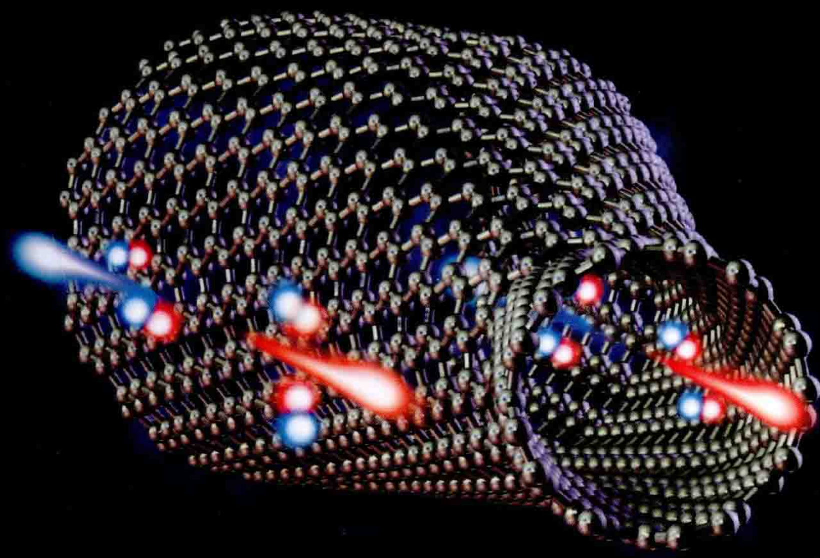
Polymer Nanotube Nanocomposites

Synthesis, Properties, and Applications



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Preface

Nanotube materials are the one of the best examples of novel nanostructures derived by bottom-up chemical synthesis processes. The chemical composition and atomic bonding configuration present in nanotubes is simple; however, these materials represent diverse structure-property relations among the nano-materials. Since the early discoveries of the nanotube materials, a large number of research studies have been devoted to demonstrate the potential of the nanotubes in improving the mechanical, electrical and thermal properties of materials. Polymer nanotube nanocomposites represent an important class of such hybrid materials where the nanotubes are embedded in the polymer matrices by employing various synthesis methodologies including solution casting, melt blending or *in-situ* polymerization in the presence of nanotubes. Uniform dispersion of nanotubes in the polymer matrix is of utmost importance in order to obtain an optimal improvement in the properties of the polymer at low fractions of nanotubes. Thus it is required to optimize the compatibility between the organic and inorganic phases as well as processing methodologies. The current book intends to assimilate the various polymer nanotube systems reported in the literature to underline the high potential of nanotubes as fillers and to provide pathways for the large scale commercial application of the nanotube nanocomposites.

Chapter 1 describes the properties and synthesis of nanotubes. It is clear from the properties of the nanotubes that tremendous gains in the properties of the composites can be achieved if the nanotubes and polymer phases are optimally mixed. Chapter 2 reviews the numerous polymer nanotube composite systems reporting superior composite properties and thus justifying the ever-increasing use of nanotubes as fillers for composite materials. Chapter 3 deals with the use of electron microscopy methods along with new advancements in understanding the microstructure of polymer nanotube nanocomposites. Chapter 4 describes the combined use of clay as well as nanotubes as reinforcements in the composite synthesis and the synergistic effects of the two fillers in the property enhancements. Chapter 5 details the non-polar nanocomposites with polyethylene as the polymer. Polar polyurethane nanocomposites with nanotubes is dealt with in Chapter 6. Commercially important PMMA nanotube nanocomposites are described in Chapter 7. Chapter 8 describes the suspension polymerization for the synthesis of vinyl polymer based nanotube nanocomposites. Biodegradable polymer system of polylactide has also been used for the synthesis of nanocomposites and properties of such composites are reported in Chapter 9. Engineering plastics like PEEK have also been reinforced with nanotubes and the microstructure and properties of these composites can be found in Chapter 10. Chapter 11 details the synthesis and resulting properties of polyvinyl alcohol nanotube nanocomposites, whereas Chapter 12 focuses on the reinforcement of elastomers with nanotubes. Controlled dispersion of nanotubes in co-continuous polymer blends are detailed in Chapter 13. Effect of structure and morphology on the tensile properties of polymer nanotube nanocomposites is the focus of Chapter 14. Chapter 15 with the help of case studies sums up the promises and current challenges present in front of the polymer nanotube nanocomposites technology.

