

## Contents

### Preface *xi*

<b>1</b>	<b>Introduction for Biomimetic Superhydrophobic Materials</b>	<b>1</b>
1.1	Water Harvesting	2
1.2	Self-Cleaning	6
1.3	Corrosion Resistance	9
1.4	Photochromism	13
1.5	Robust and Durable Superhydrophobic Materials	15
1.6	Transparent and Conductive Superhydrophobic Film	16
1.7	Anti-fingerprint Superhydrophobic Film	18
1.8	Anti-icing Ability	18
1.9	Summary	20
	References	22
<b>2</b>	<b>Superhydrophobic Surfaces from Nature and Beyond Nature</b>	<b>25</b>
2.1	Superhydrophobic Plant Surfaces in Nature	26
2.1.1	Lotus Leaf	26
2.1.2	Salvinia	27
2.1.3	Petal	29
2.2	Superhydrophobic Surfaces of Animals in Nature	31
2.2.1	Springtail	31
2.2.2	Fish Scale	31
2.2.3	Shark Skin	33
2.2.4	Snail Shell	33
2.2.5	Mosquito Eyes	33
2.2.6	Clam's Shell	33
2.3	Chemical Composition of Plant and Animal Surfaces	34
2.4	Inspired and Beyond Superhydrophobicity: from Natural to Biomimetic Structures	38
2.4.1	Inspired by Natural Superhydrophobic Surfaces	38
2.4.2	Biomimetic Superhydrophobic Materials	40
2.4.2.1	Lotus-Leaf-Like Surface with Superhydrophobicity and Self-Cleaning	40
2.4.2.2	Salvinia-Like Surface with Superhydrophobicity and Air Retention	42
2.4.2.3	Petal-Like Surface with Superhydrophobicity and Special Adhesion	43

2.5	Summary	46
	References	47
<b>3</b>	<b>Advances in the Theory of Superhydrophobic Surfaces and Interfaces</b>	<b>59</b>
3.1	Basic Theories: Contact Angle and Young's Equation	60
3.2	Wenzel Model: Adaptability and Limitations	62
3.3	Cassie–Baxter Model: Adaptability and Limitations	64
3.4	Improved Models	66
3.4.1	Hierarchical Structure	66
3.4.2	Fractal Structure	68
3.4.3	Contact Angle Hysteresis	69
3.4.4	Generalized Models of Wenzel and Cassie–Baxter	72
3.5	Cassie–Wenzel and Wenzel–Cassie Transitions on Superhydrophobic Surfaces	74
3.5.1	The Influencing Factors of the Transitions	75
3.5.2	Cassie–Wenzel Transition	75
3.5.3	Wenzel–Cassie Transition	76
3.5.4	Analyzing Transitions from Thermodynamic and Kinetic Points of View	76
3.6	Summary	77
	References	77
<b>4</b>	<b>Fabrications of Noncoated Superhydrophobic Surfaces and Interfaces</b>	<b>85</b>
4.1	Etching Method	87
4.2	Lithography	89
4.3	Anodization	92
4.4	Laser Processing	93
4.5	Sol–Gel Process	95
4.6	Electrodeposition	97
4.7	Hydrothermal Method	101
4.8	Direct Reproduction	103
4.9	Other Fabrication Methods	104
4.10	Summary	105
	References	106
<b>5</b>	<b>Biomimetic Superhydrophobic Nanocoatings: From Materials to Fabrications and to Applications</b>	<b>117</b>
5.1	Materials for Nanocoatings	118
5.1.1	Inorganic Materials	118
5.1.2	Organic Materials	122
5.1.3	Inorganic–Organic Hybrid Materials	123
5.2	Fabrications of Superhydrophobic Nanocoatings	123
5.2.1	Sol–Gel Processes	123
5.2.2	Chemical Vapor Deposition	124
5.2.3	Spray Process	125

5.2.4	Electrospinning Process	126
5.2.5	Electrodeposition	126
5.2.6	Solution Immersion Process	127
5.2.7	Others Techniques	128
5.3	Biomimetic Transparent and Superhydrophobic Coating	128
5.3.1	The Two Competitive Characters: Transparency and Superhydrophobicity	129
5.3.2	Various Materials for Transparent and Superhydrophobic Surfaces	130
5.3.2.1	Inorganic Materials	130
5.3.2.2	Organic Material Polymers	138
5.3.2.3	Hybrid Materials	143
5.3.3	Potential Applications	144
5.4	Summary	146
	References	148
<b>6</b>	<b>Adhesion Behaviors on Superhydrophobic Surfaces and Interfaces</b>	<b>161</b>
6.1	Liquid–Solid Adhesion of Superhydrophobic Surfaces	162
6.1.1	Surfaces with Special Adhesion in Nature	162
6.1.2	Artificial Superhydrophobic Surfaces with Special Adhesion	164
6.1.3	Switchable Liquid–Solid Adhesions on Superhydrophobic Surfaces	167
6.1.3.1	By Controlling the Chemical Composition and Rough Structures	167
6.1.3.2	By Controlling the External Stimuli	168
6.2	The Adhesion Conversion from Liquid–Solid to Solid–Solid States	173
6.2.1	Mechanism of Ice Crystallization	174
6.2.2	Anti-adhesion Icing Properties of Superhydrophobic Surfaces	176
6.3	Solid–Solid Adhesion of Superhydrophobic Surfaces	179
6.3.1	Protein Adsorption on Superhydrophobic Surfaces	179
6.3.2	Cell Adhesion on Superhydrophobic Surfaces	181
6.3.3	Bacterial Adhesions on Superhydrophobic Surfaces	181
6.4	Summary	183
	References	184
<b>7</b>	<b>Smart Biomimetic Superhydrophobic Materials with Switchable Wettability</b>	<b>191</b>
7.1	Single-Response Smart Responsive Surfaces	192
7.1.1	pH-Responsive Wettable Materials	192
7.1.2	Photo-Induced Self-Cleaning Properties	194
7.1.3	Temperature-Responsive Wettable Materials	201
7.1.4	Ion-Responsive Wettable Materials	206
7.1.5	Other External Stimuli	207
7.2	Dual-Responsive and Multiple-Responsive Surfaces	214
7.3	Summary	217
	References	219

