# CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preface</td>
<td>xi</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>xiii</td>
</tr>
<tr>
<td><strong>1 Introduction</strong></td>
<td>1</td>
</tr>
<tr>
<td>1.1 What makes Polymers so Interesting?</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Macromolecular Engineering and Nanostructure Formation</td>
<td>4</td>
</tr>
<tr>
<td>1.3 Specific Needs in Bionanotechnology and Biomedicine</td>
<td>5</td>
</tr>
<tr>
<td>Reference</td>
<td>6</td>
</tr>
<tr>
<td><strong>2 Terminology</strong></td>
<td>7</td>
</tr>
<tr>
<td>2.1 Polymer Architectures</td>
<td>7</td>
</tr>
<tr>
<td>2.2 Multifunctionality</td>
<td>11</td>
</tr>
<tr>
<td>2.3 Bioconjugates</td>
<td>12</td>
</tr>
<tr>
<td>2.4 Biocompatibility</td>
<td>12</td>
</tr>
<tr>
<td>2.5 Biodegradation</td>
<td>14</td>
</tr>
<tr>
<td>2.6 Bioactivity</td>
<td>14</td>
</tr>
<tr>
<td>2.7 Multivalency</td>
<td>15</td>
</tr>
<tr>
<td>2.8 Bionanotechnology</td>
<td>17</td>
</tr>
<tr>
<td>References</td>
<td>18</td>
</tr>
</tbody>
</table>
3 Preparation Methods and Tools

3.1 General Aspects of Polymer Synthesis, 19
  3.1.1 Chain Growth Polymerizations, 20
  3.1.2 Step Growth Polymerizations, 23
  3.1.3 Modification of Polymers, 25

3.2 Controlled Polymer Synthesis, 25
  3.2.1 Anionic Polymerization, 26
  3.2.2 Cationic Polymerization, 30
  3.2.3 Controlled Radical Polymerization, 34
  3.2.4 Metal-Catalyzed Polymerization, 37
  3.2.5 Chain Growth Condensation Polymerization, 41

3.3 Effective Polymer Analogous Reactions, 43

3.4 Pegylation, 47

3.5 Bioconjugation, 51
  3.5.1 Polynucleotide Conjugates, 53
  3.5.2 Protein Conjugates, 55
  3.5.3 Polysaccharide Conjugates, 57

3.6 Enzymatic Polymer Synthesis, 59

3.7 Solid Phase Synthesis and Biotechnological Approaches, 63
  3.7.1 Solid Phase Synthesis, 63
  3.7.2 Biotechnology Approaches in the Synthesis of Biopolymers, 75

3.8 Hydrogels and Hydrogel Scaffolds, 81
  3.8.1 Hydrogels, 81
  3.8.2 Hydrogels as Scaffold Materials, 84

3.9 Surface Modification and Film Preparation, 92
  3.9.1 Self-Assembled Monolayers, 93
  3.9.2 Langmuir–Blodgett Films, 95
  3.9.3 Layer-by-Layer Deposition, 96
  3.9.4 Immobilization by Chemical Binding to Substrates, 97
  3.9.5 Low-Pressure Plasma, 99
  3.9.6 Electron Beam Treatment, 101

3.10 Microengineering of Polymers and Polymeric Surfaces, 102

4 Analytical Methods

4.1 Molecular Structure and Molar Mass Determination of Polymers and Biohybrids, 113
  4.1.1 Structural Characterization, 114
4.1.2 Determination of Molar Mass and Molar Mass Distribution, 132

4.2 Characterization of Aggregates and Assemblies, 137
  4.2.1 Dynamic Light Scattering, 138
  4.2.2 Pulsed Field Gradient and Electrophoretic Nuclear Magnetic Resonance, 139
  4.2.3 Field-Flow Fractionation, 142
  4.2.4 UV–Vis Spectroscopy and Fluorescence Spectroscopy, 144
  4.2.5 Electron Microscopy, 145

4.3 Characterization of Hydrogel Networks, 147
  4.3.1 Network Structure of Hydrogels, 148
  4.3.2 Swelling Degree, 148
  4.3.3 Mechanical Properties, 150
  4.3.4 Deriving Microscopic Network Parameters from Macroscopic Hydrogel Properties, 153

