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# Review of thermal conductivity in composites: Mechanisms, parameters and theory



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## ABSTRACT

Thermal conductivity has become an important parameter for new technologies, especially in aerospace and aeronautics. The advanced materials used in some electronic applications tend to undergo an increase in temperature when they are used. Increasing the thermal conductivity of a material will help to diffuse heat faster to avoid substantial overheating that could lead to premature degradation of the material.

This article reviews theoretical and experimental aspects of thermal conductivity in composites, from thermal energy generation to heat transfers. The fundamental mechanism of thermal conduction, its mathematical aspects, and certain essential parameters to be considered in this study, such as crystallinity, phonon scattering, or filler/matrix interfaces are discussed in detail to examine their impact on thermal conductivity, complementing several reviews in the field.

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## Contents

1. Introduction.....	2
2. Thermal conductivity: definition, mechanisms and parameters.....	3
2.1. Definition of thermal conductivity.....	3
2.2. Basics of thermal conductivity.....	3
2.2.1. Theoretical mechanism in crystalline materials.....	3
2.2.2. Hardness and binding energy.....	5
2.2.3. Thermal conductivity in polymers.....	5
2.2.4. Contribution of electrons.....	6
2.3. Mathematical aspect of thermal conductivity.....	6
2.3.1. Thermal conductivity equation.....	6
2.3.2. General heat equation.....	7
2.3.3. Complexity of heterogeneous materials and models.....	8

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3.	Thermal conductivity in composites .....	8
3.1.	Materials and methods used .....	8
3.2.	Structures and defects .....	9
3.2.1.	Defects in the crystalline structure .....	9
3.2.2.	Phonon scattering .....	9
3.3.	Incorporation of thermally conductive fillers .....	10
3.4.	Processing .....	10
3.5.	Influence of dispersion .....	12
3.6.	Fillers/matrix interfaces .....	13
3.7.	Sizes and aspect ratios .....	15
3.8.	Filler alignment and networking .....	18
3.9.	Filler functionalization .....	19
3.9.1.	Acid treatment .....	19
3.9.2.	Non-covalent functionalization .....	20
3.9.3.	Covalent functionalization .....	21
4.	Summary and conclusion .....	23
	Acknowledgements .....	23
	References .....	24

### Nomenclature

$\alpha$	thermal diffusivity
$\lambda$	wave length
$\bar{v}$	speed of a particle
$\rho$	density
$\sigma$	electrical conductivity
$\tau_c$	thermal diffusion characteristic time
$\varphi$	heat flow rate
Ag	silver
Al	aluminum
AlN	aluminum nitride
BN	boron nitride
C	heat capacity
$C_p$	specific heat capacity
Cal	calorie
CB	carbon black
CNF	carbon nanofibers
CNT	carbon nanotubes
Cu	copper
$E$	energy of charged atomic oscillator
$h$	Planck constant
$H_2SO_4$	sulfuric acid
$HNO_3$	nitric acid
$k$	thermal conductivity parameter
$k_e$	electronic thermal conductivity (due to electrons)
$k_p$	phonic thermal conductivity (due to phonons)
$l$	phonon mean free path
$L_c$	thermal diffusion characteristic length
$m$	mass
MWCNT	multi-walled carbon nanotube
PCA	pyrenecarboxylic acid
$Q$	thermal energy
$\dot{Q}$	heat flux
$S$	surface area
Si	silicon

SWCNT	single-walled carbon nanotube
$t$	time
$T$	temperature
$TiO_2$	titanium dioxide
UV	ultraviolet light
$V$	volume
wt.	percent weight (in % wt.)
$x$	thickness

## 1. Introduction

In everyday life, heat and temperature are commonly used and confused but these two fundamental concepts should be distinguished from a scientific perspective: they are directly related to thermal energy. Thermal energy is defined by the microscopic vibrations of particles. The temperature, describing the state of a body, is a physical property quantifying those microscopic thermal vibrations of the particles. Heat, which is directly related to the thermal conductivity, is defined as the thermal energy transfer from a particle to its adjacent particle(s), i.e., temperature tells us how much particles are vibrating and heat evaluates how much of this energy is transferred, how fast and in what direction (Fig. 1)

These general concepts regarding heat transfer help us to introduce this review and are essential to understand what is presented next. The fundamental and theoretical mechanisms result from quantum physics and mechanics, with phenomena that are difficult to extrapolate at a macroscopic scale. This review's objective is not to present thermal conductivity mechanisms at the quantum scale but to try to extrapolate and understand those mechanisms at a macroscopic scale. It complements the reviews by Han et al.

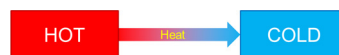


Fig. 1. Consequence of 2nd law of thermodynamics.

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