

Contents

Preface XXIII

List of Contributors XXV

Volume 1 Synthetic Techniques

- 1 **Macromolecular Engineering** 1
Krzysztof Matyjaszewski, Yves Gnanou, and Ludwik Leibler
- 2 **Anionic Polymerization of Vinyl and Related Monomers** 7
Michel Fontanille and Yves Gnanou
- 3 **Carbocationic Polymerization** 57
Priyadarsi De and Rudolf Faust
- 4 **Ionic and Coordination Ring-opening Polymerization** 103
*Stanislaw Penczek, Andrzej Duda, Przemyslaw Kubisa,
and Stanislaw Slomkowski*
- 5 **Radical Polymerization** 161
Krzysztof Matyjaszewski and Wade A. Braunecker
- 6 **Coordination Polymerization: Synthesis of New Homo- and
Copolymer Architectures from Ethylene and Propylene
using Homogeneous Ziegler–Natta Polymerization Catalysts** 217
Andrew F. Mason and Geoffrey W. Coates
- 7 **Recent Trends in Macromolecular Engineering** 249
Damien Quémener, Valérie Héroguez, and Yves Gnanou
- 8 **Polycondensation** 295
Tsutomu Yokozawa

- 9 **Supramolecular Polymer Engineering** 351
G. B. W. L. Ligthart, Oren A. Scherman, Rint P. Sijbesma, and E. W. Meijer
- 10 **Polymer Synthesis and Modification by Enzymatic Catalysis** 401
Shiro Kobayashi and Masashi Ohmae
- 11 **Biosynthesis of Protein-based Polymeric Materials** 479
Robin S. Farmer, Manoj B. Charati, and Kristi L. Kiick
- 12 **Macromolecular Engineering of Polypeptides Using the Ring-opening Polymerization-Amino Acid *N*-Carboxyanhydrides** 519
Harm-Anton Klok and Timothy J. Deming
- 13 **Segmented Copolymers by Mechanistic Transformations** 541
M. Atilla Tasdelen and Yusuf Yagci
- 14 **Polymerizations in Aqueous Dispersed Media** 605
Bernadette Charleux and François Ganachaud
- 15 **Polymerization Under Light and Other External Stimuli** 643
Jean Pierre Fouassier, Xavier Allonas, and Jacques Lalevée
- 16 **Inorganic Polymers with Precise Structures** 673
David A. Rider and Ian Manners

Volume 2

Elements of Macromolecular Structural Control

- 1 **Tacticity** 731
Tatsuki Kitayama
- 2 **Synthesis of Macromonomers and Telechelic Oligomers by Living Polymerizations** 775
Bernard Boutevin, Cyrille Boyer, Ghislain David, and Pierre Lutz
- 3 **Statistical, Alternating and Gradient Copolymers** 813
Bert Klumperman
- 4 **Multisegmental Block/Graft Copolymers** 839
Constantinos Tsitsilianis
- 5 **Controlled Synthesis and Properties of Cyclic Polymers** 875
Alain Deffieux and Redouane Borsali

- 6 **Polymers with Star-related Structures** 909
Nikos Hadjichristidis, Marinos Pitsikalis, and Hermis Iatrou
- 7 **Linear Versus (Hyper)branched Polymers** 973
Hideharu Mori, Axel H. E. Müller, and Peter F. W. Simon
- 8 **From Stars to Microgels** 1007
Daniel Taton
- 9 **Molecular Design and Self-assembly of Functional Dendrimers** 1057
Wei-Shi Li, Woo-Dong Jang, and Takuzo Aida
- 10 **Molecular Brushes – Densely Grafted Copolymers** 1103
Brent S. Sumerlin and Krzysztof Matyjaszewski
- 11 **Grafting and Polymer Brushes on Solid Surfaces** 1137
Takeshi Fukuda, Yoshinobu Tsujii, and Kohji Ohno
- 12 **Hybrid Organic Inorganic Objects** 1179
Stefanie M. Gravano and Timothy E. Patten
- 13 **Core–Shell Particles** 1209
Anna Musyanovych and Katharina Landfester
- 14 **Polyelectrolyte Multilayer Films –
A General Approach to (Bio)functional Coatings** 1249
*Nadia Benkirane-Jessel, Philippe Laval, Vincent Ball, Joëlle Ogier,
Bernard Senger, Catherine Picart, Pierre Schaaf, Jean-Claude Voegel,
and Gero Decher*
- 15 **Bio-inspired Complex Block Copolymers/Polymer Conjugates
and Their Assembly** 1307
Markus Antonietti, Hans G. Börner, and Helmut Schlaad
- 16 **Complex Functional Macromolecules** 1341
*Zhiyun Chen, Chong Cheng, David S. Germack, Padma Gopalan,
Brooke A. van Horn, Shrinivas Venkataraman, and Karen L. Wooley*

