

Review Article

Shariqsriyon Sinha Ray and Jayita Bandyopadhyay*

Nanotechnology-enabled biomedical engineering: Current trends, future scopes, and perspectives

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Abstract: Applications of nanotechnology in biomedical engineering are vast and span several interdisciplinary areas of nanomedicine, diagnostics, and nanotheranostics. Herein, we provide a brief perspective on nanotechnology as an enabling tool for the design of new functional materials and devices for medical applications. Semiconductor nanocrystals, also known as quantum dots, are commonly used in optical imaging to diagnose diseases such as cancer. Varieties of metal and metal oxide nanoparticles, and two-dimensional carbon-based nanostructures, are prospective therapeutics and may also be used in protective antiviral/antibacterial applications. Similarly, a number of nanomaterials have shown the potential to overcome the drawbacks of conventional antiviral drugs. However, assessing the adverse effects and toxicities of nanoparticles in medicine and therapeutics is becoming more critical. This article discusses the latest developments of nanomaterials in diagnosis, nanotheranostics, and nanomedicines, with particular emphasis on the importance of nanomaterials in fighting against coronavirus disease. Further, we considered the safety and toxicity of nanomaterials in the context of biomedical applications. Finally, we provided our perspective on the future of nanotechnology in emerging biomedical engineering fields.

Keywords: nanotechnology, biomedical engineering, nanomedicine, trends, scopes and perspectives



Graphical abstract

1 Introduction

Nanotechnology is an enabling tool for designing new materials and devices, which opens a new era of biomedical engineering. Biomedical engineering is an expeditious field that bridges the gap between technology, biology, and medicine. The potential use of nanotechnology in biomedical engineering includes the early detection and treatment of diseases. Cognizance in physical/chemical biology, fabrication principles, and the development of predictive methods to control them, are likely to lead the major advances in nanomedicine and nanodevices.

Paul Ehrlich, a medical doctor who expressed great interest in bacteriology and immunology, proposed the concept of targeted drug delivery that was mediated by nanoparticles in 1954 [1]. He called the delivery system “Zauberkegeln,” which translates to “Magic bullets” in English. This concept gained momentum in 1950–1960 and the controlled release of drugs has since then attracted significant attention. The historical development of nanoparticles (NPs) for biomedical applications over the years is depicted in Figure 1. Professor Peter Paul Speiser and his group first investigated polyacrylic beads for oral administration and developed NPs for drug delivery purposes and vaccines in 1973 [1,2]. Several vaccinations, such as those for tetanus and diphtheria, require multiple injections to build up sufficient antibodies for protection. It was anticipated that the sustained release mechanism of NPs would provide constant immune stimulation, and hence, one injection would be sufficient to achieve the necessary antibody response. Within a short time, the Johns Hopkins

* Corresponding author: Jayita Bandyopadhyay, Centre for Nanostructures and Advanced Materials, DSI-CSIR Nanotechnology Innovation Centre, Council for Scientific and Industrial Research, Pretoria 0001, South Africa, e-mail: jbandyopadhyay@csir.co.za
Shariqsriyon Sinha Ray: St Alban's College, 110 Clearwater Rd, Lynwood Glen, Pretoria 0081, South Africa

Molecular Engineering Of Nanotechnology Current And Future Methodologies

Kartika Sharma



Molecular Engineering Of Nanotechnology Current And Future Methodologies:

