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Green Synthesis of Nanomaterials

Biological and Environmental Applications

Edited by
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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.

Contents

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Microorganism-Based Synthesis of Nanomaterials and Their Applications

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Abstract

The advancement of nanomaterials production has shifted from mechanical and chemical-based synthesis to green synthesis by microorganisms. For the past years, the foundations of microorganism-based synthesis have been laid by scientists to point out the vast potential in terms of reliability and sustainability. This was followed by a demonstration of process enhancement using genetically modified engineering approaches, which contributed to the high yield of desired nanomaterials. Diverse microorganisms, like bacteria and fungi, have been employed and will be discussed in this chapter. This chapter will also highlight the recent development of microorganism-based synthesis of organic materials such as cellulose nanomaterials and inorganic materials like metallic nanomaterials. Different mechanisms for these nanomaterials will also be discussed. Finally, the present work on the potential applications of these microorganism-based synthesis nanomaterials like in medical and advanced manufacturing is also mentioned.

Keywords *microorganism; synthesis; nanomaterials; bacteria; bacteria nanocellulose; gold nanomaterial; silver nanomaterial*

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3.1 Introduction

The era of globalization has resulted in the rise of nanomaterials utilization in the technology industry. It is, by definition, a nano-sized material (10^{-9} m) covered in various domains from chemistry, biology, and physics to display specific material characterization of nanomaterials with diverse applications [1]. As a result, nanomaterials have been extensively studied in terms of improvement and efficiency to increase their feasibility. This, in turn, leads to the application of microorganisms for synthesizing nanomaterials as it is believed to be an environmentally friendly alternative to conventional synthesis methods for producing nanomaterials [2].

Nanomaterials have been produced traditionally via physical and chemical techniques known for using materials with high toxicity, hazardous solvents, chemicals, and toxic reagents. It is also reported to have a low material conversion and high energy consumption [3]. The standard physical approach in nanomaterial synthesis today includes laser ablation [4], lithography [5], ball milling [6], and high-energy irradiation [7]. Chemical approaches in the synthesis of nanomaterials include chemical reduction [8], electrochemistry [9], and photochemical reduction [10]. Nanomaterials are known to differ in properties compared to their bulk material while macro-sized materials are somewhat like their bulk material. The reduction of material size to nano-sized exhibit enhanced properties such as high surface area to volume ratio compared to large material and the ability to manipulate other intrinsic properties that is size dependent such as strong surface reactivity [11]. Kolahalam et al. stated that the size and shape of the nanomaterial play a vital role in the modification of its properties such as chemical reactivity, emission, excitation, and stability [12].

Nanomaterial properties can be altered or controlled by adjusting their size during synthesis using different methods and techniques. The optimization of process parameters such as temperature [13], time [14], gas ratio [15], substrate concentration [16], and stirring speed [17] was reported in previous studies to understand the synthesis mechanisms. This resulted in detailed proposed designs and conditions to fabricate nanomaterials with the required properties offered. The physical and chemical approach, more commonly known as top-down and bottom-up techniques, is widely utilized for the synthesis of nanomaterials despite the disadvantages especially in terms of environmental hazards. However, microorganisms-based synthesis is one of the main focuses in recent studies in order to reduce the use of toxic and hazardous chemicals while promoting green chemistry principles [18].

It is believed that the current and future studies regarding microorganisms-based synthesis have the potential to enhance biocompatible, high-yield, cheap, and eco-friendly procedures, which will ultimately lead to the replacement of chemical synthesis of nanomaterials with diverse applications specifically in biomedical and pharmaceutical areas [19]. Park et al. have emphasized the ability to conduct synthesis at room temperature for microorganisms-based synthesis is an energy-efficient process while having other essential advantages such as reduction of toxic chemicals usage, high feasibility for scale-up, and capability of coping in extreme conditions [20].

The use of microorganisms such as bacteria [21], fungi [22], yeast [23], and viruses [24] has escalated over the years as an alternative to conventional methods of nanomaterials synthesis. It has been reported worldwide that microorganisms based synthesis is an environmentally friendly method that can offer a nontoxic, cheap and reliable way for nanomaterials synthesis with wide range of physicochemical properties, composition and morphology [25]. Apart from the listed advantages, microorganisms also can act as templates for the synthesis and result in a well-defined structure of nanomaterials [26]. Different microorganisms would require specific mechanisms for the nanomaterial's synthesis. A diverse utilization of microorganism-based synthesis for nanomaterials as a substitute for the conventional top-down and bottom-up approaches for nanomaterials processing will require solutions to the challenges that have occurred. Grasso et al. reported the challenges that need to be overcome include decreasing polydispersity of nanomaterials, full characterization of biocapping layer agents, high efficiency of biocapping layer removal and nanomaterials purifications, the regulation of the procedure for the microbial cell culture for repeatability of the synthesis, production costs and yield [27]. Nanomaterials synthesized from microorganisms offer applications in diverse fields depending on their physicochemical properties. The potential application of nanomaterials is impacted by several factors, including their morphology and physical and chemical properties.

This chapter will focus on the knowledge of microorganism-based synthesis and related studies reported in the last decade. This chapter also details the current development, mechanism, and application of microorganism-based synthesis used to synthesize nanomaterials. The knowledge regarding this topic is briefly reviewed to provide new insights and perspectives to increase the available current studies.