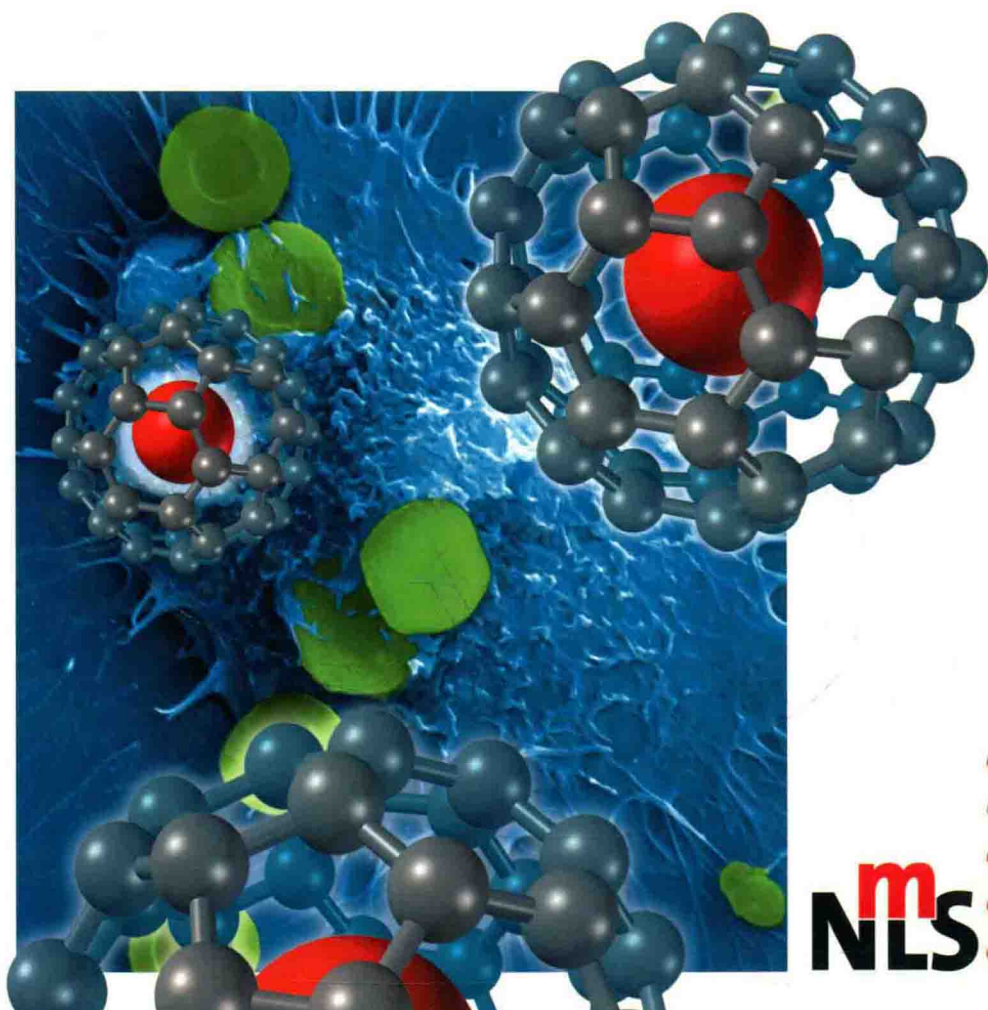


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# Carbon Nanomaterials



*Nanomaterials for the  
Life Sciences*  
Volume 9

## **Carbon Nanomaterials**

*Edited by*  
Challa S. S. R. Kumar

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## Preface

### Vol 9 – Carbon Nanomaterials for the Life Sciences

Since the discovery of the  $C_{60}$  molecule, the family of carbon nanomaterials has been steadily growing. Carbon nanotubes, the most famous, were the first to be explored for their potential in biological and biomedical applications. Since then, a number of other types of carbon nanomaterials ranging from graphene, fullerenes, carbon nanoparticles, and carbon nanohorns have also been gaining importance thanks to development of methods for their chemical modification and bio-functionalization in order to conjugate them with proteins, carbohydrates, nucleic acids and any other biomolecule. This opened up an entirely new and exciting research direction involving Carbon Nanomaterials and biology especially in targeting the cell's behavior at the sub cellular or molecular level. This book, Carbon Nanomaterials for the Life Sciences, is the 9<sup>th</sup> volume in the series on Nanomaterials for the Life Sciences and covers the latest advances in synthesis and bio-functionalization of carbon nanomaterials along with their applications in drug delivery, biosensing, tissue engineering, and cancer therapy. The book is broadly divided into two parts. In the first part, there are eleven chapters covering various aspects of synthesis, characterization and different biomedical applications. In the second part there are six chapters with their combined focus on applications in cancer treatment and diagnosis.

The book begins with a chapter on synthesis of carbon nanomaterials particularly in the context of their biofunctionalization and applications in both biochemistry and biology along with a perspective on reducing their toxicity. In the second chapter, some of the most important techniques applicable for the characterization of nanocarbons starting with classic diffraction techniques, followed by imaging techniques using electron microscopy and scanning probe microscopy are described. In addition, some important spectroscopic methods which are essential for determination of electronic structure and functionalities are also included. The third chapter is completely dedicated graphene exploring its synthesis, characterization, and biomedical applications. In this chapter evidence is provided to show its promising application in drug delivery, bio devices, and molecular imaging. The fourth chapter brings out the importance of carbon nanohorns (CNHs), a more recent addition to the list of carbon allotropes. Even though the field of carbon nanohorns is still in its infancy, a number of biomedical applications have

been explored due to their unique structures and properties and the chapter four captures the most recent ones. The theme of the fifth chapter is exploring magnetic properties of carbon nanomaterials (diamond, graphite and carbon nanotubes) and the chapter provides both fundamental explanations for magnetism as well as the latest developments related to their synthesis, characterization and applications in biomedicine.