Biomedical Engineering: Concepts, Methodologies, Tools, and Applications Management Association, Information Resources, 2017-07-13 Technological tools and computational techniques have enhanced the healthcare industry These advancements have led to significant progress and novel opportunities for biomedical engineering **Biomedical Engineering Concepts Methodologies Tools and Applications** is an authoritative reference source for emerging scholarly research on trends techniques and future directions in the field of biomedical engineering technologies Highlighting a comprehensive range of topics such as nanotechnology biomaterials and robotics this multi volume book is ideally designed for medical practitioners professionals students engineers and researchers interested in the latest developments in biomedical technology *Books In Print 2004-2005* Ed Bowker Staff, Staff Bowker, Ed, 2004 **Tomorrow's Healthcare by Nano-sized Approaches** Paula Messina, Benedini Luciano, Damian Placente, 2020-05-19 Nanomedicine a scientific branch of nanotechnology that operates on the same scale as biology offers the possibility of influencing the healing process from inside of the body by manipulating the matter at cellular or molecular levels Throughout this book current healing approaches based on this revolutionary new technology are summarized from a scientific assessment The aim of the authors is to give through select examples a deep insight to nanotechnology status and the great progress that its rigorous application will bring to human health The authors commitment is to broaden the vision of health professionals who will eventually be the future users of this knowledge **Computational Approaches in Biomedical Nano-Engineering** Ayesha Sohail, Zhiwu Li, 2019-01-14 This book comprehensively and systematically treats modern understanding of the Nano Bio Technology and its therapeutic applications The contents range from the nanomedicine imaging targeted therapeutic applications experimental results along with modelling approaches It will provide the readers with fundamentals on computational and modelling aspects of advanced nano materials and nano technology specifically in the field of biomedicine and also provide the readers with inspirations for new development of diagnostic imaging and targeted therapeutic applications **Comprehensive Nanoscience and Nanotechnology**, 2019-01-02 Comprehensive Nanoscience and Technology Second Edition Five Volume Set allows researchers to navigate a very diverse interdisciplinary and rapidly changing field with up to date comprehensive and authoritative coverage of every aspect of modern nanoscience and nanotechnology Presents new chapters on the latest developments in the field Covers topics not discussed to this degree of detail in other works such as biological devices and applications of nanotechnology Compiled and written by top international authorities in the field Bio and Nano Packaging Techniques for Electron Devices Gerald Gerlach, Klaus-Jürgen Wolter, 2012-07-16 This book discusses future trends and developments in electron device packaging and the opportunities of nano and bio techniques as future solutions It describes the effect of nano sized particles and cell based approaches for packaging solutions with their diverse requirements It offers a comprehensive overview of nano particles and nano

composites and their application as packaging functions in electron devices The importance and challenges of three dimensional design and computer modeling in nano packaging is discussed also ways for implementation are described Solutions for unconventional packaging solutions for metallizations and functionalized surfaces as well as new packaging technologies with high potential for industrial applications are discussed The book brings together a comprehensive overview of nano scale components and systems comprising electronic mechanical and optical structures and serves as important reference for industrial and academic researchers

Cancer Nanotechnology Sang Hyun Cho, Sunil Krishnan, 2016-04-19

Rapid advances in nanotechnology have enabled the fabrication of nanoparticles from various materials with different shapes sizes and properties and efforts are ongoing to exploit these materials for practical clinical applications Nanotechnology is particularly relevant in the field of oncology as the leaky and chaotic vasculature of tumors a

Toxic Effects of Nanomaterials Haseeb Ahmad Khan, Ibrahim Abdulwahid Arif, 2012

Toxic Effects of Nanomaterials provides an authoritative work of international experts in the field of nanotoxicology spanning 8 chapters A key feature of the e book is a broad coverage of phytotoxicity of nanoparticles which is largely neglected in man

Nanoelectronics Ray Robinson &, 2019-05-16

Nanoelectronics is one of the most important technologies of nanotechnology It plays vital role in the field of engineering and electronics Nanoelectronics make use of scientific techniques at atomic scale for developing the nano machines The main target is to reduce the size risk factor and surface areas of the materials and molecules Machines under nanoelectronic process under goes the long range of manufacturing steps each with accurate molecular treatment Semiconductor electronics have seen a sustained exponential reduce in size and cost and a similar augment in performance and level of integration over the last thirty years The Silicon Roadmap is laid out for the next ten years After that either economical or physical barriers will pose a huge challenge The former is connected to the difficulty of making a profit in view of the exorbitant costs of building the necessary manufacturing capabilities if present day technologies are extrapolated The latter is a direct consequence of the shrinking device size leading to physical phenomena impeding the operation of current devices The transistor is the building block to a modern processor The current silicon designed transistors are going to hit their physical limit not merely the actualization of Moore s law but also the problems with heat dissipation wire connections and the materials we use to create them Hence nanotechnology helps us to look at new ways information processing at a better speed and measure A promising alternative to the imminent challenges from the CMOS based computing is to focus on other alternatives of nano scale precision