Volume 3

Structure-Property Correlation and Characterization Techniques

- 1 **Self-assembly and Morphology Diagrams for Solution
and Bulk Materials: Experimental Aspects** 1387
Vahik Krikorian, Youngjong Kang, and Edwin L. Thomas

- 2 **Simulations** 1431
Denis Andrienko and Kurt Kremer
- 3 **Transport and Electro-optical Properties
in Polymeric Self-assembled Systems** 1471
Olli Ikkala and Gerrit ten Brinke
- 4 **Atomic Force Microscopy of Polymers:
Imaging, Probing and Lithography** 1515
Sergei S. Sheiko and Martin Moller
- 5 **Scattering from Polymer Systems** 1575
Megan L. Ruegg and Nitash P. Balsara
- 6 **From Linear to (Hyper) Branched Polymers:
Dynamics and Rheology** 1605
Thomas C. B. McLeish
- 7 **Determination of Bulk and Solution Morphologies
by Transmission Electron Microscopy** 1649
Volker Abetz, Richard J. Spontak, and Yeshayahu Talmon
- 8 **Polymer Networks** 1687
Karel Dušek and Miroslava Dušková-Smrčková
- 9 **Block Copolymers for Adhesive Applications** 1731
Costantino Creton
- 10 **Reactive Blending** 1753
Robert Jerome
- 11 **Predicting Mechanical Performance of Polymers** 1783
Han E. H. Meijer, Leon E. Govaert, and Tom A. P. Engels
- 12 **Scanning Calorimetry**
René Androsch and Bernhard Wunderlich
- 13 **Chromatography of Polymers** 1881
Wolfgang Radke
- 14 **NMR Spectroscopy** 1937
Hans Wolfgang Spiess
- 15 **High-throughput Screening in Combinatorial Polymer Research** 1967
Michael A. R. Meier, Richard Hoogenboom, and Ulrich S. Schubert

Volume 4

Applications

- 1 Applications of Thermoplastic Elastomers Based on Styrenic Block Copolymers 2001**
Dale L. Handlin, Jr., Scott Trenor, and Kathryn Wright
 - 1.1 Introduction 2001
 - 1.1.1 Origins and Development 2001
 - 1.2 Footwear 2008
 - 1.3 Bitumen Modification 2009
 - 1.3.1 Paving 2009
 - 1.3.2 Road Marking 2010
 - 1.3.3 Roofing 2010
 - 1.4 Adhesives and Sealants 2011
 - 1.5 Compounding Applications 2015
 - 1.5.1 Raw Material Selection 2015
 - 1.5.2 Processing and Forming 2018
 - 1.5.3 Automotive 2020
 - 1.5.4 Wire and Cable 2021
 - 1.5.5 Medical 2021
 - 1.5.6 Soft-touch Overmolding 2022
 - 1.5.7 Ultra-soft Compounds 2022
 - 1.6 Polymer Modification 2023
 - 1.7 Viscosity Modification and Gels 2024
 - 1.7.1 Viscosity Index Improvers 2024
 - 1.7.2 Oil Gels 2024
 - 1.8 Emerging Technology in Block Copolymers 2025
 - 1.8.1 Recycling Compatibilization 2025
 - 1.8.2 PVC and Silicone Replacement 2025
 - 1.8.3 Commercial Uses of Other Controlled Polymerized Polymers 2026
 - 1.8.4 Styrene-Isobutene-Styrene (S-IB-S) 2028
 - List of Abbreviations 2028
 - References 2029
- 2 Nanocomposites 2033**
Michaël Alexandre and Philippe Dubois
 - 2.1 Introduction 2033
 - 2.2 Generalities 2034
 - 2.2.1 Nanocomposites and Nanohybrids – Definitions 2034
 - 2.2.2 Key Details 2035
 - 2.2.3 Main Production Pathways 2036
 - 2.2.4 Enhanced Properties 2037
 - 2.3 Layered Silicates 2038

