

Contents

Preface

xvii

1 Fabrication Methods for Polymer Coatings	1
<i>Hüsniğül Yilmaz Atay</i>	
1.1 Introduction	1
1.1.1 Starting Liquid Types	2
1.1.1.1 Polymer Solutions	2
1.1.1.2 Liquid Monomers	3
1.1.1.3 Polymer Latex	4
1.1.2 Polymer Coating Methods	5
1.1.2.1 Blade Coating	6
1.1.2.2 Spray Coating	6
1.1.2.3 Thermal Spray Coating	7
1.1.2.4 Pulsed Laser Deposition	9
1.1.2.5 Plasma Polymerization	9
1.1.2.6 Flow Coating	10
1.1.2.7 Spin Coating	11
1.1.2.8 Sol-Gel	13
1.1.2.9 Dip Coating	15
1.1.2.10 Grafting	16
References	17
2 Fabrication Methods of Organic/Inorganic Nanocomposite Coatings	21
<i>Anandraj Mohan Kumar, Rajasekar Rathanasamy, Gobinath Velu Kaliyannan, Moganapriya Chinnasamy and Sathish Kumar Palaniappan</i>	
Abbreviations	21
2.1 Introduction	22
2.1.1 Transparency of Organic/Inorganic Nanocomposites	24

2.2	Fabrication Methods	25
2.2.1	Sol-Gel Method	25
2.2.2	Cold Spray Technique	25
2.2.3	Chemical Vapor Deposition	27
2.2.4	Physical Vapor Deposition	28
2.2.5	Thermal Spray Coating	29
2.2.6	Electrodeposition Method	29
2.2.7	Electroless Coating Method	30
2.3	Conclusions	31
	References	32
3	Dry Powder Coating Techniques and Role of Force Controlling Agents in Aerosol	41
	<i>Piyush P. Mehta, Atmaram P. Pawar², Kakasaheb R. Mahadik, Shivajirao S. Kadam and Vividha Dhapte-Pawar</i>	
	Abbreviations	42
3.1	Introduction	42
3.2	Dry Powder Coating	44
3.3	Dry Powder Coating Techniques	46
3.4	Analytical Techniques for Ensuring Coating Uniformity	51
3.5	Force Controlling Agents	52
3.5.1	Metal Stearates	57
3.5.2	Amino Acids	63
3.6	Inhaler Device and Capsule Coating	66
3.7	Numerical Simulation	67
3.8	Conclusion	68
	References	69
4	Superhydrophobic Polymer Coatings	75
	<i>Amir Ershad Langroudi</i>	
	Abbreviations	75
4.1	Introduction	76
4.2	Theoretical Background	76
4.2.1	Young's Equation	78
4.2.2	Wenzel Model	79
4.2.3	Cassie-Baxter Model	80
4.3	Physical and Chemical Texturing	81
4.3.1	Cleaning Process	81
4.3.2	Wet Chemical Reaction	81
4.3.3	Sol-Gel Process	82

4.3.4	Immersion Coated	82
4.3.5	Electrochemical Deposition	82
4.3.6	Ion Irradiation or Implantation	82
4.3.7	Plasma Treatment	83
4.4	Development of Superhydrophobic Coatings With Nanoparticles	84
4.4.1	CNT Nanoparticles	84
4.4.2	Carbon-Based Fillers	85
4.4.3	Silica-Based Superhydrophobic Nanocoatings	85
4.5	Transparent Superhydrophobic Coatings for Self-Cleaning Applications	86
4.6	Superhydrophobic Coatings With Additional Self-Cleaning Function	87
4.6.1	Nanoparticles in Coating	87
4.6.2	Plant Leaves	87
4.6.3	Animal (Gecko Setae)-Inspired	87
4.6.4	Marine Organisms-Inspired Antifouling Self-Cleaning	88
4.7	Summary and Outlook	88
	References	89
5	Superhydrophobic Coatings Applications	95
	<i>Hamidreza Parsimehr and Amir Ershad Langroudi</i>	
5.1	Introduction	95
5.2	Step I	97
5.2.1	Substrate	97
5.2.2	Substance	97
5.3	Step II	98
5.3.1	Restrictive Attributes	100
5.3.1.1	Biological Agents	100
5.3.1.2	Chemical Agents	101
5.3.1.3	Physical Agents	103
5.3.2	Self-Cleaning	103
5.3.2.1	Liquid Pollutants	104
5.3.2.2	Solid Pollutants	105
5.3.3	Smart Attributes	107
5.3.3.1	Conductivity	107
5.3.3.2	Energy Storage	108
5.3.3.3	Photocatalytic	108
5.3.3.4	Self-Assembly	108
5.3.3.5	Self-Healing	109

