

Contents

List of contributors	xvii
Preface	xxi
CHAPTER 1 Nanoarchitectonics: a land of opportunities	1
<i>Omar Azzaroni and Katsuhiko Ariga</i>	
1.1 Bottom-up creation of functional materials and devices	1
References.....	7
CHAPTER 2 Nitrogen functionalities assisted nanoporous carbon materials for supercapacitor studies	13
<i>Ramakrishnan Prakash and Sangaraju Shanmugam</i>	
2.1 Introduction	13
2.2 Effect of morphology, pore structure, and heteroatoms functionalization on capacitive behavior	14
2.2.1 Controlled morphology influences capacitive behavior	14
2.2.2 Pore structure influences capacitive behavior.....	15
2.2.3 Heteroatoms functionalization on capacitive behavior	17
2.3 Electrolyte influence and its limitation on overall performance	18
2.3.1 Aqueous supercapacitors.....	19
2.3.2 Inorganic redox-active electrolyte supercapacitors system.....	19
2.3.3 Organic redox-active electrolyte supercapacitors system	20
2.3.4 Nonaqueous supercapacitors.....	22
2.4 Concluding remarks	24
References.....	24
CHAPTER 3 Membrane nanoarchitectonics: advanced nanoporous membranes for osmotic power generation	29
<i>Gregorio Laucirica, Yamili Toum Terrones, María Eugenia Toimil-Molares, Christina Trautmann, Waldemar A. Marmisolle and Omar Azzaroni</i>	
3.1 Introduction	29
3.2 Fundamental concepts	30
3.2.1 Reverse electrodialysis.....	30
3.2.2 Ion selectivity in nanoporous membranes	33
3.2.3 Membrane resistance	35
3.3 Fabrication of advanced reverse electrodialysis nanoporous membranes	36
3.3.1 Multichannel membranes	36
3.3.2 2D-based membranes	37
3.3.3 3D-based membranes	38

3.4	Recent advances in upscaled membranes.....	38
3.5	Current limitations and challenges	41
3.6	Conclusions	43
	References.....	44
CHAPTER 4 Biointerfacial nanoarchitectonics: layer-by-layer assembly as a versatile technique for the fabrication of highly functional nanocoatings of biological interest		47
<i>Miguel Ángel Pasquale and Omar Azzaroni</i>		
4.1	Introduction	47
4.2	The layer-by-layer technique	50
4.2.1	Building blocks and assembly procedures	50
4.2.2	Combination of the layer-by-layer assembly technique with other fabrication procedures	52
4.2.3	Structural characteristics of layer-by-layer multilayers	55
4.2.4	Effect of assembly conditions and postassembly treatment on the multilayer properties.....	57
4.3	Interactions of materials with living systems	61
4.3.1	Cell adhesion and its relation to proliferation, motility and differentiation.....	63
4.4	Selected examples of the application of the layer-by-layer technique in biosciences.....	64
4.4.1	Platforms for cell behavior modulation.....	64
4.4.2	Simple tunable multifunctional devices	70
4.4.3	Gradients in physicochemical properties.....	72
4.5	Cell encapsulation and cell modification by layer-by-layer technique	75
4.6	Conclusions	79
	References.....	80
CHAPTER 5 Charged porphyrins as building blocks of π-electronic ion-pairing assemblies		91
<i>Kazuhisa Yamasumi and Hiromitsu Maeda</i>		
5.1	Introduction	91
5.2	Porphyrins with charged substituents at the <i>meso</i> positions	93
5.2.1	Ion-pairing assemblies comprising zwitterionic porphyrins	93
5.2.2	Ion-pairing assemblies comprising oppositely charged porphyrin derivatives	94
5.3	Porphyrins charged at the porphyrin skeleton	95
5.3.1	Negatively charged porphyrins formed by deprotonation	97
5.3.2	Heteroatom-containing charged porphyrin analogs	98

