

Contents

Biography of Book Editors *xi*

Preface *xiii*

1 Introduction *1*

Bing Ni

Part 1: Biomimetic Inorganic Nanostructures *4*

Part 2: Biomacromolecules and Structural Mimics *4*

Part 3: Nanomaterials Mimicking Biocatalytic Processes *5*

References *5*

2 Biominerals and Biomineralization *7*

Jie Wang, Zonghao Yu, Zhaoming Liu

2.1 Typical Biominerals *7*

2.2 Unique Structures of Biominerals *12*

2.3 A Crystal Growth View on Biomineralization Process *15*

2.4 Inspirations from Biomineralization *19*

2.4.1 Manufacture of Biomimetic Structures *20*

2.4.2 Controllable Arrangement of Ions – A Biomimetic Process *21*

2.4.3 Life–Material Hybrids *23*

2.5 Conclusion *25*

References *25*

3 Designing Functional Biomorphs *33*

Bing Ni

3.1 Introduction *33*

3.2 Overview of the Biomorph Formation Mechanism *35*

3.3 Influence and Potential Application of the Biomorphs *41*

3.4 Conclusion *44*

References *44*

4 Biomimetic Materials Inspired by Bone and Tooth *47*

Yifan Xu, Yuning Wang, Yanhuizhi Feng

4.1 Introduction *47*

4.2 Biomimetic Artificial Bone *48*

4.2.1	The Structure and Mineralization of Bone	48
4.2.1.1	The Composition and Structure of Bone	48
4.2.1.2	The Synthesis and Self-assembly of Type I Collagen	48
4.2.1.3	The Mineralization of Bone	50
4.2.2	Artificial Bone	52
4.2.2.1	Acellular Scaffolds	53
4.2.2.2	Electrospinning Technology	54
4.2.2.3	3D Bioprinting Technology	54
4.2.2.4	Freeze-drying Technology	54
4.2.3	Future Directions	56
4.3	Biomimetic Artificial Tooth	56
4.3.1	The Structure and Mineralization of Tooth	56
4.3.1.1	The Structure of Enamel	56
4.3.1.2	The Mineralization of Enamel	57
4.3.1.3	The Structure of Dentin	58
4.3.1.4	The Mineralization of Dentin	58
4.3.2	Biomimetic Tooth	59
4.3.2.1	Biomimetic Enamel	59
4.3.2.2	Biomimetic Dentin	64
4.3.3	Future Directions	65
	References	65
5	Biomimetic Chiral Nanomaterials	73
	<i>Lili Tan, Peng-peng Wang</i>	
5.1	Introduction	73
5.2	Biomolecular Encoding Chiral Inorganic Nanomaterials	74
5.2.1	Biomimetic Inorganic Nanomaterials with Surface Chirality	75
5.2.2	Biomolecularly Programmed Inorganic Assemblies	77
5.2.3	Chiral-shaped Inorganic Nanomaterials	80
5.3	Bioinspired Applications	81
5.3.1	Chiral Sensor	81
5.3.2	Chiral Catalyst	82
5.3.3	Chiral Therapy	85
5.4	Conclusion	86
	References	87
6	Biomacromolecular Mimics	93
	<i>Nan Wu, Xiao Sang, Xinyu Zhang, and Xinyu Liu</i>	
6.1	Introduction	93
6.2	Structure and Function of Biomacromolecules	94
6.2.1	Nucleic Acids	94
6.2.2	Proteins	95
6.2.3	Polysaccharides	97
6.3	Development of Biomacromolecular Mimics	97
6.3.1	Directly Copying the Structures of Biomacromolecules	97
6.3.1.1	Genetic and Protein Engineering	98