5.3.3.6	Stimuli-Responsive	109
5.3.3.7	Multifunctional Superhydrophobic Coatings	109
5.4	Conclusions and Summary	110
	References	110
6	Adsorptive Polymer Coatings	121
	<i>Aneela Sabir, Muhammad Hamad Zeeshan, Muhammad Shafiq, Rafi Ullah Khan and Karl I. Jacob</i>	
6.1	Introduction	121
6.2	Types of Coatings	122
6.3	Polymer Coating	122
6.4	Types of Polymer Coating	123
6.5	Adsorptive Polymer Coating	123
6.6	Materials	124
6.7	Adsorptive Polymer Coating Techniques	124
6.7.1	Spray Coating	124
6.7.2	Dip Coating	125
6.7.3	Spin Coating	126
6.7.4	Solution Casting	127
6.7.5	Blade Coating	127
6.8	Adsorptive Polymer Coating Applications	128
6.8.1	UV Protection	128
6.8.2	Biomedical	129
6.8.3	Corrosion Protection	129
6.8.4	Mechanical and Wear Properties	129
6.8.5	Packaging	129
6.9	Future Perspectives	129
	References	130
7	Polyurethane Coatings	135
	<i>Nadia Akram, Khalid Mahmood Zia, Nida Mumtaz, Muhammad Saeed, Muhammad Usman and Saima Rehman</i>	
7.1	Introduction	135
7.2	Chemistry of Polyurethane	138
7.3	Formulation of PU Coating	140
7.3.1	Raw Material for Polyurethanes	140
7.3.1.1	Polyols	140
7.3.1.2	Polyether Polyols	140
7.3.1.3	Hydrocarbon-Based Polyols	141
7.3.2	Isocyanates	142
7.3.3	Monomeric Diisocyanate	144

7.3.4	Vegetable Oil-Based Polyurethane Coating	144
7.3.5	Water Borne Polyurethane Coating	145
7.4	Applications of Polyurethane Coating	145
7.4.1	Multifunctional Polyurethane Coating	145
7.4.2	Self-Cleaning of Polyurethane Coating	146
7.4.3	Self-Healing of Polyurethane Coating	147
7.4.4	Nanodoped Polyurethane Coating	148
7.5	Advantages of Polyurethane Coating	149
7.5.1	Biodegradation of Polyurethane Coating	149
7.5.2	Antimicrobial Activity of Polyurethane Coating	149
7.5.3	Cloth Protection	150
7.5.4	Anti-Scratch and Anti-Algal Coating	151
7.5.5	Flame Retardant Waterborne Polyurethane Coating	152
7.6	New Innovations and Future of Polyurethane Coating	153
7.6.1	Development in Biomaterials	153
7.6.2	Future of Paint Industry	154
7.7	Conclusion	154
	References	154
8	Electroactive Polymer Nanocomposite Coating	159
	<i>Ayesha Kausar</i>	
8.1	Introduction	160
8.2	Electroactive Polymer	160
8.3	Electroactive Polymer and Nanocomposite Coating	161
8.4	Applications of Electroactive Polymer Nanocomposite Coating	162
8.4.1	Electroactive Anti-Corrosive Coating	162
8.4.2	Electroactive Antibacterial Coating	164
8.4.3	Electroactive Coating for Sensors and Actuators	166
8.5	Future and Summary	168
	References	169
9	Conducting Polymer Coatings for Corrosion Resistance in Electronic Materials	175
	<i>U. Naresh, N. Suresh Kumar, D. Baba Basha, K. Chandra Babu Naidu, M.S.S.R.K.N. Sarma, R. Jeevan Kumar, Ramyakrishna Pothu and Rajender Boddula</i>	
9.1	Introduction	176
9.2	Conducting Polymers	178
9.2.1	Polyaniline (PANI)	178
9.2.2	Polypyrrole (PPy)	181

