

Contents

Preface *xi*

- 1 Introduction into Nano- and Biomaterials 1**
- 1.1 Definition of Nano- and Biomaterials 1
- 1.2 History of Nano- and Biomaterials Application 1
- 1.3 Methods for Preparing of Nanomaterials 2
- 1.3.1 Mechanical Dispersion Methods for Nanomaterial Synthesis 2
- 1.3.2 Intensive Plastic Deformation Methods for Nanomaterial Synthesis 5
- 1.3.3 Obtaining of Nanomaterials by Mechanical Interaction of Various Mediums 8
- 1.3.4 Physical Dispersion Methods for Nanomaterials Preparation 9
- 1.3.5 Preparation of Nanomaterials by Evaporation–Condensation Method 10
- 1.3.6 Obtaining of Nanomaterials by Vacuum-Sublimation Technology 13
- 1.3.7 Obtaining of Nanomaterials by Using Solid Phase Transformations 14
- 1.3.8 Chemical Dispersion Methods for Nanomaterial Preparation 14
- 1.3.9 Obtaining of Nanomaterials by Using Chemical Reactions 15
- 1.3.10 Preparation of Nanomaterials by Electrochemical Methods 20
- 1.3.11 Preparation of Nanomaterials by Combinations of Physical and Chemical Transformations 21
- 1.4 Main Achievements in Nanotechnology 22
 - Case Study 1: Synthesis of Nanoparticles and Environmental Safety Considerations 22
 - Case Study 2: Property Control of Nanomaterials by Setting Experimental Conditions during Synthesis 23
 - Control Questions: 23
 - References 24
 - Further Reading 25
- 2 Classification of Nanomaterials 27**
- 2.1 Dispersive Systems and Their Classifications 27
- 2.1.1 Classification of Dispersive Systems According to their Aggregation States 27
- 2.1.2 Classification of Dispersive Systems According to Size 28
- 2.1.3 Classification of Dispersive Systems According to Dimension 31

2.2	Fullerenes	32
2.2.1	History of Fullerenes	34
2.2.2	Tetrahedral Fullerenes	34
2.2.3	Icosahedral Fullerenes	42
2.2.4	Physical Properties of Fullerenes	47
2.3	Carbon Nanotubes	49
2.3.1	Types and Classification of Carbon Nanotubes	49
2.3.2	Mechanical Properties and Physical Parameters of Carbon Nanotubes	52
	Case Study 1: Comparison of Structural Characteristics between Carbon Nanotubes and Fullerenes	54
	Control Questions	54
	References	55
	Further Reading	56
	Online Sources	56
3	Nanocomposite Materials and Their Physical Property Features	57
3.1	Nanocomposite Materials	57
3.2	Size Dependence as Nanomaterial Property	57
3.3	Thermodynamical Features of Nanomaterials	58
3.4	Phase Equilibrium Changes in Nano-sized Systems	60
3.5	Melting Temperature Changes in Nanomaterials	61
3.5.1	Polymorphic Characteristic Changes in Nanosystems	61
3.6	Structure of Nano-sized Materials	62
3.7	Crystal Lattice Defects in Nanomaterials	65
3.8	Microdistorsions of Crystal Lattice in Nanomaterials	66
3.9	Consolidation of Nano-sized Powders	68
	Case Study 1: Applications of Composite Nanomaterials Due to Their Improved Mechanical Properties	74
	Control Questions	75
	References	76
	Further Reading	76
	Online Source	77
4	Mechanical Characteristics of Dispersive Systems	79
4.1	Dispersion Characteristics of Nanomaterials	79
4.1.1	Specific Surface Area	79
4.1.2	Size Distribution in Nanomaterials	80
4.1.3	Surface, Boundaries, and Morphology of Nanomaterials	89
4.1.4	Grain Boundaries in Nanomaterials	91
4.1.5	Morphology of Nanodisperse Particles	92
4.2	Electrical Properties of Nanomaterials	95
4.2.1	Change in Length of Electron Free Path in Nanomaterials	95
4.3	Electrical Conductivity in Nanomaterials	97
4.4	Electron Work Function in Nanomediums	99
4.5	Superconductivity Phenomenon in Nanomaterials	101

	Case Study 1: Surfactant Effects on Dispersion Characteristics of Copper-Based Nanomaterials	105
	Case Study 2: Applications of Superconducting Nanomaterials	105
	Control Questions	106
	References	106
	Further Reading	106
5	Physical Properties of Nanomaterials: Graphene	109
5.1	Ferromagnetic Characteristics of Nanomaterials	109
5.1.1	Substance in Single-Domain Condition	109
5.1.2	Superparamagnetism in Nanoparticles	111
5.1.3	Size Dependence on Coercive Force	112
5.1.4	Size Dependence on Saturation Magnetization	114
5.1.5	Size Dependence on Curie Temperature	115
5.2	Thermal Property Features in Nanomaterials	115
5.2.1	Size Dependence on Heat Conductivity	116
5.2.2	Heat Conductivity of Crystal Lattice in Nanomaterials	120
5.2.3	Debye Temperature in Nanomaterials	121
5.3	Optical Characteristics of Nanomediums	122
5.3.1	Light Scattering Features of Tiny Particles	123
5.3.2	Extinction by Dielectric Nanoparticles	125
5.3.3	Extinction in Metallic Nanoparticles	128
5.3.4	Influence of Morphology and Polydispersity on Optical Properties of Nanomaterials	131
5.4	Diffusion in Nanomaterials	133
5.4.1	Diffusion in Nanopowders	133
5.5	Graphene	136
5.5.1	Structure of Graphene	137
5.5.2	Electronic Properties of Graphene	138
5.5.3	Topology of Hexagonal Lattice	138
5.5.4	Physical Properties and Ionization Potential of Graphene	139
5.5.5	Approaches in Graphene Synthesis	141
5.5.6	Characterizations of Graphene	142
5.5.7	Applications of Graphene	145
	Case Study 1: Structural Features of Graphene, Lattice Directions, Edge Location, Crystal Structure, and Energy in Reciprocal Space	145
	Control Questions	147
	References	148
	Further Reading	149
6	Chemical Properties and Mechanical Characteristics of Nanomaterial Characterization Tools in Nanotechnology	151
6.1	Chemical Properties of Nanomaterials	151
6.1.1	Size Effects in Chemical Processes	151
6.1.2	Oxidation Processes in Nanomediums	153
6.1.3	Spontaneous Combustion and Pyrophoricity of Nanomediums	157
6.1.4	Catalysis Involving Nanomaterials	160