<b>8</b>	<b>Biomimetic Superhydrophobic Materials Applied for Oil/Water Separation (I)</b>	<b>229</b>
8.1	Metallic Mesh-Based Materials	230
8.2	Fabric-Based Materials	234
8.3	Sponge and Foam-Based Materials	236
8.4	Particles and Powdered Materials	240
8.5	Other Bulk Materials	241
8.6	Theories Underlying Oil/Water Separation Behavior	242
8.7	Summary	243
	References	243
<b>9</b>	<b>Biomimetic Superhydrophobic Materials Applied for Oil/Water Separation (II)</b>	<b>249</b>
9.1	The Formation of Oil/Water Emulsions	249
9.2	Modified Ceramic Separation Membranes	251
9.3	Polymer-Based Separation Membranes	253
9.3.1	In Situ Polymerization	253
9.3.2	Mussel-Inspired Deposition	254
9.3.3	Electrospinning Deposition	255
9.3.4	Phase-Inversion Process	255
9.4	Inorganic Carbon-Based Membranes	259
9.4.1	Carbon Nanotube- or Graphene-Based Membranes	259
9.4.2	Cellulose-Based Membranes	259
9.5	Non-Two-Dimensional Separating Methods	266
9.6	Summary	267
	References	268
<b>10</b>	<b>Biomimetic Superhydrophobic Materials Applied for Anti-icing/Frosting</b>	<b>273</b>
10.1	Introduction of Anti-icing/Frosting	273
10.2	Ice and Frost Formation Mechanism	275
10.2.1	Ice Formation Mechanism	277
10.2.1.1	Classical Ice Nucleation Theories	277
10.2.1.2	Modified Ice Nucleation Theories and Surface Conception	280
10.2.2	Frost Formation Mechanism	282
10.3	Natural Superhydrophobic and Icephobic Examples	284
10.3.1	Natural Superhydrophobic Examples	284
10.3.1.1	Mosquito's Eyes	284
10.3.1.2	Butterfly's Wings	296
10.3.2	Natural Icephobic Examples	298
10.3.2.1	Pitcher Plant	298
10.3.2.2	Skunk Cabbage	298
10.4	Anti-icing Performances of SHPSs under Various Situations	299
10.4.1	SHPSs Versus Deposited Water Droplets	299
10.4.1.1	Timely Droplet Rolling	299
10.4.1.2	Sessile Droplet Freezing Delay	303
10.4.2	SHPSs Versus Impact Water Droplets	307

10.4.2.1	Impact Resistance Improvement	307
10.4.2.2	Anti-icing SHPSs upon Impact Droplets	309
10.4.2.3	Contact Time Minimization	312
10.4.2.4	Oblique Impact Dynamics on Inclined SHPSs	313
10.4.3	SHPSs Versus Condensed Water Droplets	316
10.4.3.1	Wetting Transition of Condensed Microdroplets	316
10.4.3.2	Coalescence-Induced Jumping and Charging	317
10.4.3.3	Inter-droplet Ice Bridging and Edge-Initiation Effect	321
10.5	Design and Icing-Delay Performances of SLIPSs	324
10.5.1	SLIPSs Design	324
10.5.2	Droplet Impact and Condensation on SLIPSs	326
10.5.3	Anti-frosting Performance of SLIPSs	329
10.6	Icephobic Performances of SHPSs	331
10.7	Icephobic Performances of Advanced Surfaces and Techniques	336
10.7.1	Slippery Lubricant-Infused Porous Surfaces	336
10.7.2	Self-Lubricating Liquid Water Layers	337
10.7.3	Other Icephobic Strategies	340
10.8	Theories behind Anti-icing Research	343
10.8.1	Surface Wettability Theories and Models	343
10.8.2	Water and Ice Adhesion to Solid Surface	345
10.8.3	Droplet Impacting and Bouncing	346
10.8.4	Spontaneous Jumping Departure of Condensed Droplets	348
10.9	Summary	350
	References	352
11	<b>Conclusions and Outlook</b>	373
	<b>Index</b>	377