
Jamia Millia Islamia
New Delhi, DL
India

Is Fatimah
Department of Chemistry
Faculty of Mathematics and
Natural Sciences
Universitas Islam Indonesia
Yogyakarta
Indonesia

Manoj Gadewar
Department of Pharmacology
School of Medical and Allied
Sciences, KR Mangalam University
Gurgaon, HR
India

Seema Garg
Department of Chemistry
Amity Institute of Applied
Sciences, Amity University
Noida, UP
India

Mithun Kumar Ghosh
Department of Chemistry
Government College Hatta
Damoh
India

Juhi Gupta
Bioinorganic Research Lab
Department of Chemistry
Jamia Millia Islamia
New Delhi, DL
India

Athar Adil Hashmi
Bioinorganic Lab
Department of Chemistry
Jamia Millia Islamia
New Delhi, DL
India

Afkar Rabbani Hidayatullah Hipeni
Faculty of Chemical and Process
Engineering Technology
Universiti Malaysia Pahang Al-Sultan
Abdullah. Persiaran Tun Kalil
Yaakob, Gambang Kuantan, Pahang
Malaysia

MA Motalib Hossain
Institute of Sustainable Energy
Universiti Tenaga Nasional
Kajang, Selangor
Malaysia

Gautam Jaiswar
Department of Chemistry
Dr. Bhimrao Ambedkar
University
Agra, UP
India

Sarabjeet Kaur
Surface Chemistry and Catalysis:
Characterisation and Application
Team (COK-KAT), Leuven
(Arenberg)
Leuven
Belgium

Nishat Khan
Department of Chemistry
Amity Institute of Applied
Sciences, Amity University
Noida, UP
India

Manoj Kumar
Department of Chemistry
Government Degree College
Dhadha Bujurg-Hata
Kushinagar, UP
India

Vikas Kumar
Department of Chemistry
Government College Khimlasa
Sagar, MP
India

Shivani A. Kumar
Department of Physics
Amity Institute of Applied
Sciences, Amity University
Noida, UP
India

Indu Kumari
CT Group of Institutions
Jalandhar, PB
India

Surbhi Malik
Department of Physics
Amity Institute of Applied
Sciences, Amity University
Noida, UP
India

B.R. Malini
Department of Chemistry
Akshara First Grade College
Bengaluru, KA
India

Sharifah Fathiyah Sy Mohamad
Faculty of Chemical and Process
Engineering Technology
Universiti Malaysia Pahang Al-Sultan
Abdullah. Persiaran Tun Kalil
Yaakob, Gambang Kuantan, Pahang
Malaysia

Baranya Murugan
Nanotechnology & Catalysis
Research Centre
University of Malaya
Kuala Lumpur
Malaysia

Sivasubramanian Murugappan
Department of Biomedical Engineering
Indian Institute of Technology Hyderabad
Sangareddy, TS
India

M. Mutthuraju
Department of Chemistry
Sai Vidya Institute of Technology
Affiliated to Visvesvaraya Technological University
Bengaluru, KA
India

Nahid Nishat
Inorganic Materials Research Lab
Department of Chemistry
Jamia Millia Islamia
New Delhi, DL
India

Sikandar Paswan
Department of Chemistry
Baba Raghav Das PG College
Deoria, UP
India

Monika Pebam
Department of Biomedical Engineering
Indian Institute of Technology Hyderabad
Sangareddy, TS
India

G.K. Prashanth
Research and Development Centre
Department of Chemistry
Sir M. Visvesvaraya Institute of Technology, Affiliated to Visvesvaraya Technological University
Bengaluru, KA
India

Benni F. Ramadhoni
National Research and Innovation Agency
Tangerang Selatan
Indonesia

Srilatha Rao
Department of Chemistry
Nitte Meenakshi Institute of Technology
Affiliated to Visvesvaraya Technological University
Bengaluru, KA
India

Aravind Kumar Rengan
Department of Biomedical Engineering
Indian Institute of Technology Hyderabad
Sangareddy, TS
India

Annisa Rifathin
National Research and Innovation Agency
Tangerang Selatan
Indonesia

Atish Roy
Department of Chemistry
Dr. Harisingh Gour University
Sagar, MP
India

Suresh Sagadevan
Nanotechnology & Catalysis
Research Centre
University of Malaya
Kuala Lumpur
Malaysia

Department of Chemistry
Faculty of Mathematics and
Natural Sciences
Universitas Islam Indonesia
Yogyakarta
Indonesia