2.3.1	Nanocomposites Prepared by <i>In Situ</i> Polymerization of the Matrix from Anchored Monomers or Initiators	2040
2.3.1.1	Non-controlled Polymerization Processes	2040
2.3.1.2	Controlled Polymerization Process	2043
2.4	Extrapolation to Other Nanofillers	2057
2.4.1	Other Layered Nanoparticles	2057
2.4.2	Carbon Nanotubes	2059
2.4.3	Isometric Nanoparticles	2061
2.5	Current and Potential Applications	2065
2.5.1	Automotive Industry	2065
2.5.2	Packaging Industry	2066
2.5.3	Cable and Wire Industry	2067
2.6	Conclusion	2067
	References	2068

3 **Polymer/Layered Filler Nanocomposites: An Overview from Science to Technology** 2071

Masami Okamoto

3.1	Introduction	2071
3.2	Historical Point of View	2072
3.3	Structure of Layered Filler and Its Modification	2073
3.4	Preparative Methods and Structure of PLFNCs	2075
3.4.1	Intercalation of Polymer or Pre-polymer from Solution	2075
3.4.2	<i>In situ</i> Intercalative Polymerization Method	2076
3.4.3	Melt Intercalation Method	2076
3.5	Interlayer Structure of OMLFs and Intercalation	2077
3.6	Structure and Characterization of PLFNCs	2079
3.7	Nobel Compounding Process	2083
3.8	Control of Nanostructure Properties	2086
3.8.1	Intercalation During Crystallization and Confinement	2086
3.8.2	Multiscale Micromechanical Modeling	2088
3.8.3	Flexibility of a Single Clay Layer	2090
3.8.4	Higher-order Structure Development and Crystallization Controlled by Nano-filler Surfaces	2091
3.8.5	Flocculation Control and Modulus Enhancement	2095
3.9	Melt Rheology of PLFNCs	2097
3.9.1	Linear Viscoelastic Properties	2097
3.9.2	Steady Shear Flow	2102
3.9.3	Elongational Flow and Strain-induced Hardening	2105
3.9.4	Alignment of Silicate Layers	2107
3.9.5	Electrorheology	2109
3.10	Materials Properties of PLFNCs	2110
3.10.1	Thermal Stability	2110
3.10.2	Fire Retardant Properties	2111
3.10.3	Gas Barrier Properties	2113

3.10.4	Ionic Conductivity	2115
3.10.5	Optical Transparency	2115
3.10.6	Physicochemical Phenomena	2116
3.10.6.1	Biodegradability	2116
3.10.6.2	Photodegradation	2119
3.10.6.3	Pressure–Volume–Temperature (PVT) Behavior	2121
3.11	Computer Simulation	2121
3.12	Processing Operations	2123
3.12.1	Foam Processing Using sc-CO ₂	2124
3.12.2	Electrospinning Processing	2127
3.12.3	Porous Ceramic Materials via PLSNCs	2128
3.13	Future Prospects	2130
	References	2130
4	Polymeric Dispersants	2135
	<i>Frank Pirrung and Clemens Auschra</i>	
4.1	Dispersant Application Fields	2135
4.2	Pigment Dispersants Function and Requirements	2136
4.2.1	Dispersant Application Criteria	2136
4.2.2	Design of Dispersants by Stabilization Mechanism	2138
4.2.3	Characteristic Data of Pigment Dispersants	2139
4.2.4	Chemical Architecture of High Molecular Weight Dispersants	2140
4.2.5	Anchoring Groups	2141
4.3	Classical Polymeric Pigment Dispersants	2142
4.3.1	Polyurethane-based Dispersants	2142
4.3.1.1	Polyisocyanate Resins	2142
4.3.1.2	Cross-linkers	2144
4.3.1.3	Monofunctional Side-chains	2145
4.3.1.4	Introduction of Anchoring Groups	2147
4.3.2	Polyacrylate-based Dispersants	2148
4.3.2.1	Architecture of Polyacrylate Dispersants	2150
4.3.2.2	Design of the Polyacrylate Backbone	2151
4.3.2.3	Introduction of Anchoring Groups	2153
4.3.2.4	Dispersants Based on SMA Resins	2154
4.3.3	Polyester-based Dispersants	2156
4.3.3.1	Polymeric Amine Anchoring Blocks	2156
4.3.3.2	Polyester Side Chains and Dispersant Synthesis	2157
4.3.4	Polyether-based Dispersants	2161
4.4	New Technologies and Trends in Polymeric Dispersants	2165
4.4.1	Dispersants Made by Group Transfer Polymerization (GTP)	2167
4.4.2	Dispersants Made by Controlled Free Radical Polymerization (CFRP)	2170
4.4.2.1	Atom Transfer Radical Polymerization (ATRP)	2170
4.4.2.2	Nitroxyl-mediated Radical Polymerization (NMP)	2172
4.4.2.3	Radical Addition and Fragmentation Transfer (RAFT)	2176

