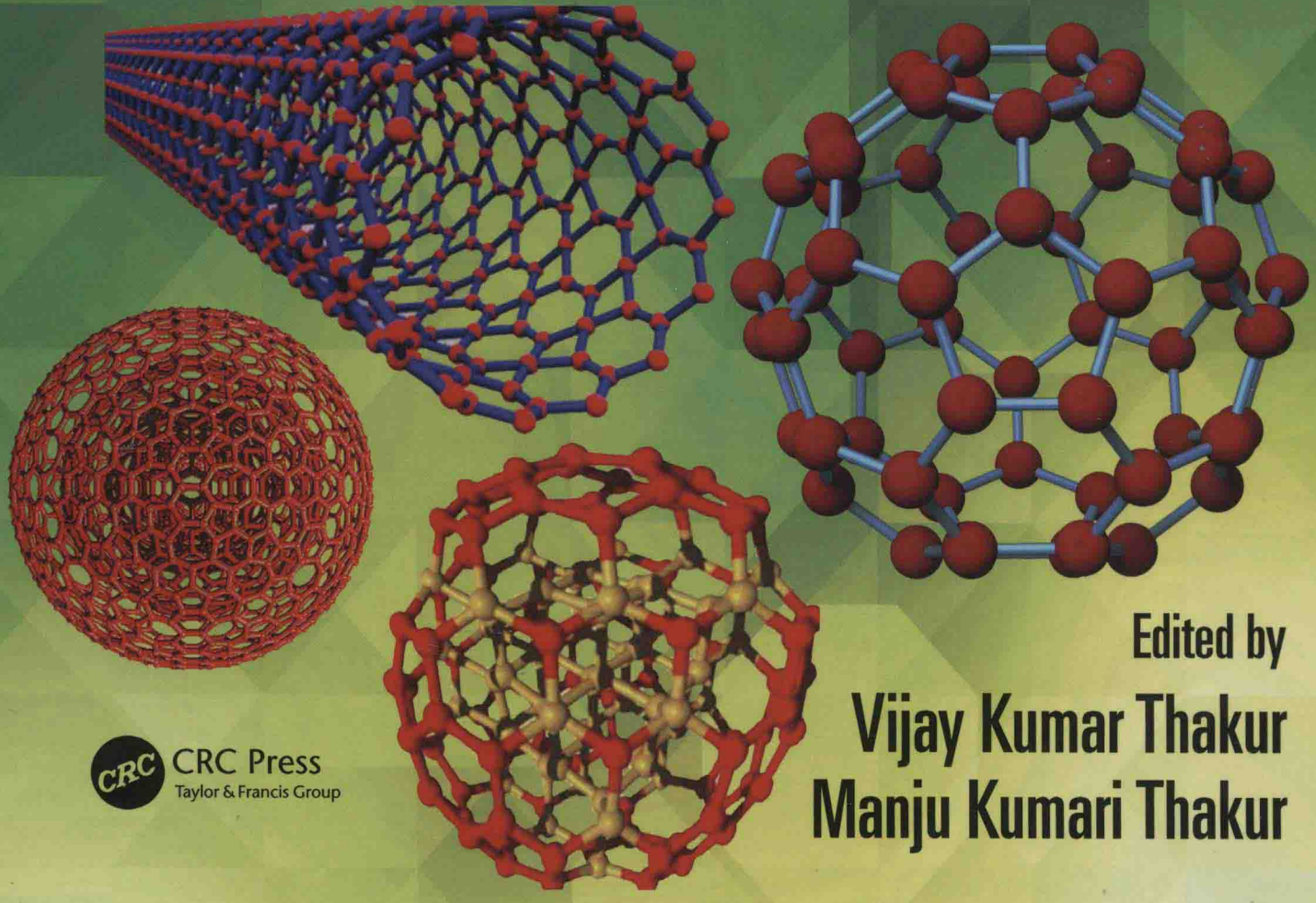
# CHEMICAL FUNCTIONALIZATION OF CARBON NANOMATERIALS

## CHEMISTRY AND APPLICATIONS



Edited by
Vijay Kumar Thakur
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# CHEMICAL FUNCTIONALIZATION OF CARBON NANOMATERIALS