Yulianti Sampora
National Research and
Innovation Agency
Tangerang Selatan
Indonesia

Sri Amruthaa Sankaranarayanan
Department of Biomedical
Engineering
Indian Institute of Technology
Hyderabad
Sangareddy, TS
India

Athanasia Amanda Septevani
National Research and
Innovation Agency
Tangerang Selatan
Indonesia

Melati Septiyanti
National Research and
Innovation Agency
Tangerang Selatan
Indonesia

Shaily
Inorganic Materials Research Lab
Department of Chemistry
Jamia Millia Islamia
New Delhi, DL
India

Adnan Shahzaib
Inorganic Materials Research Lab
Department of Chemistry
Jamia Millia Islamia
New Delhi, DL
India

Preeti Sharma
Department of Natural Sciences
University of Maryland
Eastern Shore
Princess Anne, MD
USA

K. Shwetha
Department of Chemistry
Nitte Meenakshi Institute of
Technology
Bengaluru, KA
India

A.S. Sowmyashree
Department of Chemistry
Nitte Meenakshi Institute of
Technology
Bengaluru, KA
India

Sudiyarmanto
National Research and
Innovation Agency
Tangerang Selatan
Indonesia

Abu Taha
Bioinorganic Lab
Department of Chemistry
Jamia Millia Islamia
New Delhi, DL
India
India

David Natanael Vicarneltor
National Research and
Innovation Agency
Tangerang Selatan
Indonesia

Fahmina Zafar
Inorganic Materials Research Lab
Department of Chemistry
Jamia Millia Islamia
New Delhi, DL
India

Preface

Nanotechnology and materials science have made remarkable advances in recent years, revolutionizing several industries and creating new opportunities for research and development. Nanomaterials, with their distinct physical and chemical characteristics at the nanoscale, have drawn a lot of interest and are being investigated for a wide range of applications, from electronics and energy to medicine and environmental remediation.

However, despite these promising prospects, there is rising worry regarding the sustainability and environmental impact of the conventional synthesis techniques used to create nanomaterials. Conventional methods frequently employ hazardous chemicals, consume a lot of energy, and produce a lot of waste, which raises severe concerns about their long-term effects and ecological imprint.

To overcome these issues and open the door to the manufacture of sustainable nanomaterials, the idea of "green synthesis" has evolved in this context. Utilizing both ecologically friendly natural resources including plants, microorganisms, and other natural resources, as well as green synthetic techniques, can be used to create nanomaterials.

This book, *Green Synthesis of Nanomaterials: Biological and Environmental Applications*, examines the developing area of "green synthesis of nanomaterials" and its potential biological and environmental pollution remediation applications. It explores the numerous biological sources and fabrication techniques used for the environmentally friendly production of nanomaterials, highlighting their special benefits, constraints, and possible uses.

In addition to highlighting the biological and environmental uses of the synthesized nanomaterials, the goal of this book is to provide a thorough and informative overview of the state-of-the-art methods and developments in green synthesis. The chapters include a wide range of subjects, such as biosynthesis by employing plants and bacteria, as well as the use of natural substances like cellulose and peptide for the green synthesis and biofabrication of nanomaterials and their applications in biomedical as well as environmental pollution remediation.

Readers will obtain a thorough grasp of the concepts driving green synthesis, the characterization methods used for nanomaterial analysis, and the wide range of applications in the biological and environmental domains throughout every chapter of this book. The potential applications of green nanomaterials are numerous and exciting, ranging from pollutant removal to antibacterial agents and targeted medication delivery systems.

This book is a useful resource for students, scientists, engineers, and business executives alike since the contributing authors leading academics and authorities in their respective fields have contributed their wealth of knowledge and expertise. Their combined efforts have produced a thorough compilation that not only illuminates the possibilities of green synthesis but also adds to the continuing discussion about sustainable nanotechnology.

We hope that this book will act as a catalyst for additional study, encouraging scientists to delve more deeply into the field of green synthesis and promoting the creation of brand-new, environmentally friendly nanomaterials. We may work towards a better future where scientific progress and environmental responsibility go hand in hand by harnessing the power of nature and implementing sustainable practices.

We would like to extend our sincere gratitude to everyone who helped with the writing, reviewing, and publishing of this book. We would also like to express our gratitude to the readers for their attention and participation. We can create the conditions for a sustainable and ecologically conscientious future by working together and exchanging knowledge.

