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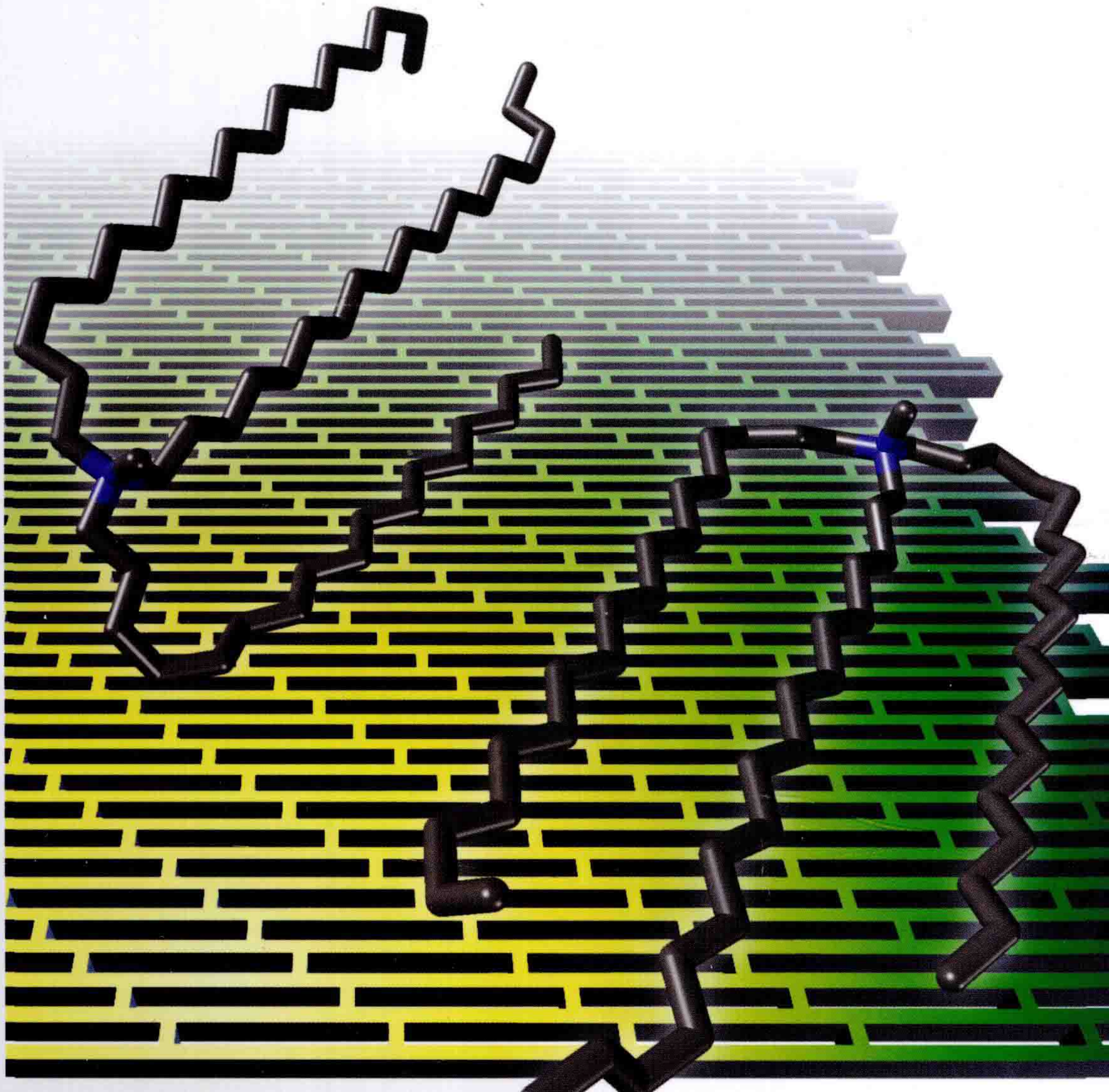
Optimization of Polymer Nanocomposite Properties



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Preface

During the past two decades, research into nanocomposites has led to the development of materials with properties that are far superior to those of not only the parent materials but also of conventional microcomposites. Nanocomposites are organic inorganic hybrid materials where the inorganic filler has at least one dimension in the nanometer scale. The nanoscale dispersion of the filler within the polymer matrices leads to tremendous interfacial contacts between the organic and inorganic phases, which in turn generates an interfacial material that has an altogether different morphology, and also has properties that are superior to those of the bulk polymer phase. As a result of this, significant improvements in the properties of nanocomposites may be realized at much lower filler concentrations. Most importantly, these properties cover the entire spectrum of the polymer nanocomposites' potential applications, from automobile body parts to high-barrier packaging materials, and from highly scratch-resistant composites to biodegradable nanocomposites.