9.2.3	Poly(3,4-ethylenedioxy thiophene): Polystyrene sulfonate (PEDOT:PSS)	184
9.3	Conclusion	186
	References	186
10	Polymer Coatings for Food Applications	189
	<i>Fatemeh Sadat Mostafavi and Davood Zaeim</i>	
10.1	Introduction	190
10.2	The Main Objectives of Coating Food Surfaces	190
10.2.1	Controlling Mass Transfer	190
10.2.2	Carrier of Functional Agents	190
10.2.3	Physical Protection	191
10.2.4	Sensorial Improvement	191
10.3	Components of Edible Coatings	191
10.3.1	Polysaccharide	192
10.3.1.1	Cellulose Derivatives	192
10.3.1.2	Chitosan	193
10.3.1.3	Starch and Starch Derivatives	193
10.3.1.4	Seaweed Extracts	193
10.3.1.5	Pectin	193
10.3.1.6	Other Polysaccharides	194
10.3.2	Proteins	194
10.3.2.1	Collagen and Gelatin	194
10.3.2.2	Corn Zein	195
10.3.2.3	Soy Protein	195
10.3.2.4	Whey Protein	195
10.3.2.5	Casein	196
10.3.3	Lipids	196
10.3.3.1	Shellac Wax	196
10.3.3.2	Carnauba Wax	196
10.3.3.3	Candelilla Wax	197
10.3.3.4	Beeswax	197
10.3.4	Additives	197
10.4	Application Methods of Edible Coating on Food Surface	198
10.5	Food Applications of Edible Coatings	199
10.5.1	Fruits and Vegetables	199
10.5.2	Meat and Meat Products	202
10.5.3	Bakery Products	206
10.5.4	Cheese	206

10.5.5	Nuts	206
10.5.6	Eggs	207
10.5.7	Fried Food	208
10.6	Microencapsulation of Bioactive Components in Food Systems	209
10.6.1	Terminology	210
10.6.2	Structure of Microcapsules	211
10.6.3	Materials for Microencapsulation	212
10.6.4	Microencapsulation Techniques	213
10.6.4.1	Spray Drying	213
10.6.4.2	Spray Cooling	213
10.6.4.3	Freeze-Drying	214
10.6.4.4	Emulsification	214
10.6.4.5	Extrusion	215
10.6.4.6	Electro-Hydrodynamic Atomization	216
10.7	Conclusions	217
	References	218
11	Biopolymers as Edible Coating for Food: Recent Trends	233
	<i>Ravichandran Santhosh, Abhinav Tiwari and Ashish Rawson</i>	
11.1	Introduction	233
11.2	Need for Edible Coatings	235
11.3	Functions of Edible Coating	236
11.4	Materials Used for Making Edible Coating	237
11.4.1	Plant Source	237
11.4.1.1	Starch	237
11.4.1.2	Cellulose Derivatives	239
11.4.1.3	Gum	242
11.4.1.4	Protein	243
11.4.1.5	Waxes	247
11.4.2	Animal Source	251
11.4.2.1	Chitosan	251
11.4.2.2	Animal Protein	253
11.4.2.3	Milk Protein: Whey and Casein	256
11.4.2.4	Shellac	256
11.5	Composite Coatings	257
11.6	Current Trends	259
11.7	Conclusion	261
	References	262