1

Introduction to Advanced and Sustainable Green Nanomaterial

Aayushi Chanderiya, Atish Roy, and Ratnesh Das

Department of Chemistry, Dr. Harisingh Gour University, Sagar, MP, India

Abstract

A magical period of scientific observation and science-based regeneration is required to advance human civilization. Technological developments are brimming with deep scientific insight and depth. Today's sustainability is in the midst of a significant crisis. Energy and environmental sustainability are critical for the advancement of human civilization. Sustainable construction is the bedrock of scientific destiny and profound scientific progress. In this chapter, the authors primarily concentrated on the success of green sustainability, synthesis, nanoscience's vast implementation range, and the novel field of specialized and sustainable nanomaterials. The other pillars of this scientific endeavor are expansion efforts. Green and environmental sustainability are today's human forerunners.

Keywords *sustainability; environmental sustainability; scientific progress; nanoscience; green sustainability; green engineering*

1.1 Introduction

Nanotechnology is characterized as the science of the small. It is the manipulation of materials on a microscopic scale. Atoms and molecules behave differently when they are little. These particles have distinct characteristics. It has a wide range of extraordinary and intriguing applications, and research in nanotechnology and nanoscience has exploded across

Green Synthesis of Nanomaterials: Biological and Environmental Applications, First Edition.
Edited by Archana Chakravarty, Preeti Singh, Saiqa Ikram, and R.N. Yadava.

various product areas. It allows for the creation and progress of materials, including medicinal usage, environmental redemption, and so on. Conventional methods may have reached their limits. However, nanotechnology is advancing in a variety of ways. As a result, nanotechnology should not be considered a singular approach that only affects specific research fields; instead, it should be viewed as an exploration of all science disciplines [1a]. Modern green methods are regarded as one of the best aspects to prevent and enhance the environment to achieve sustainable improvement. This concept has piqued the interest of scientists in adopting its principles about indicators of environmental efficiency by demonstrating the real benefit in the stages of planning, design, utilization, and sustainability in multiple vital sectors of the human being [1b, 1c, 2]. Because of their distinct size-dependent qualities, these materials are exceptional and necessary in a wide range of human activities [3]. Nanotechnology covers a wide range of subjects, from adaptations of classical equipment physics to revolutionary tactics centered on molecular self-assembly, from developing products with nanoscale size to determining if we can directly influence things on the atomic scale/level [4] (Figure 1.1).

Several science policy publications show significant potential and value in offering green nano methods that produce nanomaterials and products without pollutants that impair the environment or human health at the management, design, production, and methodology phases. As a result, nanotechnology may help to alleviate issues about safe, sustainable development, such as environmental, human health, and safety issues, as well as assist in a sustainable environment in terms of energy, water, food supply, raw substances, environmental issues, and so on [5].

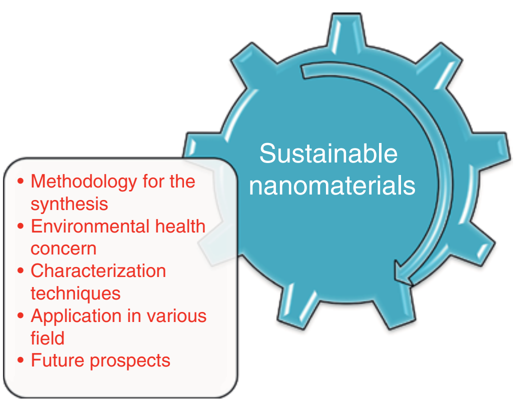

Figure 1.1 Sustainable nanomaterials.

- Advanced nanomaterials are the intelligent materials of today's human society. Advanced nanomaterials may be characterized in a variety of ways. The most extended term refers to any materials that reflect advancements above conventional materials that have been utilized for hundreds, if not thousands, of years. Consider materials early in their product and technology life cycles for a better understanding description of innovative materials.
- What is a sustainable nanomaterial?
  Sustainability is concerned with the needs of the current and coming years' decades. Nanomaterials are at the cutting edge of nanotechnology, which is continually evolving. Because of their distinctive size-dependent qualities, these materials are exceptional and necessary in many human activities.
- Sustainable and green nanomaterial
  Nanoparticles are particles with diameters ranging from 1 to 100 nm [6]. Depending on the shape, nanoparticles can be 0D, 1D, 2D, or 3D [7]. The relevance of these nanoparticles became apparent when researchers discovered that particle size might alter the physiochemical characteristics of substances, such as optical qualities. The nanoparticles are divided into many categories based on their morphology, size, and form (Figures 1.2–1.4).