5.3.3 Positively charged porphyrin metal complexes with valence mismatch	98
5.3.4 Negatively charged porphyrin metal complexes with valence mismatch	101
5.4 π -Electronic ion-pairing assemblies of charged porphyrins	102
5.4.1 Negatively charged porphyrins with π -electronic cations	102
5.4.2 Porphyrin Au ^{III} complexes with π -electronic receptor—Cl [−] complexes.....	103
5.4.3 Porphyrin Au ^{III} complexes with π -electronic anions.....	104
5.5 Summary and future perspective	110
References.....	110
CHAPTER 6 Layered structures in soft nanoarchitectonics: towards functional photonic materials	113
<i>Youfeng Yue</i>	
6.1 Introduction	113
6.2 Naturally existing layered structures	114
6.3 Fabrication of nanoarchitectonics with layered structures in soft materials	115
6.3.1 Self-assembly of amphiphilic molecules.....	116
6.3.2 Self-assembly of block copolymers.....	118
6.3.3 Cyclic deposition of two materials.....	120
6.3.4 Multilayer coextrusion	121
6.3.5 Holographic photopolymerization	121
6.4 Potential applications	121
6.4.1 Layered structures for chemical/physical sensing.....	122
6.4.2 Layered structures for anisotropic molecular diffusion	124
6.4.3 Layered structures used for light management purposes in devices	126
6.4.4 Layered structures used as soft templates for controllable synthesis.....	127
6.5 Excellent mechanical properties of nanoscale layered structures in soft materials	129
6.5.1 High fracture strength	129
6.5.2 Anisotropic mechanical properties	129
6.5.3 High crack resistance	130
6.6 Outlook and perspectives	132
Acknowledgments	132
References.....	132
CHAPTER 7 Metal Nanoarchitectonics: Fabrication of Sophisticated Gold Nanostructures for Functional Plasmonic Devices	137
<i>Hideyuki Mitomo and Kuniharu Ijiro</i>	
7.1 Introduction	137

7.2	Stimuli-responsive metal nanoparticles for configurable structures via assembly/disassembly.....	138
7.3	Nanoparticle assembly control with the aid of polymers as an additive.....	144
7.4	Precise active control of plasmonic nanostructures on polymer gels as a substrate.....	146
7.5	Active alignment control of gold nanorods with the aid of polymers brushes.....	150
7.6	Conclusion	154
	References.....	154

CHAPTER 8 Molecular Imprinting as Key Technology for Smart Nanoarchitectonics..... 161

Makoto Komiya

8.1	Introduction	161
8.2	Some technical details of molecular imprinting.....	162
8.2.1	Experimental procedures and chemicals employed for imprinting	162
8.2.2	Coverage of the surface of nanoarchitectures by MIP.....	163
8.3	Tactics to improve the guest-binding activity and selectivity of MIP	164
8.3.1	Post-imprinting modification to provide still more advanced functions.....	164
8.3.2	Cyclodextrins as functional monomers to memorize large-sized template by molecular imprinting.....	165
8.4	Examples of practical applications of MIP to nanoarchitectonics.....	166
8.4.1	Highly selective sensors.....	166
8.4.2	Biological Applications of MIP.....	168
8.4.3	Developments of highly selective catalysts through molecular imprinting.....	170
8.4.4	Adsorbents to recover uranium from seawater	171
8.5	Conclusions	172
	References.....	172
	Further Reading	174

CHAPTER 9 Self-assembled structures as emerging cellular scaffolds 175

Divya Gaur, Nidhi C. Dubey and Bijay P. Tripathi

9.1	Introduction	175
9.2	Self-assembled structures	175
9.2.1	Self-assembled vesicular structures	177
9.2.2	Coacervate droplets.....	183
9.2.3	Multicompartment self-assembled structures	184
9.3	Methods for the construction of self-assembled structures.....	185
9.3.1	Film rehydration method	185
9.3.2	Electroformation method	187

