

Contents

1	Nanomaterials (NMs) in Analytical Sciences	1
1.1	Introduction	1
1.2	Types of NMs	2
1.2.1	Graphene	2
1.2.2	Carbon Nanotubes (CNTs)	3
1.2.3	Fullerenes (FULs)	4
1.2.4	Inorganic Nanoparticles	6
1.2.4.1	Gold and Silver Nanoparticles	6
1.2.4.2	Titanium Nanoparticles	7
1.2.4.3	Silica Nanoparticles	7
1.2.5	Magnetic Nanoparticles	7
1.3	Applications of NMs	8
1.3.1	NMs in Separation Processes	8
1.3.2	NMs in Biomedical Applications	8
1.3.3	NMs in Sensor Platforms	12
1.4	Conclusions	16
	References	19
2	Special Properties of Nanomaterials (NMs) for Sample Preparation	27
2.1	Introduction	27
2.2	Mechanical Properties of NMs	28
2.2.1	Hardness and Strength	28
2.2.2	Ductility	30
2.2.3	Applications of Mechanical Properties	32
2.3	Thermal Properties of NMs	33
2.4	Electrical Properties of NMs	35
2.5	Optical Properties of NMs	36
2.6	Magnetic Properties of NMs	37
2.7	Adsorption Properties of NMs	38
2.8	Conclusions	39
	References	40

3	Adsorption Mechanism on Nanomaterials (NMs)	47
3.1	Introduction	47
3.2	Adsorption Process	48
3.2.1	Adsorption Isotherms	48
3.2.1.1	Langmuir Isotherm	50
3.2.1.2	Freundlich Isotherm	50
3.2.1.3	Temkin Isotherm	50
3.2.1.4	Dubinin–Radushkevich Model	51
3.2.1.5	Harkins–Jura and Halsey Isotherms	51
3.2.1.6	Redlich–Peterson Isotherm	51
3.2.1.7	BET (Brunauer, Emmett, and Teller) Isotherm	52
3.2.2	Adsorption Kinetics and Thermodynamics	52
3.2.2.1	Pseudo-first-order Kinetics	52
3.2.2.2	Pseudo-second-order Kinetics	53
3.2.2.3	Intraparticle Diffusion Model	53
3.2.2.4	Thermodynamic Study	53
3.2.3	Adsorption Process on Nanoparticles	54
3.2.3.1	Silver Nanoparticles	54
3.2.3.2	Gold Nanoparticles	55
3.2.3.3	Zinc Oxide Nanoparticles	56
3.2.3.4	Magnetic Fe_3O_4 Nanoparticles	56
3.2.4	Adsorption Process on Carbon Nanomaterials	58
3.2.4.1	Activated Carbon	58
3.2.4.2	Carbon Nanotubes (CNTs)	59
3.2.4.3	Graphene Oxide (GO)	60
3.3	Conclusions and Future Perspective	63
	References	63
4	Carbon Nanomaterials (CNMs) as Adsorbents for Sample Preparation	71
4.1	Introduction	71
4.2	Carbon Nanomaterials (CNMs)	72
4.2.1	Carbon Nanotubes (CNTs)	72
4.2.2	Graphene	73
4.2.3	Fullerenes (FULs)	75
4.3	Adsorption on CNMs	76
4.4	Applications of CNMs	77
4.4.1	Extraction and Separation Applications	77
4.4.2	Chromatographic Applications	80
4.4.2.1	Chromatographic Stationary Phases Having CNTs	81
4.4.2.2	Chromatographic Stationary Phases Having FULs	83
4.5	Conclusions	84
	References	84

5	Membrane Applications of Nanomaterials (NMs)	93
5.1	Introduction	93
5.2	Traditional Membranes	93
5.3	Carbon Nanomaterial-based Membranes	94
5.3.1	Graphene-based Membranes	94
5.3.2	Carbon Nanotube-based Membranes	97
5.3.3	Fullerene-based Membranes	100
5.4	Nanoparticle-based Membranes	101
5.5	Molecularly Imprinted Polymer (MIP)-based Membranes	102
5.6	Conclusions	105
	References	108
6	Surface-Enhanced Raman Spectroscopy (SERS) with Nanomaterials (NMs)	117
6.1	Introduction	117
6.2	Theory of SERS	118
6.3	SERS Mechanisms	118
6.3.1	Electromagnetic Enhancement	119
6.3.2	Chemical Enhancement	120
6.4	Determination of SERS Enhancement Factor	121
6.5	Selection Rules	121
6.5.1	Image Field Model	121
6.5.2	Electromagnetic Field Model	122
6.6	Fabrications of SERS Substrates	123
6.6.1	Template-assisted Fabrication	124
6.6.2	Hybrid Fabrication	124
6.6.3	Fabrication by Using Colloids	124
6.6.4	Direct Deposition	125
6.7	Applications of SERS	125
6.7.1	SERS-Based Separation Applications	125
6.7.2	SERS-Based Sensor Applications	126
6.7.2.1	Environmental Analysis	126
6.7.2.2	Forensic Analysis	129
6.7.2.3	Biological Applications	131
6.8	Conclusions	133
	References	133
7	Nanomaterials (NMs) for Biological Sample Preparations	147
7.1	Introduction	147
7.2	The Use of NMs in Diagnostic Platforms	148
7.2.1	The Optimization of NMs in Diagnostic Platforms	148
7.2.2	Biofunctionalization of NMs in Diagnostic Platforms	149
7.3	NMs-based Lab-on-a-chip (LOC) Platforms	150