4.4.3	Dispersants Based on Macromonomers	2177
4.4.4	Dispersants Based on Dendrimers and Hyperbranched Polymers	2177
	References	2178
5	Polymeric Surfactants	2181
	<i>Henri Cramail, Eric Cloutet, and Karunakaran Radhakrishnan</i>	
5.1	Introduction	2181
5.2	Main Surfactants Used for Heterogeneous Polymerizations in Aqueous Media	2183
5.2.1	Synthesis and Main Uses of PEO-based Copolymers	2183
5.2.1.1	PEO- <i>b</i> -PPO and PEO- <i>b</i> -PBO Block Copolymers	2183
5.2.1.2	PS- <i>b</i> -PEO and Derivatives	2186
5.2.1.3	PMMA- <i>b</i> -PEO	2191
5.2.1.4	Miscellaneous Nonionic Amphiphilic PEO-based Block Copolymers	2192
5.2.2	Synthesis and Main Uses of PAA- and PMAA-based Copolymers	2193
5.2.2.1	PMMA- <i>b</i> -PAA and PMMA- <i>b</i> -PMAA	2194
5.2.2.2	PnBA- <i>b</i> -PAA	2194
5.2.2.3	PS- <i>b</i> -PAA and PS- <i>b</i> -PMAA	2196
5.2.3	Synthesis and Main Uses of Sulfonate Block Copolymers	2196
5.2.4	Cationic and Cationizable Block Copolymers	2198
5.2.5	Miscellaneous	2200
5.3	Main Surfactants Used for Heterogeneous Polymerizations in Nonaqueous Dispersions	2204
5.3.1	PEO- and PPO-based Copolymers	2205
5.3.2	Polyolefin-based Copolymers	2206
5.3.3	Silicon-based Copolymers	2207
5.3.4	(Meth)acrylic-based Copolymers	2208
5.3.5	<i>In Situ</i> Formation of Block Copolymer Stabilizers	2209
5.4	Main Surfactants Used for Heterogeneous Polymerizations in scCO ₂	2211
5.4.1	Silicon-based Stabilizer	2211
5.4.2	Fluorinated Copolymers	2213
5.4.3	Polycarbonates	2215
5.5	Conclusion	2216
	List of Abbreviations	2216
	References	2218
6	Molecular and Supramolecular Conjugated Polymers for Electronic Applications	2225
	<i>Andrew C. Grimsdale and Klaus Müllen</i>	
6.1	Introduction	2225

6.2	Control of Properties by Substitution in Conjugated Polymers	2229
6.3	Controlling Optical Properties via Increased Planarity	2232
6.4	Minimization of Defects in Polymers by Synthetic Design	2234
6.5	Controlling Chain Packing of Conjugated Polymers	2236
6.6	Self-assembly of Supramolecular Polymers by Hydrogen Bonding	2240
6.7	Supramolecular Assembly of Discotic PAHs	2242
6.8	Optimizing Intra- and Intercolumnar Order in PAHs	2245
6.9	Carbon Nanotubes and Similar Materials from Ordered Graphite Mesophases	2249
6.10	Prospects for Molecular Electronics	2254
6.11	Conclusion	2256
	Acknowledgments	2257
	References	2257

