

Contents

The Editors XIII

List of Contributors XV

1	State of the Art – Nanomechanics	1
	<i>Amrita Saritha, Sant Kumar Malhotra, Sabu Thomas, Kuruvilla Joseph, Koichi Goda, and Meyyarappallil Sadasivan Sreekala</i>	
1.1	Introduction	1
1.2	Nanoplatelet-Reinforced Composites	3
1.3	Exfoliation–Adsorption	4
1.4	<i>In Situ</i> Intercalative Polymerization Method	5
1.5	Melt Intercalation	6
1.6	Nanofiber-Reinforced Composites	7
1.7	Characterization of Polymer Nanocomposites	7
1.8	Recent Advances in Polymer Nanocomposites	8
1.9	Future Outlook	9
	References	9
2	Synthesis, Surface Modification, and Characterization of Nanoparticles	13
	<i>Liaosha Wang, Jianhua Li, Ruoyu Hong, and Hongzhong Li</i>	
2.1	Introduction	13
2.2	Synthesis and Modification of Nanoparticles	13
2.2.1	Synthesis of Nanoparticles	13
2.2.2	Synthesis of Titania Nanoparticles	14
2.2.3	Microwave Synthesis of Magnetic Fe ₃ O ₄ Nanoparticles	15
2.2.4	Magnetic Field Synthesis of Fe ₃ O ₄ Nanoparticles	15
2.2.5	Synthesis of Fe ₃ O ₄ Nanoparticles without Inert Gas Protection	16
2.2.6	Synthesis of ZnO Nanoparticles by Two Different Methods	16
2.2.7	Synthesis of Silica Powders by Pressured Carbonation	17

2.2.8	MW-Assisted Synthesis of Bisubstituted Yttrium Garnet Nanoparticles	18
2.2.9	Molten Salt Synthesis of Bisubstituted Yttrium Garnet Nanoparticles	18
2.3	Modification of Nanoparticles	19
2.3.1	Surface Modification of ZnO Nanoparticles	20
2.3.2	Surface Modification of Fe ₃ O ₄ Nanoparticles	20
2.3.3	Surface Modification of Silica Nanoparticles	23
2.4	Preparation and Characterization of Polymer–Inorganic Nanocomposites	23
2.4.1	Nanopolymer Matrix Composites	23
2.5	Preparation of Polymer–Inorganic Nanocomposites	26
2.5.1	Sol–Gel Processing	26
2.5.2	<i>In Situ</i> Polymerization	27
2.5.3	Particle <i>In Situ</i> Formation	27
2.5.4	Blending	28
2.5.4.1	Solution Blending	28
2.5.4.2	Emulsion or Suspension Blending	30
2.5.4.3	Melt Blending	31
2.5.4.4	Mechanical Grinding/Blending	31
2.5.5	Others	31
2.6	Characterization of Polymer–Inorganic Nanocomposites	32
2.6.1	X-Ray Diffraction	32
2.6.2	Infrared Spectroscopy	33
2.6.3	Mechanical Property Test	34
2.6.4	Abrasion Resistance Test	35
2.6.5	Impact Strength	36
2.6.6	Flexural Test	37
2.6.7	Others	38
2.7	Applications of Polymer–Inorganic Nanocomposites	39
2.7.1	Applications of Bi-YIG Films and Bi-YIG Nanoparticle-Doped PMMA	39
2.7.1.1	Magneto-Optical Isolator	40
2.7.1.2	Magneto-Optical Sensor	41
2.7.1.3	Tuned Filter	42
2.7.1.4	Magneto-Optical Recorder	42
2.7.1.5	Magneto-Optic Modulator	43
2.7.1.6	Magneto-Optic Switch	44
2.8	Application of Magnetic Fe ₃ O ₄ -Based Nanocomposites	44
2.9	Applications of ZnO-Based Nanocomposites	46
2.9.1	Gas Sensing Materials	46
2.9.2	Photocatalyst for Degradation of Organic Dye	46
2.9.3	Benard Convection Resin Lacquer Coating	47
2.10	Applications of Magnetic Fluid	48
	References	49