6.3.1.2	Folding and Assembly	100
6.3.2	Chemical Modification of Bioproducts	102
6.3.2.1	Covalent Modification	102
6.3.2.2	Noncovalent Modification	104
6.3.2.3	<i>De Novo</i> Organic Synthesis	106
6.3.2.4	Enzyme-catalyzed Modification	109
6.4	Applications of Bio-macromolecular Mimics	110
6.4.1	Application of Nucleic Acid-based Mimics	111
6.4.2	Application of Protein-based Mimics	112
6.4.3	Polysaccharide-based Mimics	113
6.5	Challenges and Future Directions	115
6.6	Conclusion	115
	References	116
7	Advanced Wood-based Bionic Materials	125
	<i>Yingying Li</i>	
7.1	Wood Bionic Intelligence Science	125
7.2	Theoretical Basis of Wood Bionics Science	126
7.2.1	Hierarchal Structure of Wood	126
7.2.2	Multi-scale Porous Structure of Wood	127
7.3	Advanced Wood-based Materials	127
7.3.1	Transparent Wood-based Materials	128
7.3.2	Ultra-strong Wood	130
7.3.3	Magnetic-responsive Wood	131
7.3.4	Light-temperature Responsive Wood	133
7.3.5	Energy Storage Wood	134
7.3.6	Superhydrophobic Wood	135
7.4	Conclusion	136
	References	137
8	Bio-inspired Multifunctional Nanocellulose Materials	141
	<i>Jieming Qiu, Rui Xiong</i>	
8.1	Introduction	141
8.2	Classification of Nanocellulose	142
8.2.1	The Main Properties of Nanocellulose	143
8.2.1.1	Excellent Mechanical Properties	143
8.2.1.2	Surface Chemical Tunability	143
8.2.1.3	Biocompatibility and Biodegradability	144
8.3	Multidimensional Structural Design of Nanocellulose	144
8.3.1	1D Nanocellulose Structures	145
8.3.1.1	Individual Fibril Structure	145
8.3.1.2	Aligned Nanofibril Structure	150
8.3.2	2D Hierarchical Structure	151
8.3.2.1	Self-assembly	152
8.3.2.2	LbL Growth	153
8.3.3	3D/4D Hierarchical Architectures	154

- 8.3.3.1 3D/4D Printing 154
- 8.3.3.2 Ice-templating Assembly 156
- 8.3.3.3 Self-assembly of Chiral Nematic Liquid Crystal Structures 157
- 8.4 Conclusion and Outlook 160
- References 161

- 9 Biomass-based Materials for a Circular Economy 173**
Bing Ni
- 9.1 Introduction 173
- 9.2 Lignin Extraction and Functionalization 174
- 9.3 Conversion of Biomass to Biofuels 179
- 9.4 Biomass Conversion to Functional Carbon Materials 182
- 9.5 Conclusion 189
- References 189

- 10 Biomimetic Aerogel 197**
Hong Ju Jung
- 10.1 Introduction 197
- 10.2 Anisotropic Building Blocks 199
 - 10.2.1 2D Material Dispersions 199
 - 10.2.2 1D Material Dispersions 201
 - 10.2.3 Hybrid Material Dispersions 202
- 10.3 Assembly Techniques 203
 - 10.3.1 Self-assembly 205
 - 10.3.2 Freeze Casting 205
 - 10.3.3 Breath-figure Method 205
 - 10.3.4 Electrochemical Gelation 206
- 10.4 Applications 206
 - 10.4.1 Thermal Insulation 207
 - 10.4.2 Elastic Sponges 208
 - 10.4.3 Water Transport 208
 - 10.4.4 Bio-scaffolds 209
 - 10.4.5 Energy Storage System 209
 - 10.4.6 Other Applications for Conductive BAs 211
- 10.5 Discussion 211
 - 10.5.1 Diversity of Shapes 212
 - 10.5.2 Mass Production 212
 - 10.5.3 Structural Analysis 213
- 10.6 Conclusion 214
- References 214

- 11 Mechanical Materials with Biomimetic Hierarchical Structures 221**
Wenbing Wu
- 11.1 Introduction 221
- 11.2 Lamellar Organization 222
 - 11.2.1 Layer-by-layer Assembly 222

- 11.2.2 Freeze-casting 225
- 11.2.3 Bulk Fabrication Methods 228
- 11.2.4 Additive Manufacturing 230
- 11.3 Columnar Organization 232
- 11.4 Challenges and Perspectives 235
- References 238