7	Polymers for Microelectronics	2263
	<i>Christopher W. Bielawski and C. Grant Willson</i>	
7.1	Introduction	2263
7.2	Conjugated Polymers	2264
7.2.1	Overview	2264
7.2.2	General Considerations	2265
7.2.3	Polyacetylene	2267
7.2.4	Polyarenes: Polyphenylenevinylene, Polythiophene and Polypyrrole	2270
7.2.5	Polyaniline	2272
7.2.6	Outlook	2273
7.3	Polymeric Dielectrics	2275
7.3.1	Overview	2275
7.3.2	Polyimides	2276
7.3.3	Polybenzoxazoles	2277
7.3.4	Polybenzocyclobutanes	2278
7.3.5	Polysilsesquioxanes	2280
7.3.6	Extended Aromatic Networks	2280
7.3.7	Fluorinated Polymers	2281
7.3.8	Outlook	2281
7.4	Resists in Microlithographic Applications	2282
7.4.1	Overview	2282
7.4.2	Photolithography	2283
7.4.2.1	Background	2283
7.4.2.2	Negative Photoresists	2285
7.4.2.3	Positive Photoresists	2286
7.4.3	Electron Beam Lithography	2287
7.4.4	Immersion Lithography	2289
7.4.5	Functional Resists	2289
7.4.6	Outlook	2290

7.5	Conclusions	2290
	References	2291

8 Applications of Controlled Macromolecular Architectures to Lithography 2295

Daniel Bratton, Ramakrishnan Ayothi, Nelson Felix, and Christopher K. Ober

8.1	Introduction	2295
8.2	Specialized Nanofabrication	2295
8.2.1	Definition and Scope	2295
8.2.2	Microcontact Printing (μ CP)	2296
8.2.3	Scanning Probe Lithography (SPL)	2300
8.2.4	Particle Replication in Non-wetting Templates (PRINT)	2302
8.3	Macromolecules as Resists for Photolithography	2303
8.3.1	Introduction	2303
8.3.2	Deep-UV (248-nm) Resists	2305
8.3.3	193-nm Resists	2307
8.3.4	157-nm Resists	2308
8.3.5	Extreme UV (13.4-nm) Resists	2309
8.3.6	Dendrimers and Hyperbranched Polymers as Photoresists	2310
8.3.7	Molecular Glass (MG) Photoresists	2310
8.3.8	Supercritical CO ₂ Processing	2312
8.4	Block Copolymers	2313
8.4.1	Introduction	2313
8.4.2	Engineering Considerations for Using Block Copolymers as Lithographic Masks	2315
8.4.3	Self-assembly in Bulk Versus Thin Film	2315
8.4.4	Block Copolymers as Lithographic Resists	2316
8.4.5	Block Copolymer Thin-film Characterization	2316
8.4.6	Synthesis of Block Copolymers by Direct Polymerization	2317
8.4.7	Block Copolymers Functionalized by Post-polymerization Modification	2317
8.4.8	Block Copolymers as Templates for Advanced Lithography	2318
8.4.9	Block Copolymers as Resists for 193-, 157- and 13.4-nm Lithography	2320
8.4.10	Block Copolymers with a Fluoroalkyl Block for Supercritical CO ₂ Development	2322
8.4.11	Block Copolymers as Sequestering Agents and Additives	2322
8.5	Two-photon Lithography	2323
8.6	Conclusion	2325
	Acknowledgments	2325
	References	2325

9	Microelectronic Materials with Hierarchical Organization	2331
	<i>G. Dubois, R. D. Miller and James L. Hedrick</i>	
9.1	Introduction	2331
9.2	Porous Organosilicates from a Nucleation and Growth Phase Separation Process	2335
9.3	Role of Functionality: Nitrogenous Porogens	2337
9.4	Porous Structures via Nucleation and Growth: Role of Macromolecular Architecture	2342
9.5	Organic Nanoparticle Formation	2352
9.6	Block Copolymer Templates: Role of Macromolecular Architecture	2353
9.7	Outlook	2360
	References	2362
 10	 Semiconducting Polymers and their Optoelectronic Applications	 2369
	<i>Nicolas Leclerc, Thomas Heiser, Cyril Brochon, and Georges Hadziioannou</i>	
10.1	Introduction	2369
10.1.1	From Synthetic Metals to Semiconducting Polymers	2369
10.2	Synthesis of Conjugated Polymers	2371
10.2.1	Homopolymers	2371
10.2.2	Random and Alternating Copolymers	2379
10.2.3	Conjugated Block Copolymers	2381
10.3	Applications in Optoelectronics	2384
10.3.1	The Requirements and Design of Polymer Light-emitting Diodes	2384
10.3.1.1	State-of-the-Art	2384
10.3.1.2	Single-layer PLEDs	2385
10.3.1.3	Double-layer PLEDs	2386
10.3.1.4	Polymer Blend PLEDs	2387
10.3.2	The Requirements and Design of Polymer Laser Materials	2388
10.3.2.1	Amplified Spontaneous Emission in Polymer Films	2389
10.3.2.2	Polymer Laser	2389
10.3.2.3	Polymer Blends	2391
10.3.2.4	Electrically Pumped Polymer Laser?	2391
10.3.3	The Requirements and Design of Polymer Photovoltaic Materials	2392
10.3.4	Photovoltaic Performance of Donor–Acceptor Block Copolymers	2394
10.3.5	The Requirements and Design of Polymer Field-effect Transistors	2395
10.3.6	The Requirements and Design of Sensors Based on Polymer Semiconductors	2398
10.3.7	“Polymer Conductors”/“Synthetic Metals”	2400

