Chapter 3
Nano-Bioscience:
Introduction and Nanoparticles in Medicine

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ABSTRACT

Nanotechnology stands at the forefront of materials science, offering opportunities and applications that exploit the unique properties of nanomaterials. These materials exhibit characteristics that differ significantly from their bulk counterparts, enabling innovations across various sectors. This chapter delves into the classification of nanomaterials as outlined by Siegel, categorizing them into zero, one, two, and three-dimensional structures, each with distinct properties and potential applications.

INTRODUCTION

Nanotechnology is at the forefront of materials research, providing opportunities and applications that take advantage of the unique features of nanoparticles. These materials have properties that differ greatly from their bulk equivalents and atomic forms, allowing for advances in a variety of sectors. This chapter looks into Siegel's taxonomy of nanomaterials, which includes zero, one, two, and three-dimensional structures, each having unique features and potential applications. Zero-dimensional (0D) nanomaterials, such fullerenes and quantum dots, are especially significant. Fullerenes, which are made

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solely of carbon atoms organized in a hollow sphere, have excellent electrical, thermal, and mechanical properties, making them ideal for applications such as drug delivery systems. Quantum dots, semiconductor nanoparticles with size-tunable optical characteristics, are extremely useful in medical imaging and display technology. Magnetic Fe_3O_4 nanoparticles, in addition to 0D nanomaterials, have garnered popularity for their distinct magnetic properties. These nanoparticles improve data storage capacity in computer hard drives and are critical in emerging medical technologies such as magnetic fluid hyperthermia, which targets and heats cancer cells, and targeted drug delivery systems, which enable precise therapeutic delivery. Fe_3O_4 nanoparticles are used to remove pollutants from water and seal rotary shafts in mechanical systems. Nanomaterials have far-reaching ramifications in sectors as diverse as renewable energy, information technology, environmental research, and biology. Their unique features enable advances in solar cell efficiency, smaller data storage, and enhanced diagnostic tools, demonstrating nanotechnology's disruptive promise across numerous industries. As research advances, nanotechnology's uses are projected to grow, tackling some of society's most urgent concerns.

NANOTECHNOLOGY AND NANOBIOTECHNOLOGY

Nanotechnology and Biotechnology are critical scientific fields, and their combination, known as Nanobiotechnology, merges nanotechnology principles with biotechnology applications, making it highly interdisciplinary(Payal et al., 2021). This emerging field offers vast potential for the 21st century with numerous applications. For example, metal oxides like titanium oxide and zinc oxide are already used in skincare products, while nanoparticles have applications in biosensing (e.g., glucose and gas sensing) and drug delivery(Dhara & Mahapatra, 2019; R. Liu et al., 2020; Raveendran et al., 2017). In the food sector, technologies like nutrient delivery systems, biosensors, and edible films are being developed to address issues such as food preservation and microbial contamination(Durán & Marcat, 2013). Nanosensors, for instance, are being designed to monitor proper storage conditions like temperature. In the biomedical field, nanobiotechnology is showing promise in targeted drug delivery, where nanoparticles enhance drug concentration at disease sites. Gold nanoparticles loaded with complementary DNA strands enable highly sensitive pathogen detection, including applications in detecting anthrax. Semiconductor nanoparticles integrated with DNA, enzymes, or antibodies are also being used to create stable optical-electrical biosensors. These advancements are paving the way for significant innovations across various industries(Fakruddin et al., 2012; A. Nene et al., 2023).

NANOMATERIALS

Nanomaterials have at least a dimension in the nanometer range, so they exhibit properties distinct from their bulk counterparts. Nanotechnology is an emerging field dedicated to the generation, characterization and manipulation of nanomaterials classified by Siegel as zero, one, two, or three-dimensional. Current applications of nanomaterials include solar cells, fuel cells, audio/video tapes, computer hard drives, dental bonding agents, catalysis, water purifiers, and skincare products. In biomedical science, they are utilized for targeted drug delivery, diagnostics, and sensing applications(Patel et al., 2021).

Zero-dimensional nanomaterials include fullerenes and quantum dots. Fullerenes (C_{60}) are spherical molecules composed entirely of carbon atoms, with unique electrical and physical properties. Quantum