Chemically Assembled Electronic Nanotechnology CAEN is a promising technology which uses self alignment to construct electronic circuits from nano scale devices that take advantage of quantum mechanical effects This book is intended as an introduction to the field of nanotechnology for nanoelectronics vendors researchers and students who want to start thinking about the potential opportunities afforded by these emerging scientific developments

Innovative theranostic approaches towards neuro-immunology in gliomas Lijie Zhai, Chunsheng Kang, 2023-04-05

21st Century Nanoscience - A Handbook Klaus D. Sattler, 2020-11-13 21st Century Nanoscience A Handbook Public Policy Education and Global Trends Volume 10 will be the most comprehensive up to date large reference work for the field of nanoscience Its predecessor Handbook of Nanophysics by the same editor was published in the fall of 2010 and was embraced as the first comprehensive reference to consider both fundamental and applied aspects of nanophysics This follow up project has been conceived as a necessary expansion and full update that considers the significant advances made in the field since 2010 It goes well beyond the physics as warranted by recent developments in the field This tenth volume in a ten volume set covers nanophotonics nanoelectronics and nanoplasmonics Key Features Provides the most comprehensive up to date large reference work for the field Chapters written by international experts in the field Emphasizes presentation and real results and applications This handbook distinguishes itself from other works by its breadth of coverage readability and timely topics The intended readership is very broad from students and instructors to engineers physicists chemists biologists biomedical researchers industry professionals governmental scientists and others whose work is impacted by nanotechnology It will be an indispensable resource in academic government and industry libraries worldwide The fields impacted by nanophysics extend from materials science and engineering to biotechnology biomedical engineering medicine electrical engineering pharmaceutical science computer technology aerospace engineering mechanical engineering food science and beyond

Nanofertilizer Synthesis: Methods and Types Kamel A Abd-Elsalam, 2024-02-29 Nano Fertilizer Synthesis and Types discusses the production of a variety of nano fertilizers including biological chemical and mechanical types Nano fertilizers aid in nutrition control by increasing nutrient consumption efficiency as nutrients are bonded to nano dimensional adsorbents which in turn release nutrients considerably more slowly than traditional fertilizers As the nano fertilizer sector advances one approach is to concentrate on macro elements N P K as switching to nano fertilizers may result in significant environmental benefits by replacing the majority of these nutrients Furthermore the biosynthesis of nanomaterials employing bacteria algae yeast fungus actinomycetes and plants has opened up a new field of study for the creation of inorganic nanoparticles as environmentally benign fertilizers Because of the several fold increase in the surface to volume ratio of nano forms of nutrients and their appropriateness for foliar application where environmental losses are further decreased nano fertilizers may achieve higher efficiency However before nano fertilizers are manufactured and commercialized further research should be conducted to assess their impact for both humans and the environment While there are some nano fertilizer products available the nano fertilizer production industry still requires additional public and private sector support and development Nano Fertilizers Synthesis and Types presents the latest information highlights the benefits and impacts of each and provides a single volume resource to help effectively and efficiently identify options based on use case Exploring the topic from the various mechanistic types to the relevant regulatory safety and economic aspects this volume will be appropriate for those working with and researching new nano fertilizers Guides in the identification of appropriate nano

fertilizer options based on use case Addresses both target plant and environmental considerations Includes economic and regulatory insights **Nanotechnology-Based Approaches for Targeting and Delivery of Drugs and Genes** Vijay Mishra, Prashant Kesharwani, Mohd Cairul Iqbal Mohd Amin, Arun Iyer, 2017-05-23 Nanotechnology Based Approaches for Targeting and Delivery of Drugs and Genes provides an overview of the important aspects of nanomedicine in order to illustrate how to design and develop novel and effective drug delivery systems using nanotechnology The book is organized into three sections beginning with an introduction to nanomedicine and its associated issues Section two discusses the latest technologies in nanomedicine while the third section covers future developments and challenges in the field By focusing on the design synthesis and application of a variety of nanocarriers in drug and gene delivery this book provides pharmaceutical and materials science students professors clinical researchers and industry scientists with a valuable resource aimed at tackling the challenges of delivering drugs and genes in a more targeted manner Explores a wide range of promising approaches for the diagnosis and treatment of diseases using the latest advances in cutting edge nanomedical technologies Contains contributions from world renowned experts and researchers working in the area of nanomedicine and drug delivery Covers the associated challenges and potential solutions to working with nanotechnology in drug delivery Highlights crucial topics such as biopharmaceutical and toxicity issues quality by design drug targeting and more *Emerging*