6.2	Mechanical Characteristics of Nanomaterials	163
6.2.1	Hardness, Strength, and Plasticity in Nanomaterials	163
6.2.2	Superplasticity Phenomenon in Nanomaterials	170
6.3	Concept Map of Characterization Tools in Nanotechnology	172
6.4	Diffraction Methods for Nanomaterial Characterization	173
6.5	Microscopical Characterization of Nanomaterials	174
6.5.1	TEM Characterization of Nanomaterials	174
6.5.2	HRTEM Characterization of Nanomaterials	177
6.5.3	AFM Characterization of Nanomaterials	177
6.5.4	SEM Characterization of Nanomaterials	178
6.6	Spectroscopical Characterization of Nanomaterials	181
6.6.1	FT-IR Spectroscopy of Nanomaterials	181
6.6.2	X-ray Photoelectron Spectroscopy of Nanomaterials	182
	Case Study 1: Oxidation of Fe Nanoparticles	182
	Case Study 2: Microscopical Characterization of Nanomaterials and Sample Preparation	183
	Case Study 3: Nanomaterials Strength	184
	Control Questions	185
	References	185
	Further Reading	187
	Online Sources	187
7	Introduction to Biomaterials	189
7.1	Biomaterials: Subject, Purpose, and Problems	189
7.1.1	Current Goals of Biomaterials Field	189
7.2	General Requirements for Biomaterials	190
7.3	Biomaterials in Body Systems	191
7.4	Types and Classification of Biomaterials	192
7.4.1	Metallic Biomaterials	193
7.4.2	Composite Biomaterials	199
7.4.3	Nanostructured CaP Composites	200
	Case Study 1: Mechanical Properties of Bone Cements and Tissue Interface Formation after Implantation	203
	Control Questions	204
	References	205
	Further Reading	207
8	Properties of Biomaterials	209
8.1	Mechanical Properties of Biomaterials	209
8.1.1	Mechanical Properties of Biomaterials	209
8.1.2	Titanium Alloy with Self-Adjustable Young's Modulus	211
8.1.3	Wear Resistance of Biomaterials Used in the Living Body	212
8.2	Biological Properties of Biomaterials	215
8.2.1	<i>In Vivo</i> Tissue Biocompatibility	215
8.3	Chemical Properties of Biomaterials	220
8.3.1	Ceramic Biomaterials	222
8.3.2	Polymer Biomaterials	230

	Case Study 1: Polymeric Biomaterials Used in Load-Bearing Medical Devices	235
	Control Questions	236
	References	237
	Further Reading	238
9	Implants and Artificial Organs	239
9.1	Implants	239
9.2	Types of Implants	239
9.2.1	Intraocular Lenses	239
9.2.2	Cochlear Implants	241
9.2.3	Brain Implants	242
9.2.4	Heart Implants	243
9.2.5	Joint Implants	246
9.2.6	Other Organ Replacement Implants	247
9.3	Processes between Living Tissue and Implant Interface	249
	Case Study 1: Iris-Fixated Phakic Intraocular Lens Implantation after Retinal Detachment Surgery: Long-Term Clinical Results	252
	Case Study 2: Cardiac Pacing Systems and Implantable Cardiac Defibrillators (ICDs): A Radiological Perspective of Equipment, Anatomy, and Complications	254
	Control Questions	255
	References	256
	Further Reading	258
10	Tissue Engineering, Scaffolds, and 3D Bioprinting	259
10.1	Definition of Tissue Engineering	259
10.1.1	Biomaterials Used for Tissue Engineering	259
10.1.2	Principles of Tissue Engineering	260
10.1.3	Components of Tissue Engineered Constructs	260
10.2	Scaffolds and Scaffolding	262
10.2.1	Scaffolds for Bone Tissue Engineering	262
10.2.2	Tissue Engineering of Heart Valves	264
10.3	3D Bioprinting	266
10.4	Foreign Body Reaction	271
10.4.1	Inflammatory Response Following Material Implantation	273
10.4.2	Monocytes, Macrophages, and Foreign Body Giant Cells	274
10.5	Wound Healing	275
	Case Study 1: Bioactive Glass and Glass-Ceramic Scaffolds for Bone Tissue Engineering	275
	Case Study 2: Regulatory Considerations in the Design and Manufacturing of Implantable 3D Printed Medical Devices	276
	Control Questions	279
	References	279
	Further Reading	282
	Index	283