10.3.8	The Requirements and Design of Thin-film Conducting and Transparent Polymer Materials	2401
10.4	Conclusion	2402
	Acknowledgments	2404
	References	2404
11	Polymer Encapsulation of Metallic and Semiconductor Nanoparticles: Multifunctional Materials with Novel Optical, Electronic and Magnetic Properties	2409
	<i>Jeffrey Pyun and Todd Emrick</i>	
11.1	Introduction	2409
11.1.1	Polymeric Surfactants and Encapsulating Coatings	2410
11.1.1.1	Types of Polymeric Surfactants	2410
11.1.1.2	Approaches to Nanoparticle Functionalization with Polymers	2412
11.2	Noble Metal Nanocomposites: the Case of Au	2414
11.2.1	Structure and Properties of Metallic Nanoparticles	2414
11.2.2	Synthesis of Au Nanoparticles	2415
11.2.2.1	Gold Nanoparticles with Small Molecule Surfactants	2415
11.2.2.2	Synthesis of Gold Nanoparticles in Linear Polymer Surfactants	2416
11.2.2.3	Branched and Dendritic Polymers	2422
11.2.2.4	Conjugated Polymers	2423
11.3	Semiconductor Nanoparticles:	
	Cadmium Selenide Quantum Dots	2424
11.3.1	Structure and Properties	2424
11.3.2	Synthesis of CdSe Semiconductor Nanoparticles	2425
11.3.2.1	Small Molecule Precursors and Surfactants	2425
11.3.2.2	Polymer Ligands for Quantum Dots	2427
11.3.2.3	Dendritic Polymers	2433
11.4	Metallic Magnetic Nanoparticles: the Case of Co	2434
11.4.1	Fundamental Terms and Classifications of Magnetic Materials	2434
11.4.2	Linear Polymeric Surfactants	2437
11.4.3	Small Molecule Surfactants	2441
11.4.4	End-functional Polymeric Surfactants	2443
11.5	Perspectives	2444
	References	2444
12	Polymeric Membranes for Gas Separation, Water Purification and Fuel Cell Technology	2451
	<i>Kazukiyo Nagai, Young Moo Lee, and Toshio Masuda</i>	
12.1	Introduction	2451
12.2	Gas Separation Membranes	2452
12.2.1	Gas Separation Mechanisms	2452
12.2.2	Gas Transport in Non-porous Polymer Membranes	2454
12.2.3	Gas Permeability and Selectivity	2459

12.2.4	Reverse-selective Polymer Membranes	2463
12.3	Water Purification Membranes	2466
12.3.1	Water Purification Mechanisms	2466
12.3.2	Non-porous Nanofiltration Polymer Membranes	2467
12.3.3	Pervaporation Polymer Membranes	2469
12.4	Membranes for Fuel Cells	2472
12.4.1	Conventional Technologies	2472
12.4.2	Membrane Performance Relevant for Fuel Cell Applications	2473
12.4.3	Aromatic Polymers with Sulfonic Acid Groups in the Their Main Chains	2473
12.4.3.1	Processability	2474
12.4.3.2	Water Sorption Behavior	2475
12.4.3.3	Proton Conductivity	2477
12.4.3.4	Fuel Permeability	2478
12.4.3.5	Hydrolytic Stability and Oxidative Radical Stability	2480
12.4.4	Modified Aromatic Polymer Containing Sulfonic Acid Groups	2481
12.4.5	Modified Aromatic PBIs	2485
12.5	Conclusion	2487
	Acknowledgment	2487
	References	2487

