Preface

In many demanding applications such as automotive or aerospace, common engineering materials reaching their limits and new developments are required to fulfill the increasing demands on performance, characteristics, and functions. The properties of materials can be increased, for example, by combining different materials to achieve better properties than a single constituent or by shaping the material or constituents into a specific structure. Many of these new materials reveal a much more complex behavior than traditional engineering materials due to their advanced structure or composition. The purpose of this book is to cover one of the important physical characteristics, that is thermal properties, in detail from different points of view. This book aims to provide readers not only with a good understanding of the fundamentals but also with an awareness of recent advances in properties determination and applications of multiphase materials. The book contains 14 chapters written by experts in the relevant fields from academia and from major national laboratories/research institutes.

The first part of the book covers materials where two or more solid phases form the composite. The second part is related to porous and cellular materials where two or more solid phases form certain shapes of cells with an empty or air-filled space. Typical representatives of this group are foamed polymers or metals, which have a significant potential in multifunctional applications. The last part of the book covers problem where fluids in a solid structure fulfill technical functions – such as in the case of combustion – or significantly determining the overall characteristics of the material.

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Contents

Heat Transfer in Polyolefin Foams

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Abstract This chapter is dedicated to the study of heat transfer in polyolefin-based foams, particularly thermal conductivity, as a function of their structure and chemical composition. A small review of the main experimental techniques used to measure the thermal conductivity of these materials is also given, focusing on the transient plane source method (TPS), as well as different theoretical models commonly used for estimating its value. Alongside cellular structure (cell size, anisotropy, etc) and composition considerations, particular importance is given to the analysis of the presence of micrometric and nanometric-sized fillers in the resulting cellular composite thermal properties. This is a novel research field of particular interest, thought to extend the application range of these lightweight materials by tailoring their conductivity.

1 Introduction

It is well known that heat transfer is one the most important fields of research for cellular polymers due to the wide number of applications and uses of these materials as thermal insulators. Heat transfer in these materials strongly depends on relative density, cellular characteristics such as cell size, cell density, cell anisotropy, etc, and presence of additional phases and/or fillers (concentration, orientation and dispersion of these additional phases) [1–3].

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This chapter is focused on the study of heat transfer in polyolefin-based foams, although most of the concepts and trends presented are applicable to most of the polymeric cellular materials available in the market. It displays the main tendencies of heat transfer, focusing on thermal conductivity, as a function of the structure and chemical composition for different types of polyethylene and polypropylene foams with densities ranging from 20 to 600 kg/m^3. It also shows some strategies to modify the thermal conductivity in terms of structure, compounding and production techniques. A small review of the main experimental techniques to measure the thermal conductivity of these materials is also given and different theoretical models commonly used for determining the thermal conductivity of polymer foams have been applied.

Part of the chapter is dedicated to the analysis of the presence of third phases (micrometric and nanometric-sized fillers) in the resulting cellular composite thermal properties. This is a novel research field of particular interest, thought to extend the application range of lightweight materials by tailoring their conductivity, and actually scarce information about the thermal behaviour of thermoplastic foams with conductive fillers has been published [3–5].

1.1 The Concept of Cellular Solid

A cellular solid is a two-phase material in which a gas has been dispersed in a solid continuous matrix. If the matrix is polymeric in nature, the material is known as cellular polymer or polymer foam.

Among the most important parameters that modify the physical and transport properties of these materials are the nature and morphology of the base material, type of gas entrapped inside the cells, density, and the cellular architecture and topology, such as cell connectivity (closed, open or partially interconnected cells), cell size (ϕ) and distribution of cell sizes, cell wall thickness (δ) and respective distribution, fraction of solid in the cell struts (f_s) and cell geometry and shape [6]. Some of these basic parameters used to characterize the cellular structure are related by the following expression:

$$\phi(1 - f_s)\frac{\rho}{\rho_s} = C\delta, \quad (1)$$

where ρ/ρ_s is the so-called relative density of the cellular material (ρ: density of the foam and ρ_s: density of the respective unfoamed solid matrix) and C is a constant that depends on the cell's shape and geometry. For instance, this constant has a value of 3.46 for pentagonal dodecahedron [1] and 3.35 for tetrakaidecahedral cells [7].

The concept of foam as a two-phase material is important to understand their behaviour as that resulting from the combination of the properties of both phases and their relative content. Due to this reason, the relative density, and analogously

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