3	Theory and Simulation in Nanocomposites	53
	<i>Qinghua Zeng and Aibing Yu</i>	
3.1	Introduction	53
3.1.1	Dispersion of Nanoparticles	53
3.1.2	Interface	54
3.1.3	Crystallization	54
3.1.4	Property Prediction	54
3.2	Analytical and Numerical Techniques	55
3.2.1	Analytical Models	55
3.2.2	Numerical Methods	56
3.2.3	Multiscale Modeling	57
3.3	Formation of Nanocomposites	58
3.3.1	Thermodynamics of Nanocomposite Formation	58
3.3.2	Kinetics of Nanocomposite Formation	59
3.3.3	Morphology of Polymer Nanocomposites	60
3.4	Mechanical Properties	62
3.4.1	Stiffness and Strength	62
3.4.2	Stress Transfer	64
3.4.3	Mechanical Reinforcement	64
3.4.4	Interfacial Bonding	65
3.5	Mechanical Failure	65
3.5.1	Buckling	65
3.5.2	Fatigue	66
3.5.3	Fracture	66
3.5.4	Wear	66
3.5.5	Creep	67
3.6	Thermal Properties	67
3.6.1	Thermal Conductivity	67
3.6.2	Thermal Expansion	68
3.7	Barrier Properties	69
3.8	Rheological Properties	70
3.9	Conclusions	71
	References	72
4	Characterization of Nanocomposites by Scattering Methods	75
	<i>Valerio Causin</i>	
4.1	Introduction	75
4.2	X-Ray Diffraction and Scattering	76
4.2.1	Wide-Angle X-Ray Diffraction	76
4.2.2	Wide-Angle X-Ray Diffraction in the Characterization of Polymer-Based Nanocomposites	77
4.2.3	Wide-Angle X-Ray Diffraction in the Characterization of the Structure of the Polymer Matrix	83
4.2.4	Small-Angle X-Ray Scattering	84
4.3	Neutron Scattering	93

4.4	Light Scattering	96
	References	99
5	Mechanical–Viscoelastic Characterization in Nanocomposites	117
	<i>Vera Realinho, Marcelo Antunes, David Arencón, and José I. Velasco</i>	
5.1	Introduction	117
5.2	Factors Affecting the Mechanical Behavior of Nanocomposites	118
5.2.1	Influence of the Filler’s Aspect Ratio and Dispersion	118
5.2.2	Influence of the Filler–Matrix Interphase	120
5.3	Micromechanical Models for Nanocomposites	121
5.3.1	Basic Assumptions and Preliminary Concepts	122
5.3.1.1	Continuum Models	122
5.3.1.2	Equivalent Continuum Model and Self-Similar Model	123
5.3.1.3	Finite Element Modeling	123
5.3.2	Micromechanical Nanocomposites Modeling	125
5.4	Mechanical Characterization of Nanocomposites under Static Loading	127
5.4.1	Polymer-Layered Silicate Nanocomposites	127
5.4.2	Polymer–CNT Nanocomposites	129
5.4.3	Particulate Polymer Nanocomposites	130
5.5	Characterization by Dynamic Mechanical Thermal Analysis	131
5.6	Mechanical Characterization by Means of Indentation Techniques	133
5.7	Fracture Toughness Characterization of Nanocomposites	135
5.8	Conclusions	139
	References	140
6	Characterization of Nanocomposites by Optical Analysis	147
	<i>Lucilene Betega de Paiva and Ana Rita Morales</i>	
6.1	Introduction	147
6.2	Influence of Nanoparticles on the Visual Aspect of Nanocomposites	148
6.3	Characterization of Appearance	151
6.3.1	Gloss	152
6.3.2	Haze	153
6.3.3	Color	154
6.4	Characterization by UV–Visible Spectrophotometry	156
6.5	Characterization by Optical Microscopy	158
	References	160
7	Characterization of Mechanical and Electrical Properties of Nanocomposites	163
	<i>Iren E. Kuznetsova, Boris D. Zaitsev, and Alexander M. Shikhabudinov</i>	
7.1	Introduction	163
7.2	The Influence of the Molding Temperature on the Density of the Nanocomposite Samples Based on the Low-Density Polyethylene	164

