WOODHEAD PUBLISHING IN MATERIALS

ADVANCED NANOCARBON POLYMER BIOCOMPOSITES

SUSTAINABILITY TOWARDS ZERO BIOWASTE

Edited by
MD REZAUR RAHMAN
MUHAMMAD KHUSAIRY BIN BAKRI

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WOODHEAD PUBLISHING
An imprint of Elsevier

Woodhead Publishing is an imprint of Elsevier
50 Hampshire Street, 5th Floor, Cambridge, MA 02139, United States
125 London Wall, London EC2Y 5AS, United Kingdom

ISBN: 978-0-443-13981-9 (print)

ISBN: 978-0-443-13982-6 (online)

For information on all Woodhead Publishing publications
visit our website at https://www.elsevier.com/books-and-journals

Publisher: Matthew Deans
Acquisitions Editor: Gwen Jones
Editorial Project Manager: Tessa Kathryn
Production Project Manager: Maria Bernard
Cover Designer: Greg Harris

Typeset by MPS Limited, Chennai, India

Dedication

This work is dedicated to my amazing wife and daughters—Shirin Akther, Fahriah Rahman, and Faizah Rahman, who are very special to me and made it possible for me to complete this work.

–Ts. Dr. Md Rezaur Rahman

First, I would like to thank the Almighty God for the guidance, strength, power of mind, protection, and for giving us a healthy life. All of these we offer to you. Every difficult task needs self-effort as well as the guidance of elders, particularly those who are near to our hearts. I offer my humble dedications to my beautiful and loving father, mother, wife, and brothers, whose devotion, love, support, and nightly prayers have enabled me to work toward this significant achievement, along with all the dedicated, well-liked, and well-respected teachers and supervisors.

–Ts. Dr. Hj. Muhammad Khusairy Bin Bakri

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Preface

Integrating nanotechnology and polymer composites has emerged as a transformative paradigm in the rapidly evolving landscape of materials science and engineering, offering unprecedented opportunities to develop advanced materials with tailored properties and multifunctional applications. This book, *Advanced Nanocarbon Polymer Biocomposites*, represents a comprehensive exploration of the synergistic possibilities of the fusion of nanocarbons, polymers, and biocompatible elements.

Nanocarbon materials extracted from wood (pine and aspen) biomass (natural fiber, etc.) exhibit exceptional mechanical, thermal, and electrical properties. Harnessing the unique characteristics of these nanoscale entities and combining them with polymers, which provide flexibility, processability, and a wide range of functionalities, opens new frontiers in material design. Moreover, incorporating biocompatible components facilitates the development of materials that excel in mechanical, morphological, and chemical performance and demonstrate compatibility with living systems, paving the way for applications in biomedicine, construction and building, packaging, and sustainable technologies.

This book is crafted to provide a comprehensive overview of the fundamental and state-of-the-art research and developments in nanocarbon polymer biocomposites. Each chapter is meticulously crafted by experts in the respective areas, covering fundamental principles, synthesis methods, characterization techniques, and diverse applications. The chapters are organized to guide readers through the intricate landscape of nanocarbon polymer biocomposites, from theoretical foundations to practical applications, fostering a holistic understanding of this burgeoning field.

The multidisciplinary nature of this book makes it an invaluable resource for researchers, academics, and practitioners working at the intersection of nanotechnology, polymer science, and biocompatible materials. Whether delving into the fundamental science behind nanocarbon interactions with polymers or seeking insights into the practical applications of these advanced materials, this book serves as a roadmap to navigate the complexities and potentials of nanocarbon polymer biocomposites.

As editors, we would like to express our gratitude to the contributing authors for their scholarly contributions and dedication to advancing the knowledge in this field. We believe this compilation will inspire further exploration, foster collaboration, and contribute to the evolution of nanocarbon polymer biocomposites as a transformative technology.

Md Rezaur Rahman
Muhammad Khusairy Bin Bakri

CHAPTER FOUR

Biosynthetic and natural nanocarbon production

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4.1 Introduction

Carbon, with its various allotropes, is one of the most common elements in the universe. Nanocarbon is an example of an allotrope with a well-defined structure and a particle size on the nanometer scale (Vivekchand et al., 2004). The utilization of various carbon nanomaterials (CNMs) has gained significant traction in recent years, with extensive global research efforts dedicated to exploring their exceptional properties. It is crucial to acknowledge the remarkable technological advancements that can be achieved through the utilization of bio-based carbons, as their potential should not be underestimated (Dalvand et al., 2016; Murthy et al., 2021; Dutta et al., 2022). Exclusively, the vast majority of porous carbons are regarded as cost-effective and possess environmental prominence potential. Comparatively, porous carbons are frequently used in industrial applications and have always been of great interest in categories such as gas storage (Ji et al., 2014), compression (Zhong et al., 2010), heat management (Canseco et al., 2014), detection and separation (Lafdi et al., 2008), supercapacitors (Kholmanov et al., 2015), solar energy storage (Mesalhy et al., 2006), batteries and fuel cells (Liu et al., 2011; Thostenson & Chou, 2006), electrochemical energy storage and conversion (Kockrick et al., 2010), catalysis (Sharma et al., 2019; Wu et al., 2022), photocatalysis (Blanco et al., 2008; Kante et al., 2019; Van Thuan et al., 2022), pollutants elimination in gas as well as liquid (Li et al., 2017;