At this juncture, I would like to express my gratitude to Scrivener Publishers for their kind support in the project. I dedicate this book to my family, especially to my mother, for being constant source of inspiration without which I would not have achieved this or any goal. Moreover, heartfelt thanks to my wife Preeti for her continuous help in the project from inception till completion.

Vikas Mittal
Ludwigshafen, March 2010.

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Carbon Nanotubes: An Introduction*

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Abstract

Carbon nanotubes represent high potential fillers owing to their remarkably attractive mechanical, thermal and electrical properties. The incorporation of nanotubes in the polymer matrices can thus lead to synergistic enhancements in the composite properties even at very low volume fractions. This chapter provides a brief overview of the properties and synthesis methods of nanotubes for the generation of polymer nanocomposites.

Keywords: nanotubes, nanocomposites, electrical, mechanical, vapor deposition, laser, arc.

1.1 Introduction

Carbon nanotubes, which are allotropes of carbon, are regarded as the ultimate carbon fibers (1,2). Their mechanical properties (strength, stiffness) are expected to approach that of an ideal carbon fiber, which has the perfect orientation of defect-free graphene (single layer of graphite) layers along the fiber axis. These graphene layers are also represented to be as thinnest possible layers to form the nanotubes. Nanotube materials are the one of the best examples of novel nanostructures derived by bottom-up chemical synthesis processes (3). The chemical composition and atomic bonding configuration present in nanotubes is simple, however, these materials represent diverse structure-property relations among the nano-materials (2). A single-walled nanotube (SWNT) can be formed by rolling a sheet of graphene into a cylinder along an (m,n) lattice vector in the graphene

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plane as shown in Figure 1.1 (3). The (*m,n*) indices determine the diameter and chirality, which are key parameters of a nanotube. Depending on the chirality (the chiral angle between hexagons and the tube axis), SWNTs can be either metals or semiconductors. As grown, the nanotubes are closed at both ends by a hemispherical cap which is formed by the replacement of hexagons with pentagons in the graphite sheet leading to curvature in the structure.

The credit for realizing the nanotubes in an arc discharge apparatus is given generally to Iijima who could successfully prove the existence of first multi walled carbon nanotubes (MWCNT) mixed with other forms of carbon (4). He observed a graphitic tubular structure

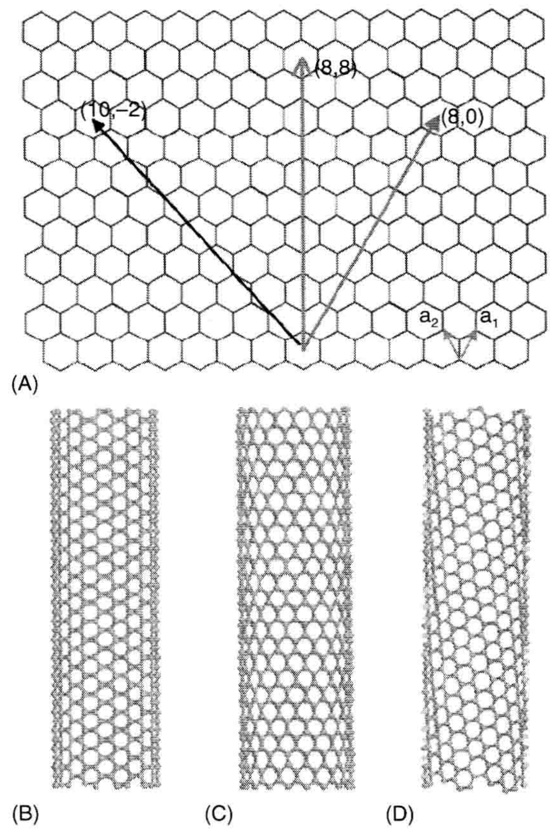

Figure 1.1. (a) Schematic honeycomb structure of a graphene sheet. Single-walled carbon nanotubes can be formed by folding the sheet along lattice vectors. The two basis vectors a_1 and a_2 are shown. Folding of the (8,8), (8,0), and (10,–2) vectors leads to armchair (b), zigzag (c), and chiral (d) tubes, respectively. Reproduced from reference 3 with permission from American Chemical Society.