Nanotechnologies for Medical Applications Nabeel Ahmad, Gopinath Packirisamy, 2023-02-07 Emerging Nanotechnologies for Medical Applications focuses on both commercial and premarket tools and their applications in medicine The book develops the concept of integrating different technologies along a hierarchical structure of biological systems and clarifies biomechanical interactions on different levels for the analysis of multiscale pathophysiological phenomena With a focus on nano scale processes and biomedical applications it demonstrates how knowledge can be utilized in a range of areas including the diagnosis and treatment of various human diseases and in alternative energy production This book is an important reference source for scientists and researchers involved in micro and nano engineering bio nanotechnology biomedical engineering nanomedicine and industries involved with optical devices computer simulation and pharmaceuticals Shows how nanotechnology is being used to improve outcomes in areas of cancer tissue grafting and printing drugs Explores a variety of nanoengineering techniques used for biomedical applications including for cardiovascular renal and dental treatments Assesses the major challenges of manufacturing nanomaterials based medicines on an industrial scale

Nanofertilizer Delivery, Effects and Application Methods Kamel A Abd-Elsalam, 2024-01-13 Nanofertilizer Delivery Effects and Application Methods explores the science of nutrient nanoformulation a potential tool toward sustainable and climate sensitive crops Wide spread use of chemical fertilizers has been shown to causes significant damage to soil structure mineral cycles soil microbial flora plants and creating human health risk both immediately and for future generations Through methods that include targeted distribution and gradual or controlled release nanostructured fertilizers can improve nutrient

usage efficiency According to recent studies through environmental cues and biological demands nano fertilizers can respond to specific challenges and boost agricultural yield by increasing the rate of seed germination seedling growth photosynthetic activity nitrogen metabolism and carbohydrate and protein synthesis *Nanofertilizer Delivery Effects and Application Methods* discusses the potential agricultural benefits of nanofertilizers from coverage of their formulation and delivery to application plant uptake translocation and destiny and their overall effect on plant physiology and metabolism This book is ideal for researchers in industry and academia Highlights types uses and advantages of a wide range and variety of nanofertilizers on agri food sectors Looks at current practices their challenges and future development opportunities Includes methods and applications for real world insights *Plant-Based Nanoparticle Synthesis for Sustainable Agriculture* Ranjit Pabbati,Kalyani Chepuri,Kondakindi Venkateswar Reddy,Naga Raju Maddela,2025-03-13 The use of nanotechnology in agriculture has created many concerns related to toxicity and environmental implications Green synthesis techniques for producing nanomaterials utilizing plants microorganisms and other natural resources have been developed in response to the demand for green chemistry and nanotechnology This book provides in depth information on the plant based synthesis of nanoparticles and how it promotes sustainable agriculture It critically reviews nanomaterials synthesized from plants and their potential applications including nanoscale insecticides herbicides fungicides fertilizers and sensors which can help to study and manage plant health and soil fertility The features of this volume include A comprehensive resource on plant based nanoparticle synthesis and its usage in gene transformation Strategies and limitations of plants that are genetically engineered using nanotechnology Explanation of the design and use of nanofertilizers and nonopesticides for environmental sustainability Discussions around the toxicity levels of nanoparticles in plants Aids for professionals and scholars to learn advanced techniques to monitor soil and plant systems using nanotechnology This is an excellent reference for researchers academics students and professionals in nanotechnology biochemistry biomedical sciences biotechnology environmental engineering agricultural sciences and plant sciences *Nano-Hype* David M. Berube,2009-12-04 Nanotechnology the science of molecular engineering at the atomic scale has captured the popular imagination From movies to TV series to video games utopian fantasies and horror scenarios involving nanotechnology have become a staple of the entertainment industry The hyperbole surrounding this new technology comes not only from the media but also from scientists who exaggerate the anticipated benefits of nanotechnology to justify research funding as well as from environmentalists and globalization opponents who sometimes indulge in doom and gloom prophecies to advance their own agendas The result is widespread misinformation and an uninformed public In an effort to set the record straight professor of communication studies David M Berube has written this thoroughly researched accessible overview of nanotechnology in contemporary culture He evaluates the claims and counterclaims about nanotechnology by a broad range of interested parties including government officials and bureaucrats industry leaders and entrepreneurs scientists journalists and other persons in the media Berube appraises