The focus of the sixth chapter is multi-walled nanotubes (MWNT). MWNTs by definition are many nested tubes of multiple concentric sidewalls with diameters of a few nanometers up to hundreds of nanometers and lengths in the micron range. In this chapter application of MWNT for a broad array of drug delivery applications including delivery of agents to modify genetic function, transdermal delivery, antibiotic agents and delivery of chemotherapeutic agents directly via intracellular transport or indirectly via hyperthermia to induce intracellular transport are presented. Moving from drug delivery applications, the seventh chapter provides reader with up to date information on investigations into suitability of carbon nanotubes as biomaterial for tissue engineering highlighting a broad range of issues starting from fabrication, properties and performance of three dimensional carbon nanotube-based matrices. Highlight of this chapter is the attention on the biocompatibility studies proving the capability of carbon nanotubes to support long-term survival of osteoblast and fibroblast cells.

Yet another fascinating application of carbon nanomaterials in general and carbon nanotubes in particular is biosensing taking advantage of their electrochemistry. In the eighth chapter, therefore, various properties of CNTs including mechanical, electrical, and chemical/electrochemical properties that make them enticing for biosensing were discussed. This was followed description of latest results regarding various types of electrochemical sensors were highlighted including those based on amperometric, enzymatic systems. Continuing to elaborate on biosensors, the ninth chapter describes the use of various types of single-walled carbon nanotube field effect transistors (SWNT-FETs) in biomedical applications. It will be obvious from reading the chapter that it is possible to develop highly sensitive biosensors for diverse purposes by using SWNT-FETs and suitable receptors.

The final two chapters in the first section deal with two conceptually different topics. In the first chapter, tenth in the book, readers are provided an opportunity to understand fullerenes from the point of view of environmental hazard assessment. In the last chapter utilization of computational simulations tools for the development of PEGylated-lipophilic polymers with or without functionalized SWNT as drug delivery carriers for anticancer therapeutics is presented. This chapter is extremely important as it demonstrates the necessity of computer modeling to identify biocompatible and safe nanomaterials and nanotools for early detection of diseases.

With around 1.5 million people diagnosed and 1/3 rd of them dead in year 2009, Cancer continues to be one of the top deadliest diseases of humankind. Adding to the problem is several types of cancers such as pancreatic, glioblastoma multiforme remain essentially incurable. Successful nanotechnology-based approaches,

for both sensitive and timely diagnosis as well as effective therapy of a number of primary and metastatic tumors, are providing a glimmer of hope for cancer patients. The second section in this book is completely dedicated to similar efforts albeit focusing only on carbon nanomaterials. In this section, the first chapter explains several important advances for the use of carbon nanotubes, especially in the photothermal treatment, drug delivery and tumor imaging for cancer treatment in pre-clinical models. Continuing to stress on one of the most important properties of carbon nanotubes, their strong absorbance of light in the near-infrared range (700-1400 nm), leading to their heating, the next chapter (Chapter 13) summarizes progress on the use of carbon nanotubes to treat cancer through heating of the nanotubes by near-infrared or radiofrequency field radiation. The chapter also covers therapeutic approaches taking advantage of complexation of the nanotubes with anticancer agents. The next chapter in this section is devoted to targeted cancer therapy using carbon nanotubes. CNTs for drug delivery have the potential to practically realize the concept of "magic bullet." The chapter provides latest review on the topic. This is the first review of its kind focusing on advantages of CNT based nanocarriers in targeted cancer drug delivery including details about CNT functionalization and cellular uptake.

In the 15<sup>th</sup> chapter, readers will find most recent review on application of CNTs to brain tumor therapy. It highlights critical characteristics of CNTs for biological applications. It also brings out current challenges in brain tumor therapy with special emphasis on the use of CNTs to target tumor macrophages with a perspective on toxicity issues. The penultimate chapter summarizes the role of carbon nanotubes in several forms of cancer therapy. It also brings out the essential role of CNTs in boron neutron capture therapy (BNCT), a technology that appears promising. Form BNCT, the last chapter takes the readers to photo dynamic therapy; a non-surgical, minimally invasive approach for the treatment of solid tumors and many non malignant diseases. In this chapter, the ability of fullerenes to absorb visible light leading to generation of reactive single oxygen (ROS) that can efficiently inactivate viruses and kill cancer cells and pathogenic microbial cells is highlighted. Thanks to fullerenes the field of PDT got a new lease of life even though fullerenes do have some disadvantages in their optical absorption spectrum compared to currently well established materials. However, according to the authors of the chapter, rational strategies to overcome these deficiencies do exist and more will likely be developed.

Overall, this book is the first of its kind summarizing the literature to date on application of Carbon Nanomaterials in life sciences. It is invaluable for the reader as contributors for each of the chapters are renowned experts in their particular fields. I am grateful for their contributions. Thank you for reading!

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