Advanced Nanocarbon Polymer Biocomposites.
DOI: https://doi.org/10.1016/B978-0-443-13981-9.00004-1

Mao et al., n.d), and protection against electromagnetic waves (Travlou & Bandosz, 2017). Given the importance of porous materials, the pursuit of natural, recyclable, cost-effective, and high-performing precursors holds considerable value. Due to the diverse array of potential compositions and varying porosity scales, bio-based raw materials possess the capacity to be utilized in all the aforementioned applications (Jiang et al., 2009). Carbon encompasses a diverse array of allotropic configurations, spanning from 0D to 3D nanostructures as demonstrated in Fig. 4.1. Among these configurations, certain forms like graphene and its derivatives have gained significant traction, particularly due to the discovery and utilization of novel characteristics. These advancements have paved the way for the development of distinctive functional nanomaterials with applications in the environmental domain (Seredych et al., 2008).

Iijima discovered carbon nanoparticles in the form of nanofibers in 1991, with the lowest diameter being 2.2 nm and the majority ranging from 4 to 30 nm (Iijima, 1991). Researchers have begun to look into this unusual substance and its possible use in a range of sectors. Carbon nanoparticles have received increased attention in various areas and applications due to their better physicochemical properties when compared to numerous other carbon allotropes such as graphite, amorphous carbon, and diamond (Qiu & Yang, 2017). Graphene, a carbon nanoparticle, represents

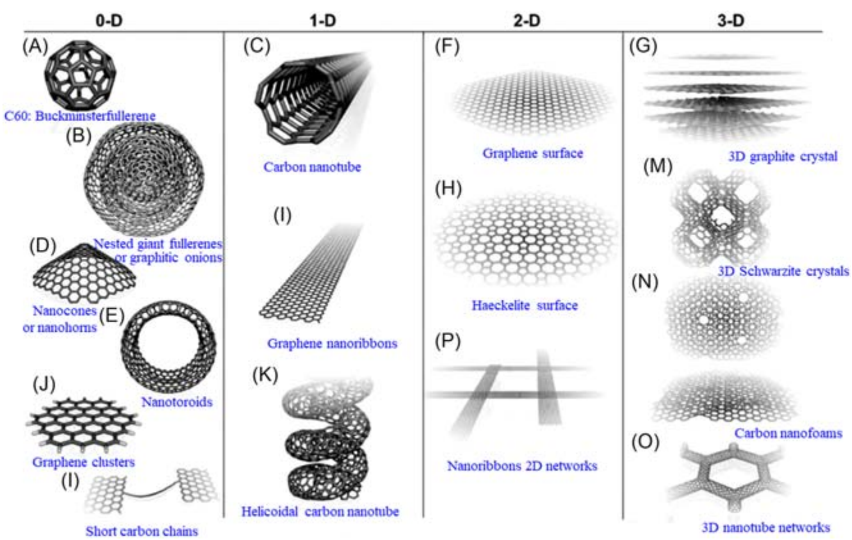

Figure 4.1 Molecular model of various varieties of hybridized carbon nanostructures with varying dimensions: 0D, 1D, 2D, and 3D (Terrones et al., 2010).

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The book covers the latest research findings on nanocarbon polymer biocomposites, their properties and manufacturing, as well as the possible ways to reduce waste and improve their sustainability.

Nanocarbon polymer biocomposites have gained increased attention from both researchers and manufacturers due to the significant improvement in their physico-mechanical, thermal, and barrier properties when compared to conventional materials. Their dimensions, biodegradable character, cost-effectiveness, and sustainability are among the main drivers for increasing demand. However, it is difficult to achieve uniform dispersion between the carbon filler and matrix as it easily forms agglomerations. Production of nanocarbon polymer biocomposites with high mechanical and thermal properties is also limited, but there has been rapid progress in processing possibilities to produce nanocomposites based on various biodegradable fillers. Advanced Nanocarbon Polymer Biocomposites collects all these novel scientific findings in one place. It discusses in detail their physical, chemical, and electrical properties and presents the latest research findings on nanocarbon polymer biocomposites with filler loadings and their improvement on compatibility. The book will be of great interest for those researchers who are concerned with the production and use of nanocarbon polymer biocomposites as a new innovative advanced material.

Key Features

- Emphasizes on nanoscale fillers and their improvement on compatibility
- Evaluates the impact of polymer production through life cycle analysis of both single and hybrid polymers and nanocomposites
- Puts a strong focus on sustainability and green chemistry perspectives

About the Editors

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ISBN 978-0-443-13981-9

9 780443 139819