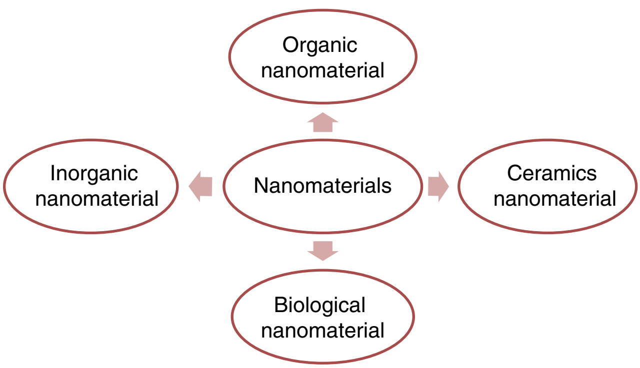

Figure 1.2 Types of nanomaterials.

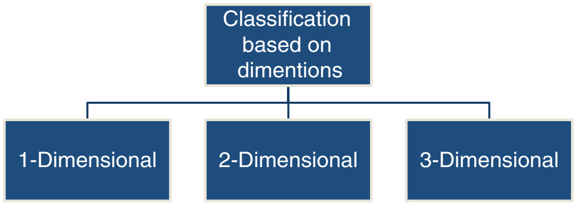

Figure 1.3 Classification based on dimensions of nanomaterials.

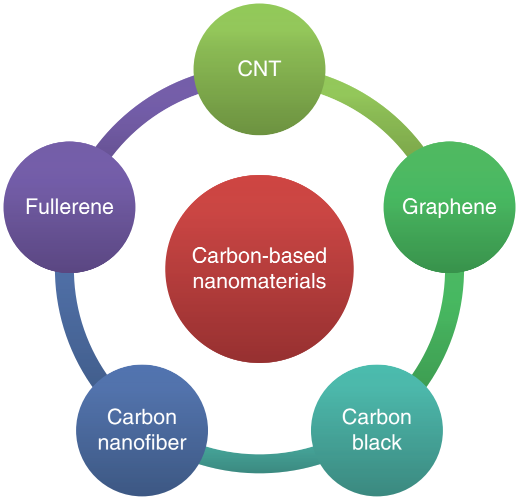

Figure 1.4 Carbon-based nanomaterials.

1.2 Synthesis Methods of Nanomaterials

Metal nanoparticles may be created in a variety of methods. There are two types of conversion methodologies: top-down and bottom-up. Several nanoparticle synthesis processes have been developed, and they are suitable for synthesizing nanoparticles of various sizes and shapes. The top-down technique is destructive, breaking down large molecules into tiny parts before changing them into the desired nanoparticles. Decomposition methods such as chemical vapor deposition (CVD), grinding, and physical vapor deposition (PVD) are used in this procedure. Milling is used to remove nanoparticles from coconut shells, with the size of the crystallites decreasing with time. This method produced iron oxide, carbon, dichalcogenides, and cobalt (III) oxide nanoparticles.

Bottom-up strategy method includes the gradual synthesis of nanoparticles from basic materials. It is least harmful to the environment, more practicable, and less expensive. Typically, the materials used in reduction and sedimentation techniques include green synthesis, biochemical, spin coating, sol–gel, and so on. This method has been used to create titanium dioxide, gold, and bismuth nanoparticles (Figure 1.5).

Nanoparticle synthesis might potentially utilize chemical or biological mechanisms [8]. Some chemical synthesis strategies for nanoparticles include the sol–gel method, wet chemical synthesis, hydrothermal method,