4.4 Surface Characterization, 154
  4.4.1 X-Ray Photoelectron Spectroscopy, 154
  4.4.2 Contact Angle Measurements by Axisymmetric Drop Shape Analysis, 157
  4.4.3 Electrokinetic Measurements, 158
  4.4.4 Spectroscopic Ellipsometry, 159
  4.4.5 Quartz Crystal Microbalance with Dissipation Monitoring, 160
  4.4.6 Surface Plasmon Resonance, 161
  4.4.7 Scanning Force Techniques, 162
  4.4.8 Environmental Scanning Electron Microscopy, 164

4.5 Biophysical Characterization and Biocompatibility, 166
  4.5.1 Biophysical Characterization, 167
  4.5.2 Biocompatibility, 175

References, 183

5 Multifunctional Polymer Architectures 187

5.1 Multifunctional (Block) Copolymers, 187
  5.1.1 Multifunctionality through Copolymerization, 187
  5.1.2 Multifunctionality by Polymer Analogous Reactions, 189
  5.1.3 Spatially Defined Multifunctionality by Phase Separation and Self-Assembly of Segmented Copolymers, 190
5.2 Dendritic Polymers, 196
  5.2.1 Synthesis of Dendrimers and Hyperbranched Polymers, 198
  5.2.2 Properties and Applications, 200
5.3 Glycopolymers, 203
  5.3.1 Linear Glycopolymers, 205
  5.3.2 Globular Glycomacromolecules, 207
5.4 Peptide-Based Structures, 212
  5.4.1 Hierarchical Self-Assembly of Peptide Molecules, 214
  5.4.2 General Design Concepts for Peptide-Based Structural Materials, 215
  5.4.3 Noncanonical Amino Acids in Peptide/Protein Engineering, 217
  5.4.4 Peptide-Based Materials Inspired by Naturally Occurring Structural Proteins, 217
  5.4.5 Polypeptide Materials Based on other Naturally Occurring or De Novo Designed Self-Assembling Domains such as Coiled Coils, 221
  5.4.6 Self-Assembly of Short Peptide Derivates and Peptide-Based Amphiphilic Molecules, 222
5.5 Biohybrid Hydrogels, 224
  5.5.1 Composition, Basic Principles, and Formation of Biohybrids, 225
  5.5.2 Polynucleotide Biohybrids, 228
  5.5.3 Polypeptide or Protein Biohybrids, 231
  5.5.4 Polysaccharide Biohybrids, 232
References, 235

6 Functional Materials and Applied Systems

6.1 Organic Nanoparticles and Aggregates for Drug and Gene Delivery, 241
  6.1.1 Polymeric Micelles, Polymersomes, and Nanocapsules, 241
  6.1.2 Polymeric Beads and Micro/Nanogels Based on Dendritic Structures, 254
  6.1.3 Polyplexes for Gene Delivery, 263
6.2 Polymer Therapeutics and Targeting Approaches, 264
  6.2.1 Current Status of Polymer Therapeutics, 264
  6.2.2 Implications and Rationale for Effective Delivery Systems, 266
  6.2.3 Cellular Uptake and Targeting, 267
6.3 Multi- and Polyvalent Polymeric Architectures, 271
   6.3.1 Polyvalent Interactions on Biological Interfaces, 272
   6.3.2 Prospects for Multivalent Drugs, 277
6.4 Bioresponsive Networks, 280
   6.4.1 Active Principle, 280
   6.4.2 Homeostatic Regulation of Blood Coagulation, 281
   6.4.3 Insulin Release in Response to Glucose Concentration, 282
   6.4.4 Urate-Responsive Release of Urate Oxidase, 283
   6.4.5 Cell-Responsive Degradation of Hydrogel Networks, 284
6.5 Biofunctional Surfaces, 284
   6.5.1 Concepts and Aims of Biofunctional Material Surfaces, 284
   6.5.2 Biofunctional Surfaces for the Prevention of Biofouling, 287
   6.5.3 Anticoagulant Coatings for Blood-Contacting Devices, 292

References, 295

Abbreviations 303
Index 309