12 Polymer Coatings for Pharmaceutical Applications	275
<i>Muhammad Harris Shoaib, Rabia Ismail Yousuf, Farrukh Rafiq Ahmed, Fatima Ramzan Ali, Faaiza Qazi, Kamran Ahmed and Farya Zafar</i>	
12.1 Introduction	275
12.2 Polymers for Coating Pharmaceuticals, A Historical Perspective	276
12.3 Types of Coatings Used on Pharmaceutical Drug Products	278
12.3.1 Solvent-Based Coatings	278
12.3.1.1 Sugar Coating	278
12.3.1.2 Film Coating	279
12.3.1.3 Soluble Film Coating	279
12.3.1.4 Insoluble Film Coating	293
12.3.1.5 Gastro-Resistant Film Coating	293
12.3.1.6 Semi-Permeable Film Coating	300
12.3.1.7 Mucoadhesive Coating Polymers	302
12.3.2 Solvent-Less Coating Procedures	303
12.3.2.1 Compression Coating	303
12.3.2.2 Hot Melt Coating	304
12.3.2.3 Dry Powder Coating	304
12.3.2.4 Electrostatic Spray Powder Coating	304
12.3.2.5 Supercritical Fluid-Based Coating	305
12.3.2.6 Photocurable Coating	305
12.3.3 Polymer Coatings for Micro/Nano Particulate Drug Delivery Systems (DDS)	305
12.3.3.1 Types of Polymer Coating Systems for Specialized DDS	306
12.4 Mechanism of Drug Release through Coating Systems	308
12.4.1 Diffusion	308
12.4.2 Dissolution	308
12.4.3 Erosion	309
12.4.4 Osmosis	309
12.5 Ideal Characteristics of Coating Polymers	310
12.5.1 Solubility	310
12.5.2 Viscosity	310
12.5.3 Permeability	310
12.5.4 Glass Transition Temperature	310
12.5.5 Mechanical Strength	311
12.6 Conclusion	311
References	311

13 Self-Healing Polymer Coatings	319
<i>Sathish Kumar Palaniappan, Moganapriya Chinnasamy, Rajasekar Rathanasamy and Samir Kumar Pal</i>	
13.1 Introduction	319
13.2 Self-Healing: Introduction and Benefits	321
13.3 Summary of Progress in Self-Healing Coating Technology	323
13.3.1 Coatings for Self-Regeneration	323
13.3.2 Anti-Corrosion Protective Layer Fractures	325
13.4 Realistic Frameworks of Self-Healing Polymeric Coatings	327
13.5 Potential Historic Activity	327
13.6 Conclusions	328
References	329
14 Polymer Coatings for Biomedical Applications	333
<i>Tahir Farooq, Arruje Hameed, Muhammad Sajid Hamid Akash and Kanwal Rehman</i>	
14.1 Introduction	333
14.2 Applications in Tissue Engineering	336
14.3 Polymer Coating for Drug Delivery	339
14.4 Polymer Coating as Antimicrobial Surfaces	341
14.5 Conclusion	343
References	343
15 Antimicrobial Polymer Coating	347
<i>Kanwal Irshad, Kanwal Rehman, Hina Sharif and Muhammad Sajid Hamid Akash</i>	
15.1 Introduction	348
15.2 Mechanism of Action	349
15.2.1 Passive Action	350
15.2.2 Active Action	352
15.3 Factor Affecting Activity of Antimicrobial	352
15.3.1 Polymers	352
15.3.2 Molecular Weight	352
15.3.3 Charge Density	354
15.3.4 Hydrophilicity	354
15.3.5 Counter Ions	354
15.3.6 pH	355
15.4 Medical Applications	355
15.5 Conclusion	355
References	356