9.3.3 Solvent displacement techniques	187
9.3.4 Polymerization-induced self-assembly	189
9.4 Applications.....	189
9.4.1 Cell models and cell mimics	190
9.4.2 Intracellular delivery vehicles.....	193
9.4.3 Micro-/nanoreactors for catalytic cascades	194
9.5 Conclusion.....	194
References.....	195
CHAPTER 10 2D materials-based nanoarchitectonics for metal-ion batteries.....	207
<i>Maria K. Ramos and Aldo J.G. Zarbin</i>	
10.1 Introduction: novel materials for battery electrodes	207
10.1.1 Graphene	209
10.1.2 Molybdenum disulfide	210
10.1.3 Black phosphorus.....	211
10.1.4 Metallic nitrides and carbides (MXenes)	211
10.2 Nanoarchitected structures applied to metal-ion batteries	212
10.2.1 2D/2D nanoarchitected structures.....	212
10.2.2 2D/Oxides nanoarchitectonics	220
10.2.3 2D/Carbon nanotubes nanoarchitectonics	225
10.2.4 2D/conjugated polymer nanoarchitectonics	228
10.3 Conclusions	234
Acknowledgments	234
References.....	234
CHAPTER 11 Thin film nanoarchitectonics via Langmuir–Blodgett and layer-by-layer methods.....	241
<i>Katsuhiko Ariga</i>	
11.1 Introduction	241
11.2 Langmuir–Blodgett nanoarchitectonics	242
11.3 Layer-by-layer nanoarchitectonics.....	245
11.3.1 Layer-by-layer basics	245
11.3.2 Hierarchical layer-by-layer nanoarchitectonics with microfabrication.....	246
11.3.3 Hierarchical layer-by-layer nanoarchitectonics with artificial cell.....	247
11.3.4 Hierarchical layer-by-layer nanoarchitectonics with graphene and ionic liquid	248
11.3.5 Hierarchical layer-by-layer nanoarchitectonics with mesoporous carbon	250
11.3.6 Hierarchical layer-by-layer nanoarchitectonics, future	252
11.4 Short perspective	252
References.....	252

CHAPTER 12 Langmuir films—a universal method for fabricating organized monolayers from nanomaterials	255
<i>Michal Bodik and Peter Siffalovic</i>	
12.1 Introduction	255
12.2 History and present of Langmuir films	258
12.3 Experimental details.....	261
12.3.1 Suitable subphases	261
12.3.2 Suitable solvents	261
12.3.3 Experimental procedure for preparation of Langmuir films.....	263
12.3.4 Film deposition techniques	265
12.3.5 Experimental procedure for preparation of self-assembled Langmuir films.....	266
12.4 Applications.....	266
12.4.1 Plasmonics.....	266
12.4.2 Gas sensing	269
12.4.3 Electronics.....	271
12.4.4 Substrate patterning	272
12.4.5 Batteries.....	273
12.5 Summary.....	274
References.....	275
CHAPTER 13 MXenes and their applications in sensors	281
<i>Jun-Ge Liang and Lijia Pan</i>	
13.1 MXenes' properties	282
13.1.1 Chemical properties	282
13.1.2 Electric properties	283
13.1.3 Optical properties.....	284
13.1.4 Mechanical properties.....	285
13.1.5 Magnetic properties	286
13.1.6 Stability	286
13.2 MXenes synthesis.....	288
13.2.1 Hydrofluoric etching	288
13.2.2 Fluoride etching	289
13.2.3 Molten mixed fluoride	290
13.2.4 In situ electrochemical method.....	291
13.2.5 Acidic and alkaline etching	291
13.2.6 Electrochemical etching	293
13.2.7 Chemical vapor deposition	294
13.2.8 MXenes compounds preparation	294
13.2.9 MXenes 3D porous structure	296