programs and grand initiatives here and abroad and he examines the environmental concerns raised by opponents as well as the government and private responses to these concerns With so much argumentation on both sides it is difficult for anyone to determine what is true Nano Hype provides up to date objective information to inform the public Based on over a decade of research and interviews with many of the movers and shakers in nanotechnology this critical study will help the reader separate the realistic prospects from the hype surrounding this important cutting edge technology **Medical**

Informatics: Concepts, Methodologies, Tools, and Applications Tan, Joseph, 2008-09-30 Provides a collection of medical IT research in topics such as clinical knowledge management medical informatics mobile health and service delivery and gene expression *Applied Chemistry* Siddharth Venkatesh, 2025-02-20 Discover the essential aspects of chemistry in

various industries with *Applied Chemistry Practical Applications* This comprehensive textbook provides an in depth understanding of fundamental chemical principles and their real world applications Covering a wide range of topics from chemical reactions and materials science to environmental chemistry and sustainable practices it caters to students researchers and professionals Written by experts our book blends theoretical concepts with practical examples offering a solid foundation in key concepts followed by discussions on their applications in industry technology and everyday life We emphasize sustainability green chemistry principles and environmentally friendly practices Clear explanations of complex topics are supported by diagrams illustrations and tables Our book integrates modern research findings and technological advancements in chemistry End of chapter summaries review questions and exercises reinforce learning and facilitate self assessment Supplementary materials including online resources and laboratory exercises enhance the learning experience Whether you re a student seeking an introduction to applied chemistry or a professional looking to expand your knowledge *Applied Chemistry Practical Applications* is an invaluable resource for understanding the practical aspects of chemistry in industry technology and society **Omics and Genome Editing** Kartika Sharma, 2025-03-15 This book offers up to date

research on genome editing and omics technologies from renowned academics with established backgrounds from throughout the globe The world population is expected to touch 9 10 billion by 2050 and to feed the growing population 50% more food must be produced globally than is currently produced Nonetheless it is a difficult challenge to increase the food output of the currently existing crops on available land Over the past few decades traditional crop enhancement techniques like plant breeding and other agricultural technology have made a significant contribution to food and nutritional security With the use of strong technologies genome editing strategies can significantly improve the productivity and efficiency of current agricultural practices Discovering the underlying mechanisms influencing features of economic value has been made possible through genome editing through CRISPR Cas9 primer and base editing and OMICs through genomics proteomics metabolomics transcriptomics and phenomics This book provides a wealth of information on omics and genome editing approaches and their application to develop abiotic biotic and climate tolerant crops as well as RNA interference next

generation sequencing and metabolomics for sustainable crop production Researchers are actively using both genome editing and omics for crop improvement however there is limited literature offered in a single source Undergraduate and postgraduate students researchers policymakers and stakeholders will find this book to be an invaluable resource

Molecular Engineering Of Nanotechnology Current And Future Methodologies Book Review: Unveiling the Magic of Language

In an electronic era where connections and knowledge reign supreme, the enchanting power of language has become more apparent than ever. Its ability to stir emotions, provoke thought, and instigate transformation is really remarkable. This extraordinary book, aptly titled "**Molecular Engineering Of Nanotechnology Current And Future Methodologies**," written by a highly acclaimed author, immerses readers in a captivating exploration of the significance of language and its profound effect on our existence. Throughout this critique, we shall delve to the book's central themes, evaluate its unique writing style, and assess its overall influence on its readership.

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