

Contents

Preface IX

1	Introduction	1
1.1	Nanomaterials and Nanocomposites	5
1.2	Elementary Consequences of Small Particle Size	11
1.2.1	Surface of Nanoparticles	11
1.2.2	Thermal Phenomena	12
1.2.3	Diffusion Scaling Law	13
	References	19
2	Surfaces in Nanomaterials	21
2.1	General Considerations	21
2.2	Surface Energy	23
2.3	Some Technical Consequences of Surface Energy	33
	References	40
3	Phase Transformations of Nanoparticles	41
3.1	Thermodynamics of Nanoparticles	41
3.2	Heat Capacity of Nanoparticles	42
3.3	Phase Transformations of Nanoparticles	45
3.4	Phase Transformation and Coagulation	54
3.5	Structures of Nanoparticles	55
3.6	A Closer Look at Nanoparticle Melting	60
3.7	Structural Fluctuations	64
	References	69
4	Gas-Phase Synthesis of Nanoparticles	71
4.1	Fundamental Considerations	71
4.2	Inert Gas Condensation Process	78

4.3	Physical and Chemical Vapor Synthesis Processes	79
4.4	Laser Ablation Process	83
4.5	The Microwave Plasma Process	86
4.6	Flame Aerosol Process	92
4.7	Synthesis of Coated Particles	103
	References	108
5	Magnetic Properties of Nanoparticles	109
5.1	Magnetic Materials	109
5.2	Superparamagnetic Materials	113
5.3	Susceptibility and Related Phenomena in Superparamagnets	125
5.4	Applications of Superparamagnetic Materials	132
5.5	Exchange-Coupled Magnetic Nanomaterials	136
	References	143
6	Optical Properties of Nanoparticles	145
6.1	General Remarks	145
6.2	Adjustment of the Index of Refraction	145
6.3	Optical Properties Related to Quantum Confinement	149
6.4	Quantum Dots and Other Lumophores	161
6.5	Metallic and Semiconducting Nanoparticles in Transparent Matrices	169
6.6	Special Luminescent Nanocomposites	180
6.7	Electroluminescence	188
6.8	Photochromic and Electrochromic Materials	194
6.8.1	General Considerations	194
6.8.2	Photochromic Materials	195
6.8.3	Electrochromic Materials	200
6.9	Magneto-optic Applications	204
	References	207
7	Electrical Properties of Nanoparticles	211
7.1	Fundamentals of Electrical Conductivity in Nanotubes and Nanorods	211
7.2	Carbon Nanotubes	216
7.3	Photoconductivity of Nanorods	222
7.4	Electrical Conductivity of Nanocomposites	225
	References	230
8	Mechanical Properties of Nanoparticles	233
8.1	General Considerations	233
8.2	Bulk Metallic and Ceramic Materials	236
8.2.1	Influence of Porosity	236
8.2.2	Influence of Grain Size	238
8.2.3	Superplasticity	251

8.3	Filled Polymer Composites	253
8.3.1	Particle-Filled Polymers	253
8.3.2	Polymer-Based Nanocomposites Filled with Platelets	257
8.3.3	Carbon Nanotube-Based Composites	262
	References	266
9	Nanofluids	267
9.1	Definition	267
9.1.1	Nanofluids for Improved Heat Transfer	267
9.2	Ferrofluids	270
9.2.1	General Considerations	270
9.2.2	Properties of Ferrofluids	271
9.2.3	Applications of Ferrofluids	272
	References	277
10	Nanotubes, Nanorods, and Nanoplates	279
10.1	Introduction	279
10.1.1	Conditions for the Formation of Rods and Plates	283
10.1.2	Layered Structures	285
10.1.3	One-Dimensional Crystals	286
10.2	Nanostructures Related to Compounds with Layered Structures	288
10.2.1	Carbon Nanotubes	288
10.2.2	Nanotubes and Nanorods from Materials other than Carbon	300
10.2.3	Synthesis of Nanotubes and Nanorods	303
	References	311
11	Characterization of Nanomaterials	313
11.1	Global Methods for Characterization	313
11.1.1	Specific Surface Area	313
11.2	X-Ray and Electron Diffraction	319
11.3	Electron Microscopy	327
11.3.1	General Considerations	327
11.3.2	Interaction of the Electron Beam and Specimen	331
11.3.3	Localized Chemical Analysis in the Electron Microscope	334
11.3.4	Scanning Transmission Electron Microscopy using a High-Angle Annular Dark-Field (HAADF) Detector	340
	References	342
	Index	343