7.3	Experimental Study of the Temperature Dependence of the Permittivity of the Nanocomposite Materials	168
7.4	Elastic and Viscous Properties of the Nanocomposite Films Based on the Low-Density Polyethylene Matrix	172
7.4.1	Technology of Producing the Nanocomposite Polymeric Films	172
7.4.2	Determination of the Coefficients of Elasticity and Viscosity of Nanocomposite Polymeric Films	173
7.5	Effect of the Nanoparticle Material Density on the Acoustic Parameters of Nanocomposites Based on the Low-Density Polyethylene	179
7.6	Conclusions	182
	References	183

8 Barrier Properties of Nanocomposites 185

Amrita Saritha and Kuruvilla Joseph

8.1	Introduction	185
8.2	Nanocomposites from Ceramic Oxides	186
8.3	Nanocomposites from Nanotubes	186
8.4	Layered Silicate Nanocomposites	187
8.5	Composite Models of Permeation	191
8.5.1	Nielsen Model	191
8.5.2	Bharadwaj Model	191
8.5.3	Fredrickson and Bicerano Model	192
8.5.4	Cussler Model	193
8.5.5	Gusev and Lusti Model	193
8.6	Techniques Used to Study the Permeability of Polymers and Nanocomposites	195
8.7	Calculation of Breakthrough Time	196
8.8	Applications	197
8.9	Conclusions	198
	References	198

9 Polymer Nanocomposites Characterized by Thermal Analysis Techniques 201

Carola Esposito Corcione, Antonio Greco, Mariaenrica Frigione, and Alfonso Maffezzoli

9.1	Introduction	201
9.2	Thermal Analysis Methods	202
9.2.1	Differential Scanning Calorimetry	202
9.2.2	Thermogravimetric Analysis	209
9.3	Dynamic Mechanical Thermal Analysis	211
9.4	Thermal Mechanical Analysis	214
9.5	Conclusions	215
	References	215

10	Carbon Nanotube-Filled Polymer Composites	219
	<i>Dimitrios Tasis and Kostas Papagelis</i>	
10.1	Introduction	219
10.2	Processing Methods	220
10.2.1	Common Approaches	220
10.3	Novel Approaches	223
10.3.1	CNT-Based Membranes and Networks	223
10.3.2	CNT-Based Fibers	229
10.4	Mechanical Properties of Composite Materials	232
10.5	Basic Theory of Fiber-Reinforced Composite Materials	232
10.6	Stress Transfer Efficiency in Composites	234
10.7	Mechanical Properties: Selected Literature Data	236
10.8	Electrical Properties of Composite Materials	236
10.9	Electrical Properties: Selected Literature Data	240
10.10	CNT–Polymer Composite Applications	243
	References	244
11	Applications of Polymer-Based Nanocomposites	249
	<i>Thien Phap Nguyen</i>	
11.1	Introduction	249
11.2	Preparation of Polymer-Based Nanocomposites	250
11.3	Applications of Nanocomposites	251
11.3.1	Mechanical Properties and Applications	251
11.3.2	Thermal Properties and Applications	253
11.3.3	Electrical Properties and Applications	255
11.3.4	Optical Properties and Applications	257
11.3.4.1	Transmission of Light	257
11.3.4.2	Energy Conversion	259
11.4	Energy Conversion and Storage Capacity and Applications	265
11.5	Biodegradability and Applications	266
11.5.1	Nanocomposites for Medical Applications	266
11.5.2	Nanocomposites for Drug Release Applications	268
11.5.3	Nanocomposites for Food Packaging	268
11.6	Conclusion and Outlook	269
	References	270
12	Health Hazards and Recycling and Life Cycle Assessment of Nanomaterials and Their Composites	279
	<i>Lucas Reijnders</i>	
12.1	Introduction	279
12.2	Health Hazards of Inorganic Nanoparticles	280
12.3	Nanocomposite Life Cycles and Life Cycle Assessment	281
12.4	Life Cycle Assessment of Nanoparticles and Nanocomposites in Practice	284

12.5	Nanocomposite Life Cycle Management, Including Recycling	285
12.6	Reducing Nanoparticle-Based Health Hazards and Risks Associated with Nanocomposite Life Cycles	289
12.7	Conclusion	291
	References	291
	Index	295