# Chapter 6
# Application of Carbon Nanotubes in Nanomedicine: New Medical Approach for Tomorrow

**Omid Moradi**
*Islamic Azad University, Iran*

**Ramin Shahryari-Ghoshekandi**
*Islamic Azad University, Iran*

**Hamidreza Sadegh**
*Islamic Azad University, Iran*

**Mehdi Norouzi**
*Tehran University of Medical Sciences, Iran*

## ABSTRACT

*Carbon Nanotubes (CNTs) have become a technological field with great potential since they can be applied in almost every aspect of modern life. One of the sectors where CNTs are expected to play a vital role is the field of medical science. This chapter focuses on the latest developments in applications of CNTs for nanomedicine. A brief history of CNTs and a general introduction to the field are presented. Then, the preparation of CNTs that makes them ideal for use in medical applications is highlighted. Examples of common applications, including cell penetration, drug delivery, and gene delivery and imaging are given. Finally, the toxicity of carbon nanotubes is discussed.*

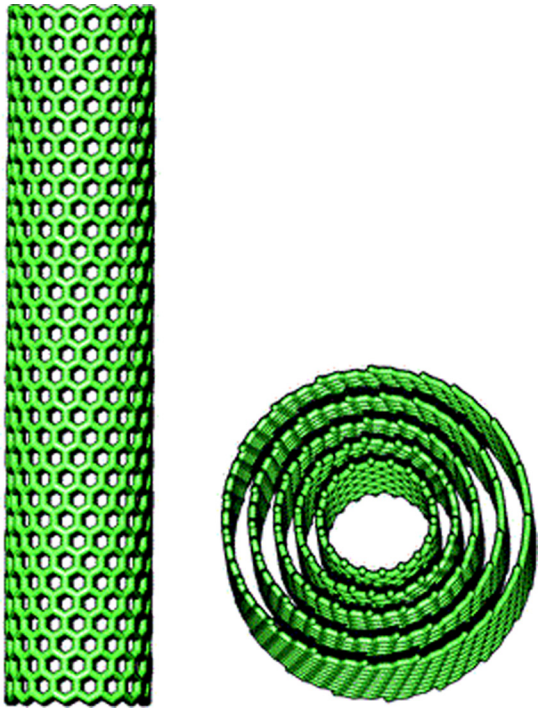
## INTRODUCTION

Since Carbon Nanotubes (CNTs) were discovered by Iijima (Iijima, 1991), they have become the subject many studies because of their unique electrical, optical, thermal, and mechanical properties (Moradi, Yari, & Najafi, 2012; Troiani, Miki-Yoshida, & Jose-Yacaman, 2003; Ouyang, Huang, & Lieber, 2002) Carbon nanotubes (CNTs) can be visualized as a sheet of carbon atoms rolled up into a tube with a diameter of around tens of nanometers. There are two main types of CNTs, Single-walled (SWCNTs) and Multi-walled carbon nanotubes (MWCNTs), the latter being formed by several concentric layers of rolled graphite (Figure 1). In particular, SWCNTs are characterized by a high aspect ratio. In last decade, CNTs are intensively explored for in-vitro and in-vivo delivery of therapeutics, which was inspired by an important finding that CNTs can penetrate cells by themselves without apparent cytotoxic effect to the cells (Moradi, Sadegh, & Shahryari-ghoshekandi, 2014; Khani & Moradi, 2013; Kostarelos, Lacerda, & Bianco, 2007). The high aspect ratio makes CNTs outstanding from other types of round nanoparticles in that the

DOI: 10.4018/978-1-4666-6363-3.ch006

needle-like CNTs allow loading large quantities of payloads along the longitude of tubes without affecting their cell penetration capability. With the adequate loading capacity, the CNTs can carry multifunctional therapeutics, including drugs, genes and targeting molecules, into one cell to exert multi-valence effects. In the other side, owing to the ultrahigh surface area along with the strong mechanical properties and electrically conductive nature, CNTs are excellent material for Nano-scaffolds and three dimensional Nano-composites. In recent year, CNT-based devices have been successfully utilized in tissue engineering and stem cell based therapeutic applications, including myocardial therapy, bone formation, muscle and neuronal regeneration. Furthermore, owing to the distinct optical properties of CNTs, such as, high absorption in the near-infrared (NIR) range, photoluminescence, and strong Raman shift (Zhang, Zhang, & Zhang, 2011; Ando, 2010) CNTs are excellent agents for biology detection and imaging. Combined with high surface area of CNTs for attaching molecular recognition molecules, CNT-based, targeted Nano-devices have been developed for selective imaging and sensing. There are many areas where CNTs are extremely useful. Given the scope in this chapter, describe strategies for preparation of CNTs for their use in medicine. Specifically, we focus and highlight the important Nanomedicine applications of CNTs in the field of Cell Penetration, drug delivery, gene delivery and imaging.

*Figure 1. Schematics of a SWCNT and MWCNT*



## PREPARATION OF CNTs FOR USE IN MEDICINE

Raw CNTs, persisting metallic nature, are highly hydrophobic. Therefore, surface modification of CNTs, or CNT functionalization, so as to disperse them into aqueous solutions becomes a key step for their medical applications. The CNT modification methods are involved in non-covalent and covalent strategies. The non-covalent modification utilizes the hydrophobic nature of CNTs, especially, π-π interactions for coating of amphiphilic molecules. The covalent modification generates chemical bonds on carbon atoms on CNT surface via chemical reactions followed by further conjugation of hydrophilic organic molecules or polymers rendering CNTs better solubility. These modifications not only offer CNTs water solubility, but also produce functional moieties that enable linking of therapeutic agents, such as genes, drugs, and recognition molecules for medical applications.

### Non-Covalent Functionalization

The methods of functionalization of CNTs based on non-covalent interaction can be performed without destroying the intrinsic $sp^2$-hybridized structure of the nanotube sidewall, so that the original electronic structure and properties of CNTs can be preserved. Different kinds of non-covalent functionalization have been explored.