Chapter 12
Nanotechnology Applications in Biomedical Engineering

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ABSTRACT

The 21st century has seen a massive explosion in the applications of nanotechnology. These applications cover all areas of Science, Technology, Engineering, and Mathematics (STEM). The advantage of nanotechnology comes from the fact that it has revolutionized the miniaturizations of many products that are useful to the well-being of society. A typical nanotechnology application example in biomedical engineering is its usage as drug eluting interfaces for implantable devices, such as vascular stents, orthopedic implants, and dental implants. The purpose of this chapter is to discuss the various applications of nanotechnology to biomedical engineering. Some of the future nanotechnology applications in biomedical engineering include healthcare/medical, consumer medical goods, environmental, and electronics. The impact of nanotechnology applications to biomedical engineering is in many ways enabling humans to survive different ailments that otherwise could have been very difficult to manage. The safety aspects in the applications of nanotechnology to biomedical engineering are also examined.

INTRODUCTION

The 21st century has seen diverse but very important applications of Nanotechnology. It is a field that has very long history and richness and its areas of applications are unlimited. It started with the first description of the concept of nanoscience in 1959 by Richard P. Feynman who was a physicist (Feynman, 1960). In 1974, Taniguchi (1974) came up with the term nanotechnology describing it as a field of engineering with precision having tolerances of micron or less. It was not until the mid1980s that Drexler (1986) with the publication of his book entitled “Engines of Creation” that the term nanotechnology became known to the public.

Nanotechnology applications cover all areas of science, technology, engineering and mathematics (STEM). It can be defined as that technology that has the ability to create using structures, devices and systems that have novel properties and functions because of their small and/or intermediate size. The

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sizes (nanoscales) range from 1 nanometer (nm) to 100 (nm). Simply, nanotechnology means the world of "small things", such as atoms and molecules. It also concerns as well as nanoscience, very important materials called nanomaterials or nanotechnology materials.

The commercial applications as a result of the manipulations of these nanoscale materials include electronic, magnetic and optoelectronic, biomedical, pharmaceutical, cosmetic, energy, catalytic and materials applications. In this chapter, the focus will be on the nanotechnology applications to biomedical engineering. The specific application areas include sensors, "lab-on-chip" techniques, molecular imaging, drug delivery, biomedical electronics, biomedical nanorobots, etc. Nanotechnology applications in biomedical engineering presents many revolutionary opportunities in the fight against all kinds of cancer, cardiac and neurodegenerative disorders, infection and other diseases.

The applications of nanotechnology in biomedical engineering imply creation of materials and devices designed to interact with the body at sub-cellular scales with a high degree of specificity. This could be potentially translated into targeted cellular and tissue-specific clinical applications aimed at maximal therapeutic effects with very limited adverse-effects. The anticipated results include several direct products that are channeled to the improvements of diagnostics and therapeutics of the human body conditions.

The chapter will explore the different categories in the application of nanotechnology materials to the biomedical engineering field. The challenges facing scientists and engineers working in the field of nanotechnology will be discussed as they are quite enormous and extraordinarily complex in nature. The chapter is divided into eleven sections. Sections 1 and 2 cover the introduction and overview to nanotechnology applications while sections 3 and 4 cover the nanoscale materials and the nanotechnology particles respectively. Section 5 discusses the commercial applications of nanotechnology in biomedical engineering and in Section 6; we discuss the application of nanotechnology in biomedical engineering. In Sections 7 and 8; we discuss the nanotechnology safety issues and solutions and the future of nanotechnology applications in biomedical engineering respectively. Section 9 is the solutions and recommendations while Sections 10 and 11 are the future research directions and summary and conclusion and references respectively. Section 12 is the key terms and definitions.

OVERVIEW OF NANOTECHNOLOGY APPLICATIONS

In Nanoscience and Nanotechnologies (2004) and Knowles (2006), Nanometer, nanoscale and nanoscience are defined as follows: One thousand millionths of meter is called a *Nanometer (nm)*. An example is that of a human hair that is about 80,000 nm wide; a red blood cell is about 7,000 nm wide; and a water molecule is about 0.3 nm wide. In the case of *Nanoscale*, it is the size range from 100 nm down to 0.2 nm. The study of the phenomena and manipulation of materials at atomic, molecular and macromolecular scales where properties of the materials can be quite different from those of larger scales are called *Nanoscience*. Nanotechnology as well as nanoscience concern very important materials called *nanomaterials* or *nanotechnology materials*.

There are three different categories that will be explored in the application of nanotechnology materials in biomedical engineering. The first is the current applications that include coatings, clay, composites, tougher tools, and cosmetics. The second category is the short-term applications that include displays, fuel additives, paints, catalysts, batteries, and fuel cells. The third category is the long-term application of nanotechnology materials that include military battle suits, nanotube composites, water purification, machinable ceramics, medical implants, magnetic materials, and lubricants.

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