

Smart Nanomaterials Technology

Showkat Ahmad Bhawani
Mohammad Jawaid *Editors*

Nanomaterials for Separation of Hazardous Contaminants from Wastewater

 Springer


Showkat Ahmad Bhawani · Mohammad Jawaid
Editors

Nanomaterials for Separation of Hazardous Contaminants from Wastewater

 Springer

Editors

Showkat Ahmad Bhawani
Faculty of Resource Science
and Technology
Universiti Malaysia Sarawak
Kota Samarahan, Malaysia

Mohammad Jawaid 
Department of Chemical and Petroleum
Engineering, College of Engineering
United Arab Emirates University
Al Ain, United Arab Emirates

ISSN 3004-8273 ISSN 3004-8281 (electronic)
Smart Nanomaterials Technology
ISBN 978-981-95-6078-3 ISBN 978-981-95-6079-0 (eBook)
<https://doi.org/10.1007/978-981-95-6079-0>

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Singapore Pte Ltd. 2026

This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd. The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

If disposing of this product, please recycle the paper.

Contents

Processing and Properties of Nanomaterials	1
Nur Aqilah Makshut and Zainab Ngaini	
Graphene Nanomaterials for Separation of Hazardous Materials from Wastewater	21
Ravi Kumar	
Composite Nanoclay Materials for Removal of Ions from Water	37
A. H. Bhat, Amal S. Al Rahbi, Veena Doss, Bhupinder Kaur, Showkat Ahmad Bhawani, and Geetha Devi	
Silica-Based Nanomaterials for Wastewater Separation	55
Isaac John Umaru, Hauwa A. Umaru, Rimamskep Danbeki, and Kerenhappuch Isaac Umaru	
Functional Oxide Materials for the Removal of Heavy Metals	71
Ebenezer Morayo Ale, Isaac John Umaru, Olanrewaju Roland Akinseye, and Kerenhappuch Isaac Umaru	
Inorganic Supported Nanocomposites and Their Applications in the Removal of Toxic Contaminants for Wastewater	87
Priyanka Singh and Kafeel Ahmad Siddiqui	
Magnetic Nanocomposites and Their Applications in the Removal of Toxic Contaminants from Wastewater	107
Naseem Ahmad, Saimah Khan, Sanjana Yadav, Umme Salma, Nafish Fatima, Kashif Raees, Mohammad Shahadat, and Nafees Ahmad	
Nanomaterials for the Removal of Metal Ions from Wastewater	123
Basree, Arif Ali, and Musheer Ahmad	
Nanomaterials for the Removal of Pharmaceutical Drugs from Wastewater	147
Shama Firdaus, Shaikh Arfa Akmal, and Aiman Ahmad	

Processing and Properties of Nanomaterials

Nur Aqilah Makshut and Zainab Ngaini

Abstract Nanomaterials have garnered extensive interest due to their unique properties, which significantly differ from those of their bulk counterparts. This chapter explores the diverse methods employed in the production of nanomaterials, emphasising both top-down and bottom-up approaches. Top-down techniques, such as ball milling, lithography, sputtering, laser ablation and arc discharge, physically reduce the size of bulky materials to nano-sized particles. Conversely, bottom-up techniques, including chemical vapour deposition, hydrothermal, solvothermal, sol-gel synthesis and co-precipitation, facilitate the creation of nanomaterials with controlled sizes and shapes from the smallest atoms. In recent years, green synthesis has emerged as a sustainable and environmentally friendly technique, utilising biological entities like plants, microorganisms, algae and actinomycetes as precursors of reducing agents to produce metal nanomaterials, such as silver, copper and cerium. The chapter highlights the importance of nanomaterial processing techniques in determining the structural, optical, mechanical, electrical and magnetic properties of the resulting materials. Despite significant advancements, challenges persist in achieving precise control over nanomaterial properties and scaling up production for industrial applications. This chapter addresses the research gap by examining the latest advancements, methodologies and their impact on various fields. It highlights the pivotal role of nanomaterial processing in enabling innovative applications and overcoming existing limitations. The choice of synthesis technique is discussed in the context of desired properties, applications and environmental considerations.