13 Utilization of Polymers in Sensor Devices 2493

Basudam Adhikari and Alok Kumar Sen

13.1	Introduction	2493
13.2	Different Analytes and Their Sensing Principles	2494
13.2.1	Chemical Analytes	2494
13.2.1.1	Gases and Volatile Chemicals	2494
13.2.1.2	Hydrogen Ion	2504
13.2.1.3	Selective Ions	2505
13.2.1.4	Alcohols	2511
13.2.1.5	Drugs	2512
13.2.1.6	Amines	2513
13.2.1.7	Surfactant	2513
13.2.1.8	Insecticides and Fungicides	2513
13.2.1.9	Aromatic Compounds	2515
13.2.1.10	Hydrazine	2515
13.2.1.11	Humidity	2516
13.2.2	Biosensor Analytes	2519
13.2.2.1	Glucose	2521
13.2.2.2	Urea	2524
13.2.2.3	Creatinine	2524
13.2.2.4	Amino acids	2525
13.2.2.5	Pyruvate	2525
13.2.2.6	Cholesterol	2526
13.2.2.7	Peroxide	2526

13.2.2.8	Lactate	2527
13.2.2.9	Fructose	2527
13.2.2.10	Foodstuffs and Drinks	2528
13.2.2.11	Environmental Pollutants	2529
13.2.2.12	DNA-sensitive Infectious Agents and Pollutants	2529
13.3	Measurement of Sense of Taste	2530
13.4	Trends in Sensor Research	2532
13.5	Conclusion	2533
	References	2534

14 Polymeric Drugs 2541

Tamara Minko, Jayant J. Khandare, and Sreeja Jayant

14.1	Introduction	2541
14.2	Polymeric Drug Delivery	2542
14.2.1	Water-soluble Polymers	2542
14.2.2	Classification of Water-soluble Polymeric Drugs	2543
14.2.2.1	Linear Polymer (LP) Systems	2544
14.2.2.2	Linear Polymer–Linear Spacer (LPLS) Systems	2545
14.2.2.3	Linear Polymer–Branched Spacer (LPBS) Systems	2546
14.2.2.4	Branched Polymer (BP) Systems	2547
14.2.3	Advantages of Polymeric Drugs	2547
14.2.4	Future Directions	2548
14.3	Prodrug Approach	2548
14.3.1	Prodrug Approach First Type Prodrugs	2548
14.3.2	Second Type Prodrugs	2549
14.3.3	Tumor-activated Prodrugs (TAP)	2550
14.3.4	Drug Delivery Systems	2550
14.3.5	Antedugs	2551
14.4	Controlling Properties and Function of Polymeric Drugs by Molecular Architecture	2551
14.4.1	Design and Synthesis of Polymeric Prodrugs	2552
14.4.2	Polymeric Bioconjugates in Drug Delivery	2555
14.4.2.1	Dextran and Its Prodrug Conjugates	2555
14.4.2.2	PEG and Its Prodrug Conjugates	2558
14.4.2.3	Prodrug Conjugates of <i>N</i> -(2-Hydroxypropyl)methacrylamide (HPMA) Copolymer	2561
14.4.2.4	Dendrimers and Their Conjugates	2564
14.4.2.5	Applications of Molecular Modeling in Prodrug Conjugates	2567
14.4.3	Crucial Aspects in Bioconjugation	2569
14.4.3.1	Reactivity of the Polymer and Biocomponent	2569
14.4.3.2	Use of an Appropriate Method for Preparation of Bioconjugates	2569
14.4.3.3	Steric Hindrance	2570
14.4.4	Future Directions	2571
14.5	Controlled Drug Release	2571