7.3.1	Paper-based LOC Platforms	152
7.3.2	Centrifugal LOC Platforms	152
7.3.3	Droplet-based LOC Platforms	152
7.3.4	Digital LOC Platforms	152
7.3.5	Surface Acoustic Wave-based LOC Platforms	152
7.3.6	LOC Platforms for Biological Applications	153
7.4	Biomedical Applications of NMs	155
7.5	Sensor Applications of NMs	157
7.6	Conclusions	162
	References	162

8 Magnetic Nanomaterials for Sample Preparation 173

8.1	Introduction	173
8.2	Synthesis of Magnetic Nanoparticles	174
8.2.1	Thermal Decomposition Technique	174
8.2.2	Coprecipitation Technique	175
8.2.3	Sol-Gel Synthesis	175
8.2.4	Hydrothermal Synthesis	176
8.2.5	Microemulsion-Based Synthesis	176
8.2.6	Flow Injection Synthesis	176
8.2.7	Aerosol/Vapor-Phase-Based Synthesis	176
8.3	Solid-Phase Extraction (SPE)	177
8.4	Magnetic Solid-Phase Extraction (MSPE)	177
8.4.1	MSPE for Environmental Samples	178
8.4.2	MSPE for Food and Beverage Samples	183
8.4.3	MSPE for Biological Samples	185
8.5	Conclusions and Future Trends	186
	References	187

9 Lab-on-a-Chip with Nanomaterials (NMs) 195

9.1	Introduction	195
9.2	Lab-on-a-Chip (LOC) Concept	196
9.2.1	Paper-based LOC Systems	198
9.2.2	Centrifugal LOC Systems	198
9.2.3	Droplet-Based LOC Systems	198
9.2.4	Digital LOC Systems	199
9.2.5	Surface Acoustic Wave-Based LOC Systems	199
9.3	NM-Based LOC Platforms	199
9.3.1	NM-Based Transducers	199
9.3.1.1	Electrochemical Detection Systems	199
9.3.1.2	Optical Detection Systems	202
9.3.1.3	Other Detection Techniques	205
9.3.2	Nanoparticles as Labels in Microfluidics	206
9.3.3	NMs for Process Improvement	208
9.4	Conclusions and Future Perspectives	209
	References	210

10	Toxicity and Risk Assessment of Nanomaterials	219
10.1	Introduction	219
10.2	Hazard Assessment of Nanomaterials	220
10.2.1	Dermal Toxicity of Nanomaterials	220
10.2.2	Inhalational Toxicity of Nanomaterials	221
10.2.3	Carcinogenicity and Genotoxicity of Nanomaterials	223
10.2.4	Neurotoxicity of Nanomaterials	226
10.3	Toxicity Mechanism of Nanomaterials	227
10.4	The Traditional Risk Assessment Paradigm	229
10.5	Strategies for Improving Specific Risk Assessment	230
10.5.1	Combining Life Cycle Methodology with the Risk Assessment Approach	230
10.5.2	The Support of Risk-Based Classification Systems	231
10.6	Conclusions	232
	References	232
11	Economic Aspects of Nanomaterials (NMs) for Sample Preparation	241
11.1	Introduction	241
11.2	Toxicity Concerns of NMs	242
11.3	Global Market for NM-Based Products	243
11.4	Conclusions	245
	References	246
12	Legal Aspects of Nanomaterials (NMs) for Sample Preparation	251
12.1	Introduction	251
12.2	Safety Issues of NMs	251
12.3	Regulatory Aspects of NMs	252
12.3.1	Ethical Concerns in the Environmental Effects of NMs	253
12.3.2	Ethical Concerns in Occupational Health and Safety of Workers	254
12.3.3	Ethical Concerns of NMs in Food	255
12.3.4	Ethical Concerns of NMs in Drugs, Cosmetics, and Human Health	255
12.4	Conclusions	256
	References	257
13	Monitoring of Nanomaterials (NMs) in the Environment	261
13.1	Introduction	261
13.2	Toxicity and Safety Concerns of NMs	262
13.3	Main Sources and Transport Routes of Nanopollutants	264
13.4	Requirements of Analytical Approaches	266
13.5	Sampling of NMs in Environmental Samples	266
13.6	Separation of NMs in Environmental Samples	267
13.7	Detection Techniques for the Characterization of NMs	268
13.8	Conclusions	270
	References	270

14	Future Prospect of Sampling	275
14.1	Introduction	275
14.2	Sampling	276
14.3	Sample Preparation	276
14.4	Green Chemistry	278
14.5	Miniaturization of Analytical Systems	280
14.5.1	Miniaturization of Separation Techniques	281
14.5.2	Lab-on-a-Valve (LOV) as a Powerful Tool to Meet Green Chemical Principles	283
14.6	Conclusions	283
	References	284
	Index	289