Keywords Nanomaterials · Processing · Properties · Green synthesis

N. A. Makshut (✉) · Z. Ngaini (✉)

Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, Kota Samarahan, Sarawak, Malaysia

e-mail: aqilahmakshut@gmail.com; 24010218@siswa.unimas.my

Z. Ngaini

e-mail: nzainab@unimas.my

great potential in biomedicine, health and environmental remediation. These nanomaterials can lead to advancements in targeted drug delivery, diagnostic imaging and pollution control. The field of nanomaterials continues to make significant contributions to technological innovations and sustainable solutions, driving progress across various sectors.

Acknowledgements The authors thank Universiti Malaysia Sarawak for financial support through the Graduate Research Grant (UNI/F07/GRADUATE/86745/2025).

References

1. P Jiamboonsri S Wanwong 2021 Photoassisted synthesis of silver nanoparticles using riceberry rice extract and their antibacterial application *J Nanomater* 2021 1 18 <https://doi.org/10.1155/2021/5598924>
2. Idris DS, Roy A (2023) Synthesis of bimetallic nanoparticles and applications—an updated review. *Crystals* (Basel) 13:637. <https://doi.org/10.3390/cryst13040637>
3. I Lacatusu D Istrati N Bordei 2020 Synergism of plant extract and vegetable Oils-based Lipid Nanocarriers: emerging trends in development of advanced cosmetic prototype products *Mater Sci Eng, C* 108 110412 <https://doi.org/10.1016/j.msec.2019.110412>
4. SF Ahmed M Mofijur N Rafa 2022 Green approaches in synthesising nanomaterials for environmental nanobioremediation: Technological advancements, applications, benefits and challenges *Environ Res* 204 111967 <https://doi.org/10.1016/j.envres.2021.111967>
5. F Ridwan M Fadel 2021 Preparation of avocado leaf simplicia macro/nano particles by using high energy ball mill *IOP Conf Ser Mater Sci Eng* 1041 012059 <https://doi.org/10.1088/1757-899x/1041/1/012059>
6. E Sharma R Rathi J Misharwal 2022 Evolution in lithography techniques: microlithography to nanolithography *Nanomaterials* 12 2754
7. PK Dikshit J Kumar AK Das 2021 Green synthesis of metallic nanoparticles: applications and limitations *Catalysts* 11 902
8. I Ijaz E Gilani A Nazir A Bukhari 2020 Detail review on chemical, physical and green synthesis, classification, characterizations and applications of nanoparticles *Green Chem Lett Rev* 13 59 81
9. NS Alharbi NS Alsubhi AI Felimban 2022 Green synthesis of silver nanoparticles using medicinal plants: characterization and application *J Radiat Res Appl Sci* 15 109 124 <https://doi.org/10.1016/j.jrras.2022.06.012>
10. J Zhao Y Zhang Y Wang 2018 The application of nanostructured transition metal sulfides as anodes for lithium ion batteries *J Energy Chem* 27 1536 1554
11. N Salah SS Habib ZH Khan 2011 High-energy ball milling technique for ZnO nanoparticles as antibacterial material *Int J Nanomedicine* 6 863 869 <https://doi.org/10.2147/ijn.s18267>
12. Qi Z, Zhao X, Xiuli G, et al (2024) Nano materials preparation mechanism of planetary ball mill. Preprint 1:5001409
13. S Nawaz M Ahmad S Asif 2022 Phyllosilicate derived catalysts for efficient conversion of lignocellulosic derived biomass to biodiesel: a review *Bioresour Technol* 343 126068
14. ML Menegazzo GG Fonseca 2019 Biomass recovery and lipid extraction processes for microalgae biofuels production: a review *Renew Sustain Energy Rev* 107 87 107
15. Mohamed EH, Ebeid HM, Ashoush IS et al (2023) Nano-capsulation of ginger, red cabbage and broccoli ball mill extracts as sources of anti-oxidant and anti-cancer and application in lentil soup powder. *Egypt J Chem* 66:361–379. <https://doi.org/10.21608/EJCHEM.2022.154781.6692>