In recent years, nanocomposites with practically all polymer systems have been used to improve one property or another, with varying degrees of success. A range of factors that influence not only the morphology but also the final properties of composites have been identified, including interfacial interactions between the filler and the polymer phase (optimization of filler surface modification, kinetic and thermodynamic factors influencing intercalation and exfoliation, etc.), the nature of the polymer (polar or nonpolar, molecular weight, etc.), the nature of the filler (aspect ratio, size, geometry, cation-exchange capacity, etc.), the processing methodologies, and the amount of inorganic filler. Yet, these improved properties are the result of many different mechanisms at play, owing to the presence of inorganic fillers within the polymers; consequently, an enhancement of one property does not directly translate into an enhancement of the other properties. Thus, it is important to gain insights into these different factors and considerations that are responsible for enhancing the various properties, the optimization of which may–in time–lead to nanocomposites being designed according to need.

This book describes the mechanisms of enhancement for the different properties in polymer nanocomposites, with each chapter focusing on a specific characteristic property. Chapter 1 reviews the synthesis methodologies of the

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nanocomposites with both polar and nonpolar polymer matrices, and also provides details on the characterization of the microstructure and recent advances in filler surface modifications. Chapters 2 to 4 focus on the morphology developments in various polymer systems. As the generation of intercalated/exfoliated filler morphologies in the polymer matrices requires specific considerations, depending on the nature of the polymer used, it is necessary to consider polar and nonpolar polymer systems separately, as reported in Chapters 2 and 4 respectively. In the meanwhile, Chapter 3 focuses on the mechanisms of morphological development in rubbers, based on their completely different nature and their interactions with fillers other than polar (e.g., epoxy) or nonpolar (e.g., polyolefin) polymers. Chapters 5 details the rheological properties of the polymer nanocomposites, both in solution and in the melt state, and describes the relationships between the generated morphology and the rheological behavior of the composite materials that have been established to optimize these properties. Chapter 6 then focuses on the factors that must be considered in order to enhance the mechanical properties of nanocomposites, while Chapter 7 explains the various mechanisms of stress transfer and fracture in polymer nanocomposites. Chapter 8 considers the optimization of the nanocomposites' barrier properties; these are highly sensitive to minute changes at the interface between organic and inorganic components, and nanocomposites in which polar or nonpolar polymer systems are used for barrier applications differ totally in this respect. Following a similar theme, the mechanisms whereby the thermal stability of nanocomposites may be enhanced are explained in Chapter 9, while Chapter 10 details the optimization of polymer nanocomposites for use in tribology. Owing to the need to generate environment-friendly nanocomposites, it is important to optimize biodegradability in these materials, and this topic is dealt with in Chapter 11. Another subject of much recent interest is that of self-healing, the generation of which in polymers, in the presence of nanofillers, is described in Chapter 12. In Chapter 13, the optimization of polymer crystallization in nanocomposites is outlined, by examining the molecular-level interactions between the filler and the polymer phases. The ability to predict the properties of nanocomposites is equally important when optimizing their design and properties, and this is described in Chapter 14, using both analytical and numerical methods. A nanocomposite's morphology and interfacial interactions, as well its ultimate properties, are strongly affected by the aspect ratio of the filler; hence, the role of fillers with different aspect ratios, and how they affect both microstructure and properties, is considered in Chapter 15. Finally, Chapter 16 reviews the criteria applied to the optimization of the thermomechanical properties of nanocomposites, while Chapter 17 outlines the role of the various processing conditions on the resultant composite morphology and properties. In the latter case, considerations of both thermoplastic and thermoset polymer systems have been included.

It gives me immense pleasure to thank those people without whose help this project may not have become reality. I am indebted to Wiley-VCH for providing the opportunity to publish this book. I am equally thankful to my dear wife, Preeti,

who coedited the book and whose continuous support and positive criticism throughout the project was immensely helpful. I dedicate this book to my family, and especially to my mother, who has been an ever-increasing source of inspiration for me.

Ludwigshafen, November 2009 *Vikas Mittal*

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