16	Characterization Techniques for Polymer Coatings	359
	<i>Hina Sharif, Kanwal Rehman, Kanwal Irshad and Muhammad Sajid Hamid Akash</i>	
16.1	Introduction	359
16.2	Polymer Coating	360
16.3	Technique for Coating	361
16.4	Types of Coating	361
16.4.1	Film Coating	361
16.4.2	Extended Release Coating	363
16.4.3	Organic-Inorganic Nanocomposites Hybrid Coating	363
16.4.4	Enteric Coating	364
16.5	Characterization of Coating System	364
16.5.1	Water Vapor Permeability	364
16.5.2	Oxygen Permeability	365
16.5.3	Thermal Properties	366
16.5.3.1	Glass Transition Temperature (T_g)	366
16.5.3.2	Minimum Film Forming Temperature (MFFT)	366
16.5.4	Mechanical Testing	367
16.5.5	Polymer Adhesion	367
16.5.6	Surface Roughness	368
16.5.7	Film Thickness and Uniformity	368
16.6	Conclusion	368
	References	368
17	Polymer Coatings for Corrosive Protection	371
	<i>Gobinath Velu Kaliyannan, Mahesh Kumar Karavalasu Velusamy, Sathish Kumar Palaniappan, Mohan Kumar Anandraj and Rajasekar Rathanasamy</i>	
17.1	Introduction	372
17.2	Basics of Corrosion	373
17.2.1	Essentials of Corrosion	375
17.2.2	Methods of Coatings	376
17.2.2.1	Zinc-Rich Coating	376
17.2.2.2	Inhibitive Coating	376
17.3	Conducting Polymer-Based Coatings for Protection Against Corrosion	377
17.3.1	Chemical Oxidative Polymerization Technique	378
17.3.2	Electro-Chemical Oxidative Polymerization Technique	379

17.4	Synthesis of Conducting Polymer Commonly Used in Protection Against Corrosion	381
17.4.1	Synthesis of Conducting Polymer: PANI	381
17.4.2	Synthesis of Conducting Polymer: PPy	383
17.4.3	Synthesis of Conducting Polymer: PTh	385
17.5	Performance Improvement and Bulk Modifications of Conducting Polymers	385
17.5.1	Doping	386
17.5.2	Layering	386
17.5.3	Copolymerization	386
17.6	Conducting Copolymer Composites and Nanocomposites	387
17.7	Summary of Conducting Polymers-Based Protective Coatings	388
17.8	Conclusions	389
	References	389
18	Polymer Coating for Industrial Applications	397
	<i>Moganapriya Chinnasamy, Rajasekar Rathanasamy, Sathish Kumar Palaniappan, Mahesh Kumar Karavalasu Velusamy and Samir Kumar Pal</i>	
18.1	Introduction	397
18.2	Polymer Coating in Oil and Gas Industry	398
18.3	Polymeric Coatings for Tribo-Technical Applications	400
18.4	Polymer Coating for Drug Delivery	402
18.5	Polymer Coating for Corrosion Protection	403
18.6	Polymer Coating for Antibacterial Activity	404
18.7	Polymer Coating for Micro Bit Storage	406
18.8	Polymer Coating for Micro Batteries	407
18.9	Polymer Coating for Biomedical Applications	407
18.10	Polymer Coating for Pipe Line Applications	409
18.11	Conclusions	410
	References	410
19	Formulations for Polymer Coatings	415
	<i>Mallesh Kurakula, N. Raghavendra Naveen and Khushwant S. Yadav</i>	
19.1	Introduction	416
19.2	Film Coating	416
19.2.1	Polymers for Film Coating	416
19.2.2	Plasticizer	417
19.2.3	Polymer-Plasticizer Compatibility	417
19.2.4	Mechanism of Film Formation	418

19.3	Functions of the Polymeric Coating	419
19.3.1	Application of Film Coating in Modified Release System (Enteric Release)	420
19.3.2	Liposomal Coating	422
19.3.3	Aerosol Coating	424
19.4	Polymeric-Coating Approaches to Targeted Colon Delivery	424
19.4.1	Enzymatically Degradable Film Coatings [64]	430
19.4.1.1	Film Coatings Based on Naturally Occurring Polysaccharides	430
19.4.1.2	Film Coating on the Basis of Synthetic Azo Polymers	430
19.4.2	pH-Sensitive Film Coatings	431
19.4.2.1	Film Coating on Basis of Enteric Solubility of Polymers	431
19.4.2.2	Film Coatings on the Basis of Acid Solubility of Polymers	431
19.5	Natural Polymers Applications in Modified Release Dosage Forms	431
19.6	Application of Polymer Coating in Biomedicine	432
19.7	Pellet Coating (Film Coating and Dry Coating)	433
19.7.1	Pellets by Solution/Suspension Layering	433
19.7.2	Dry Coating	436
19.8	Conclusion	437
	References	437
	Index	445