## CHEMISTRY AND APPLICATIONS

*To my parents and teachers, who helped me become what I am today.*

**Vijay Kumar Thakur**

# Preface

Carbon-based nanomaterials are rapidly emerging as one of the most fascinating materials in the twenty-first century. Carbon is a very important element in the periodic table that essentially forms the basis of life on Earth. Elemental carbon exists in two natural allotropes, diamond and graphite, having $sp^3$- and $sp^2$-hybridized carbon atoms, respectively. Both allotropes of carbon represented the carbon family for a long time, until the discovery of fullerene in 1985. The serendipitous discovery of fullerene marked the beginning of an era of synthetic carbon allotropes from naturally occurring diamond and graphite. Soon after the discovery of 0D fullerene, the synthetic carbon family has been graced by the addition of quasi-1D carbon nanotubes (CNTs), whose discovery in 1991 created a boom in the scientific world. Their large length (up to several microns) and small diameter (a few nanometers) result in a large aspect ratio. They can be seen as the nearly 1D form of fullerenes. Therefore, these materials are expected to possess additional interesting electronic, mechanical, and molecular properties. More recently, the discovery of graphene made it a flagship material harbingering the age of nanotechnology. The arrangement of carbon atoms in each crystal is the fundamental difference between these various structures. These revolutionary allotropes of carbon represent an attractive research field in the nanomaterials sector with important economic potential. The most popular nanomaterials of the carbon family to date are fullerenes, CNTs, and graphenes, with dimensions ranging from 0.5 to 100 nm. These carbon-based nanomaterials possess unique and novel properties, such as remarkable mechanical strength, electrical conductivity, and optical, chemical, and thermal properties due to their unique and intriguing size. The prime advantages of the carbon nanomaterials include high surface-area-to-volume ratio and unique thermal, optical, mechanical, and electrical properties to name a few. The characteristic structures of carbon-based nanomaterials promote them to interact with organic molecules through covalent and noncovalent bonds. Noncovalent interaction can be named as hydrogen bonding, $\pi$–cation interaction, $\pi$–$\pi$ stacking, $\pi$–anion electrostatic forces, hydrophobic interactions, and van der Waals forces. Carbon allotropes have attracted scientists, and materials that consist of conjugated $\pi$-bond systems are topologically confined objects in zero, one, two, or three dimensions. In spite of their numerous advantages, carbon-based nanomaterials also suffer from a few drawbacks. One of the biggest disadvantages is their low solubility in nearly all solvents and the lack of bonding caused by different forces, such as the attractive van der Waals interaction. Solubility is a vital property for processability as it concerns purification. Another significant drawback is the lack of compatibility/bonding/inertness toward other materials. To overcome the disadvantages of these carbon-based nanomaterials, surface modification through chemical functionalization is an imperative technique capable of overcoming the inherent advantages of the various carbon nanomaterials. Functionalizing carbon-based nanomaterials with an element of interest facilitated a lot to conquer their demerits and also augment their activity in many cases. Functionalization of carbon-based nanomaterials can be achieved by different techniques, and the two most practiced methodologies include covalent functionalization and noncovalent functionalization. Given their practical implications for commercial use, the surface chemistry of carbon nanomaterials is a topic of huge interest, and strong efforts are being dedicated in developing novel methods for the modification and qualitative and quantitative characterization of the surface functional groups.

Thus, given the immense advantages of carbon nanomaterials, this book primarily focuses on their chemical functionalization using different techniques. Several critical issues and suggestions for future work are comprehensively discussed with the hope to provide a deep insight into the state of the art of functionalized carbon nanomaterials. We thank Leong Li-Ming (acquisitions editor) and the publisher (CRC Press and Taylor & Francis Group) for the invaluable help in the organization of the editing process.

Finally, we thank our parents for their continuous encouragement and support.

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**Manju Kumari Thakur, MSc, MPhil, PhD,** is an assistant professor of chemistry at the Division of Chemistry, Government Degree College Sarkaghat, Himachal Pradesh University, Shimla, India, since June 2010. She earned a BSc in chemistry, botany, and zoology; an MSc and an MPhil in organic chemistry; and a PhD in polymer chemistry at the Chemistry Department at Himachal Pradesh University, Shimla, India. She has a rich experience in the field of organic chemistry, biopolymers, composites/nanocomposites, hydrogels, applications of hydrogels in the removal of toxic heavy metal ions, drug delivery, etc. She has published more than 30 research papers in several international journals, coauthored 2 books, and also published 28 book chapters in the field of polymeric materials.

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