- 12 Nanozyme 247**
Ying Liu, Ruijie Qin, Run Yang, Huan Guo, Zhe Hao, Zhicheng Zhang, Ruizhong Zhang, Xiyan Li, Libing Zhang
 - 12.1 Introduction of Nanozyme 247
 - 12.2 Classification of Nanozymes 249
 - 12.2.1 Carbon-based Nanomaterials for Nanozyme 249
 - 12.2.2 Metal-based Nanomaterials for Nanozyme 250
 - 12.2.3 Metal Oxide-based Nanomaterials for Nanozymes 251
 - 12.2.4 Single-atomic Nanomaterials for Nanozymes 253
 - 12.3 Applications of Nanozymes in Bioanalysis 254
 - 12.3.1 Detection of Ions 254
 - 12.3.2 Detection of Small Biological Molecules 255
 - 12.3.3 Detection of Biological Macromolecules 256
 - 12.3.4 Detection of Bacteria 257
 - 12.3.5 Detection of Cancer Cells and Extracellular Vesicles 258
 - 12.4 Applications of Nanozymes in Therapy 259
 - 12.4.1 Nanozymes for Prooxidative Therapy 260
 - 12.4.1.1 Antibacterial Applications 260
 - 12.4.1.2 Anti-tumor Applications 260
 - 12.4.2 Nanozymes for Cytoprotection and Antioxidant Therapy 262
 - 12.4.2.1 Cytoprotection Applications 262
 - 12.4.2.2 Antioxidant Applications 262
 - 12.5 Challenges and Perspective 264
 - Acknowledgment 265
 - References 265

- 13 Photosynthesis and Photocatalytic Water Splitting 273**
Xiaoke Li, Rui Yang, Zhicheng Zhang
 - 13.1 Introduction 273
 - 13.2 Photosynthesis: A Natural Masterpiece 274
 - 13.3 Artificial Photocatalytic Water Splitting 275
 - 13.3.1 Photocatalysts 276
 - 13.4 Comparison of Natural and Artificial Systems 276
 - 13.4.1 Quantum Efficiency 276
 - 13.4.2 Mechanistic Differences 278
 - 13.4.3 Charge Separation and Recombination 279
 - 13.5 Potential Improvements in Artificial Systems 280
 - 13.5.1 Improved Photocatalysts 280
 - 13.5.2 Nanostructuring 281

- 13.5.3 Spatial Separation of HER and OER 284
- 13.6 Conclusion and Outlook 285
 - Acknowledgment 286
 - References 286

- 14 CO₂ Conversion 291
 - Ziru Wang, Peilei He
 - 14.1 Introduction: Basic Principles of Photocatalytic Reduction of CO₂ 291
 - 14.2 Nanostructures for Photocatalytic CO₂ Reduction 293
 - 14.2.1 Semiconductor Nanostructures 293
 - 14.2.2 Metal-organic Frameworks 295
 - 14.2.3 CO₂ Fixation Enzymes: Biomimetic Approaches 296
 - 14.3 Challenges and Perspectives 297
 - References 298

- 15 Artificial N₂ Fixation 303
 - Jinzheng Liu, Mingzhu Li, Mingliang Hu, Ruizhong Zhang, Xiyan Li, Zhicheng Zhang, Libing Zhang
 - 15.1 Introduction 303
 - 15.2 Electrocatalytic Nitrogen Fixation 306
 - 15.2.1 Precious Metal-based Materials for Electrocatalytic Nitrogen Fixation 309
 - 15.2.2 Non-precious Metal-based Materials for Electrocatalytic Nitrogen Fixation 312
 - 15.2.3 Nonmetallic Base Material for Electrocatalytic Nitrogen Fixation 314
 - 15.3 Photocatalytic Nitrogen Fixation 314
 - 15.3.1 Precious Metal-based Materials for Photocatalytic Nitrogen Fixation 317
 - 15.3.2 Non-noble Metal-based Materials for Photocatalytic Nitrogen Fixation 319
 - 15.3.3 Nonmetallic Base Material for Photocatalytic Nitrogen Fixation 321
 - 15.4 Conclusion and Outlook 321
 - Acknowledgment 321
 - References 322

- Index 329