13.3	MXenes and their applications in biosensors	297
13.3.1	The application prospect of MXene in biosensors.....	298
13.3.2	Application of MXene in electrochemical biosensors	303
13.3.3	Application of MXene in optical biosensors.....	307
13.4	MXenes and their applications in strain sensor.....	311
13.4.1	Detection principle of strain sensor based on MXene	311
13.4.2	The critical process and preparation method of MXene strain sensors	313
13.5	MXenes and their applications in pressure sensor	319
13.5.1	Pressure sensor based on Pure MXene.....	319
13.5.2	MXene pressure sensor based on flexible substrate.....	319
13.5.3	Flexible pressure sensor based on MXene composite aerogel	324
13.5.4	Flexible pressure sensor based on MXene composite film	325
13.5.5	Flexible pressure sensor based on MXene composite hydrogel.....	326
13.6	MXenes in gas sensors.....	327
13.6.1	MXene gas-sensitive mechanism.....	328
13.6.2	Gas-sensitive properties	330
13.6.3	Humidity sensitivity of MXene	341
	References.....	343
CHAPTER 14	Composite materials based on mesoporous oxides and noble metal nanoparticles	355
	<i>Ianina L. Violi, M. Cecilia Fuertes and Paula C. Angelomé</i>	
14.1	Introduction	355
14.1.1	Mesoporous oxides	355
14.1.2	Metallic nanoparticles	357
14.1.3	Combination of metallic nanoparticles and mesoporous oxides	359
14.2	Mesoporous oxides as support for metallic nanoparticles	360
14.2.1	Mesoporous oxides as simple supports	361
14.2.2	Mesopores as templates for nanoparticles formation.....	361
14.3	Mesoporous oxides as stabilizers for nanoparticles	363
14.3.1	Metallic nanoparticles inside the mesopores.....	366
14.3.2	Metallic nanoparticles covered with a mesoporous shell	367
14.4	Mesoporous oxides as hosts for functional molecules	367
14.5	Mesoporous oxides as active hosts	369
14.5.1	Mesoporous oxides as synthetic hosts.....	369
14.5.2	Synergy between the mesoporous oxide and the nanoparticles.....	371
14.6	Mesoporous oxides as filters.....	373
14.7	Conclusions and perspectives	375
	Acknowledgments	377
	References.....	377

CHAPTER 15 Nanoarchitectonics of Metal–Organic Frameworks (MOFs) for energy and sensing applications	387
<i>Melina Arcidiácono, Ana Paula Martíre, Juan A. Allegretto, Matías Rafti, Waldemar A. Marmisollé and Omar Azzaroni</i>	
15.1 Introduction	387
15.2 Common strategies for the integration of metal–organic frameworks into nanoarchitectonic objects.....	388
15.3 Nanoarchitectonics for the integration of metal–organic frameworks into electrochemical devices	389
15.3.1 Metal–organic frameworks in supercapacitors.....	389
15.3.2 Metal–organic frameworks in electrocatalysis.....	394
15.4 Nanoarchitectonics for the integration of metal–organic frameworks into electronic devices, nanoporous membranes, and photoresponsive materials	398
15.4.1 Metal–organic frameworks with tailored electronic properties and field effect transistors: sensing applications.....	398
15.4.2 Metal–organic frameworks and nanoporous membranes: separation and selective ionic transport	403
15.4.3 Photoresponsive metal–organic frameworks and applications in photonic crystals	409
15.5 Conclusions and outlook	415
References.....	417
CHAPTER 16 Ionic nanoarchitectonics for nanochannel-based biosensing devices	429
<i>Yamili Toum Terrones, Gregorio Laucirica, Vanina M. Cayón, M. Lorena Cortez, María Eugenia Toimil-Molares, Christina Trautmann, Waldemar A. Marmisollé and Omar Azzaroni</i>	
16.1 Introduction	429
16.2 Fundamental concepts in ion transport across nanopores and nanochannels for biosensing applications.....	430
16.2.1 What is a biosensor?	430
16.2.2 Ionic transport measurements and transduction mechanisms	431
16.3 Nanofabrication and functionalization techniques	435
16.3.1 Nanofabrication methods	435
16.3.2 Functionalization of solid-state nanochannels.....	437
16.4 Biosensors based on solid-state nanochannels	439
16.4.1 Proteins.....	439
16.4.2 Enzymes	440
16.4.3 Nucleic acids-related molecules	443
16.5 Conclusions	447