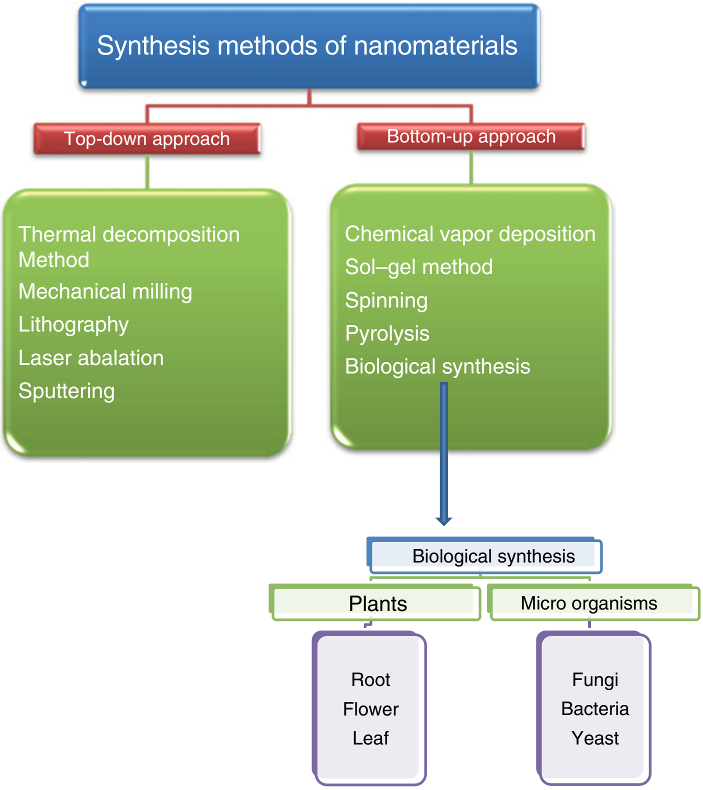

Figure 1.5 Synthesis methods of nanomaterials.

thermal decomposition, microwave method, and so on [9]. In contrast, biological processes contain enzymes, bacteria, plant extracts, and fungi.

1.3 Green Synthesis

Green chemistry and its ideas and environmental efficiency metrics are frequently viewed as fundamental to creating long-term profitability. Green chemistry principles include prevention, atom economy, less hazardous chemical synthesis, safer compound development, energy-efficient design, employing renewable fuel sources, catalysis, and constructing for decay. Green nanomaterial synthesis is an environmentally friendly method of nanomaterial synthesis that employs nontoxic, biodegradable ingredients. This method may be used to mass-produce nanomaterials on a

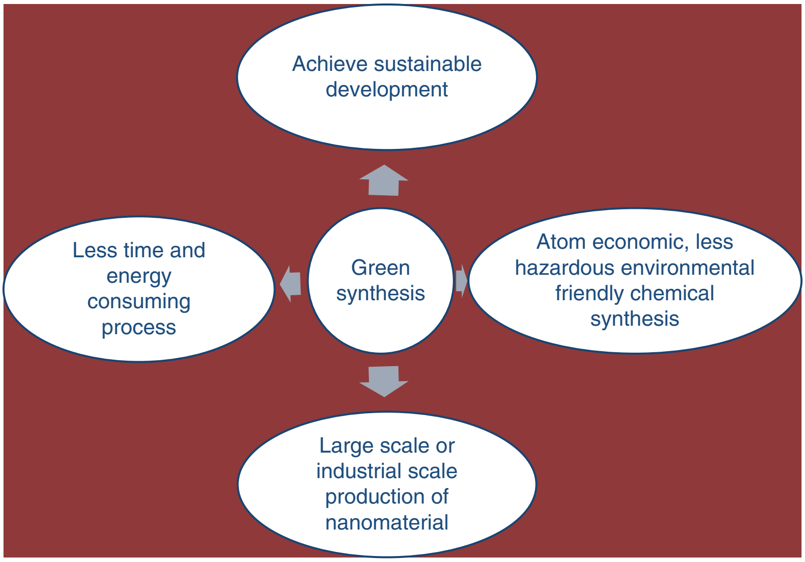

Figure 1.6 Advantages of green synthesis.

considerable scale. In green synthesis, the external experimental conditions should also be ambient, such as nil or low energy requirements and pressure, which leads to an energy-saving procedure. Nanotechnology is an essential aspect of putting the earth on a sustainable path because it combines all of the rewards of the present technology with compact goods that consume minimal energy and resources to run, produce, and integrate the possibility of recycling (Figure 1.6).

1.4 Biosynthesis of Nanoparticles from Plants

Bacteria, fungi, and plants all synthesize different types of nanoparticles [10]. Plants are better suited to the production of nanoparticles (NPs) than bacteria or fungi because metal ion reduction requires less incubation time. Plant tissue culture (PTC) and downstream processing approaches promise to generate metal and oxide NPs on a bigger scale. It has been shown that plants exhibit an innate ability to reduce metals via their particular metabolic pathways [11]. Stampoulis et al. [12] investigated the effects of ZnO, Cu, Si, and Ag NPs on root elongation, seed germination, and biomass production in *Cucurbita pepo* cultivated hydroponically. Compared to the untreated standards, test results showed that root length is reduced by 77% and by 64% when subjected to bulk Cu powder when seedlings are exposed to Cu nanoparticles.