14.5.1	Advantages of Controlled Drug Release	2571
14.5.2	Types of Controlled Drug Release	2572
14.5.3	Future Directions	2575
14.6	Anticancer Polymeric Drugs	2575
14.6.1	General Considerations	2576
14.6.2	Tumor-targeted Anticancer Polymeric Drugs	2576
14.6.2.1	Passive Targeting	2576
14.6.2.2	Passive Targeting Active Targeting	2578
14.6.3	Proapoptotic Anticancer Polymeric Drugs	2581
14.6.4	Future Directions in Targeted Proapoptotic Anticancer Polymeric Drugs	2583
	References	2587
15	From Biomineralization Polymers to Double Hydrophilic Block and Graft Copolymers	2597
	<i>Helmut Cölfen</i>	
15.1	Biomineralization	2597
15.2	Active Biomineralization Polymers	2600
15.2.1	Proteins	2601
15.2.2	Polysaccharides	2603
15.2.3	Glycoproteins	2603
15.3	The Role of Biomineralization Polymers and Reduction to Their Functional Units	2604
15.4	Double-hydrophilic Block Copolymers (DHBCs) and Double-hydrophilic Graft Copolymers (DHGCs)	2605
15.4.1	Concept of DHBCs and DHGCs	2605
15.4.2	Synthesis of Double Hydrophilic Block Copolymers	2608
15.4.2.1	Living Anionic Polymerization	2608
15.4.2.2	Living Cationic Polymerization	2612
15.4.2.3	Group Transfer Polymerization (GTP)	2612
15.4.2.4	Radical Polymerization	2612
15.4.2.5	Polymerization with Macro Initiators	2612
15.4.2.6	Coupling of Two Polymeric Blocks	2614
15.4.2.7	Polymer Analogous Reactions	2615
15.4.3	Synthesis of Double Hydrophilic Graft Copolymers (DHGCs)	2615
15.4.4	Applications of DHBCs and DHGCs	2616
15.4.4.1	DHBC Superstructures	2616
15.4.4.2	DHBCs as Novel Surfactants	2620
15.5	Conclusion	2631
	List of Abbreviations	2632
	References	2635

16	Applications of Polymer Bioconjugates	2645
	<i>Joost A. Opsteen and Jan C. M. van Hest</i>	
16.1	Introduction; Control at the Molecular Level Over Synthetic and Biological Macromolecules	2645
16.2	Synthetic Methodologies	2646
16.2.1	Controlled Polymerization Methods	2646
16.2.2	Polypeptide Synthesis	2647
16.2.3	Conjugation Methods	2649
16.3	Pharmaceutical Applications	2650
16.3.1	Anti-cancer Therapeutics	2651
16.3.2	Application of Polymer–Peptide/Protein/Antibody Conjugates as Therapeutics	2655
16.3.3	Well-defined Macromolecular Therapeutic Architectures	2656
16.4	Bioactive Surfaces	2662
16.4.1	Bioconjugate Arrays	2662
16.4.2	Cell Adhesive Coatings	2666
16.4.3	Non-fouling Coatings	2669
16.4.4	Antimicrobial Coatings	2670
16.5	Smart Materials	2672
16.5.1	Smart Polymer Bioconjugates	2672
16.5.2	Self-assembled Structures/Supramolecules; Towards Nanotechnology	2675
16.6	Conclusions and Outlook	2678
	References	2679
17	Gel: a Potential Material as Artificial Soft Tissue	2689
	<i>Yong Mei Chen, Jian Ping Gong, and Yoshihito Osada</i>	
17.1	Introduction	2689
17.2	Molecular Design of Robust Gels	2690
17.2.1	Topological Gel	2691
17.2.2	Nanocomposite Gel	2691
17.2.3	Double Network Gel	2692
17.2.4	Robust Gels from Bacterial Cellulose	2696
17.3	Surface Friction and Lubrication of Gels	2698
17.3.1	Complexity of Gel Friction	2699
17.3.2	Template Effect on Gel Friction	2702
17.3.3	Low Friction by Dangling Chains	2704
17.4	Polymer Gels as Scaffolds for Cell Cultivation	2706
17.4.1	Modulation of Cell Growth on Various Gels	2706
17.4.2	Effect of Charge on Cell Growth	2710
17.5	Application of Gels as Substitutes for Biological Tissues	2712
17.5.1	Robust Gels with Low Friction – an Excellent Candidate as Artificial Cartilage	2713
17.5.2	Wearing Properties of Robust DN Gels	2715
	References	2716

18	Polymers in Tissue Engineering	2719
	<i>Jeffrey A. Hubbell</i>	
18.1	Introduction and Historical Perspective	2719
18.1.1	Tissue Engineering and Its Challenges for Macromolecular Engineering	2719
18.1.1.1	Cells	2720
18.1.1.2	Biomolecules	2721
18.1.1.3	Materials	2724
18.1.1.4	Examples of Tissue Engineering Constructs	2725
18.1.2	History of Polymers in Tissue Engineering	2726
18.2	Degradable Polymer Scaffolds	2727
18.3	Degradable Polymer Matrices	2732
18.4	Biofunctionalization and Drug Release	2735
18.5	Outlook	2739
	References	2740
	 IUPAC Polymer Terminology and Macromolecular Nomenclature	 2743
	<i>R. F. T. Stepto</i>	
	 Subject Index	 2747