Acknowledgments	448
References.....	448
CHAPTER 17 Molecular, supramolecular, and macromolecular engineering at hybrid mesoporous interfaces: choose your own nanoarchitectonic adventure	453
<i>Cintia Belen Contreras, Galo J.A.A. Soler-Illia and Omar Azzaroni</i>	
17.1 Introduction—“soft chemistry” serving as a bridge toward nanoarchitected hybrid materials	453
17.2 Design of hybrid organic–inorganic materials synthesized via sol–gel chemistry	454
17.2.1 Synthetic pathways	454
17.2.2 Structural control	455
17.3 Integration of functional molecular assemblies and supramolecular machineries into/onto mesostructured oxide supports	466
17.4 Incorporation of macromolecular building blocks into mesoporous materials—Synthetic strategies toward functional hybrid polymer–inorganic mesostructures	472
17.4.1 Monomer impregnation/inclusion followed by polymerization	472
17.4.2 Functionalization of mesoporous materials with dendrimers and dendronized macromolecules.....	480
17.4.3 Molecular assembly of polymerizable structure-directing agents	483
17.4.4 Complex micelles as structure-directing, functionalizing, and pore-generating agents	484
17.4.5 Confined polymerization at “activated” mesoporous walls	484
17.4.6 Infiltration of polymers into mesoporous frameworks.....	489
17.4.7 Nanostructured polymer–inorganic hybrids via surface-initiated polymerization in mesoporous hosts	493
17.4.8 One-pot synthesis of functional polymer-mesoporous hybrids	504
17.5 Spatially-addressing macromolecular functional units on mesoporous supports—tailoring “inner” and “outer” chemistries in hybrid nanostructured assemblies.....	507
17.6 Conclusions	509
References.....	510
CHAPTER 18 Nanomaterials and catalysis	519
<i>Tanna E.R. Fiúza, Danielle S. Gonçalves, Tathiana M. Kokumai, Karen A. Resende, Priscila Destro and Daniela Zanchet</i>	
18.1 Overview: nanoscience and catalysis	519
18.2 Design of model catalytic systems	523
18.2.1 Colloidal synthesis of metallic and hybrid nanoparticles targeting catalytic applications	524

18.2.2	Nanooxides.....	532
18.3	Challenges and selected state-of-art characterization techniques for nanomaterials and heterogeneous catalysts	534
18.4	Probing the catalyst complexity: the AuCu system	542
18.5	Conclusions	548
	References.....	548
CHAPTER 19 Design of supramolecular chemosensor arrays and their applications to optical chips.....		561
<i>Yui Sasaki and Tsuyoshi Minami</i>		
19.1	Introduction	561
19.2	General introduction of chemosensors	563
19.2.1	General introduction of chemosensor arrays.....	563
19.2.2	Strategy of general chemosensor array designs	565
19.2.3	“Zero” synthetic supramolecular chemosensor arrays	568
19.3	Realization of chemosensor arrays for real sample analysis	573
19.3.1	Approaches to paper-based chemosensor arrays.....	573
19.3.2	Paper-based zero-synthetic supramolecular chemosensor arrays	576
19.4	Conclusion and perspective	581
	References.....	581
CHAPTER 20 3D graphene fabrication and application for energy storage systems.....		587
<i>Yuta Nishina and Rizwan Khan</i>		
20.1	Introduction	587
20.2	Fabrication of 3D graphene-based nanomaterials	588
20.2.1	Template-assisted method.....	589
20.2.2	Self-assembly or template-free chemical method.....	589
20.2.3	Electrochemical approaches	590
20.2.4	Freezing technique	591
20.2.5	Sugar blowing method	591
20.3	Applications for energy storage systems	593
20.3.1	Application of 3D graphene for supercapacitors	593
20.3.2	3D graphene for lithium ion batteries	598
20.4	Conclusion	602
	References.....	603
Index		611