

Contents

List of Contributors — IX

1	Carbon Nanomembranes — 1
1.1	Molecular Mechanisms of Electron-Induced Cross-Linking — 5
1.2	Tuning of CNM's Properties on a Molecular Level — 12
	Acknowledgments — 25
	References — 25
2	Controlled Functionalization of Graphene by Oxo-addends — 30
2.1	Introduction — 30
2.2	History of GO and Graphite Oxide — 31
2.3	Structure of GO — 32
2.3.1	Considerations about the Structure of GO — 33
2.4	Nomenclature of Functionalized Graphene — 34
2.5	Oxo-Functionalized Graphene — 34
2.5.1	Oxo-G ₁ from Graphite — 35
2.5.2	Oxo-G ₁ from Graphite Sulfate — 36
2.5.3	Organosulfate in Oxo-G ₁ and GO — 37
2.6	Raman Spectroscopy of Graphene, GO and Oxo-G ₁ — 38
2.6.1	Raman Spectra of Graphene — 39
2.6.2	Raman Spectra of Graphene with Defects — 40
2.6.3	Raman Spectra of GO, rGO, Oxo-G ₁ and Related Graphene — 40
2.6.4	SRS and Microscopy — 41
2.7	Conventional Chemistry of GO — 42
2.7.1	Non-Covalent and Covalent Approaches — 43
2.7.2	Considerations about Carbon–Carbon Bond Formation — 48
2.8	Controlled Oxo-Functionalization of Graphene — 50
2.8.1	Stability of GO — 50
2.8.2	Stability of Oxo-G ₁ — 53
2.8.3	Reduction of Oxo-G ₁ — 54
2.8.4	Synthetic Modification of Oxo-G ₁ — 56
2.9	Conclusions — 60
	References — 61
3	Chemical Synthesis of Cycloparaphenylenes — 67
3.1	Introduction — 67
3.2	Synthetic Efforts toward CPPs — 67
3.3	Synthetic Strategies toward CPPs — 70
3.4	Synthesis of [5]–[12] and [18]CPP by Bertozzi and Jasti — 71

3.5	Synthesis of [7]–[16]CPP by Itami —	74
3.5.1	Synthesis of [5]–[13] and [16]CPP by Yamago —	78
3.6	Synthesis of Armchair Carbon Nanorings —	82
3.6.1	Synthesis of Chiral and Zigzag Carbon Nanorings —	89
3.7	Synthesis of Heteroatom-Containing Carbon Nanorings —	91
3.8	Synthesis of Carbon Nanocages —	94
3.9	Summary —	98
	References —	98
4	Controlled Chemical Synthesis in CVD Graphene —	104
4.1	Introduction —	104
4.2	Layer Number Control —	106
4.2.1	Layer Number Control on Ni Substrate —	106
4.2.2	Bilayer Graphene and Stacking on Cu Substrate —	118
4.3	Large-Sized Single-Crystal Graphene on Cu Substrate —	123
4.3.1	Substrate —	123
4.3.2	Growth Parameters —	128
4.4	Direct Growth on Insulating Substrates —	131
4.5	Doping —	133
4.6	Conclusions and Perspectives —	134
	References —	136
5	Chemical Functionalization of Graphene Family Members —	146
5.1	Graphene —	146
5.1.1	Covalent Functionalization Reactions —	147
5.1.2	Non-covalent Functionalization Reactions —	153
5.2	Graphene oxide —	154
5.2.1	Covalent Functionalization Reactions —	155
5.2.2	Non-covalent Functionalization Reactions —	159
5.3	Reduced GO —	159
5.3.1	Covalent Functionalization —	160
5.3.2	Non-covalent Functionalization Reactions —	160
5.4	Characterization of Graphene Family Members —	161
5.4.1	UV-Visible Spectroscopy —	161
5.4.2	Fourier transform infrared Spectroscopy —	161
5.4.3	Atomic Force Microscopy —	162
5.4.4	Transmission Electron Microscopy —	163
5.4.5	Raman spectroscopy —	164
5.4.6	X-Ray Photoelectron Spectroscopy —	165
5.4.7	Thermogravimetric Analysis —	165
5.5	Conclusions —	166
	Acknowledgments —	167
	References —	167

6	Graphene via Molecule-Assisted Ultrasound-Induced Liquid-Phase Exfoliation: A Supramolecular Approach — 173
6.1	Introduction — 173
6.2	Ultrasound-Induced Liquid-Phase Exfoliation — 174
6.3	Molecule-Assisted UILPE — 177
6.3.1	Dispersions in Aqueous Solutions — 177
6.3.2	Graphene Dispersions in Organic Solvents — 183
6.4	Conclusion — 185
	Acknowledgments — 186
	References — 186
7	Solution Synthesis of Atomically Precise Graphene Nanoribbons — 194
7.1	Introduction — 194
7.2	Structure of Solution-Synthesized GNRs — 198
7.3	Synthetic Approaches Toward Atomically Precise GNRs — 201
7.3.1	Suzuki Coupling — 201
7.3.2	Yamamoto Coupling — 201
7.3.3	Diels–Alder Reaction — 203
7.3.4	Planarization of Synthesized Polymers — 204
7.3.5	Alternative Approaches — 205
7.4	Chemical Modification — 206
7.4.1	Nitrogen Doping — 207
7.4.2	Edge Chlorination — 209
7.5	Characterization Techniques for Solution-Synthesized GNRs — 209
7.6	Challenges in Solution-Based Synthesis of GNRs — 215
7.6.1	Solubility — 216
7.6.2	Isomerization — 217
7.7	Summary and Future Outlook — 219
	References — 220
8	Nanodiamonds for Biological Applications — 226
8.1	Introduction — 226
8.2	Biocompatibility of NDs — 226
8.2.1	In Vitro Biocompatibility Evaluation of NDs — 227
8.2.2	In Vivo Biocompatibility Evaluation of NDs — 228
8.3	Surface Coating for Improving ND Stability and Biocompatibility in Biological Environments — 229
8.3.1	Covalent Coating of NDs — 229
8.3.2	Non-covalent Coating of NDs — 231
8.3.3	Silica Coating — 233
8.4	Functionalization of NDs with Biomolecules — 234
8.4.1	Introduction of Proteins onto NDs — 234
8.4.2	Modification of DNA on NDs — 235

8.4.3	Self-Assembled NDs on Bionanostructures —	235
8.5	ND for Drug delivery —	237
8.5.1	Drug Delivery with Detonation ND Clusters —	237
8.5.2	Drug Delivery with Polymer-Modified NDs —	239
8.6	NDs for Imaging and Biosensing —	240
8.6.1	Fluorescence Imaging with NDs —	243
8.6.2	NDs as Nanoscale Magnetometer —	243
8.6.3	Magnetic Resonance Imaging with Hyperpolarized NDs —	246
8.7	Conclusions —	247
	Acknowledgments —	248
	References —	248
9	Polycyclic Hydrocarbons with an Open-Shell Ground State —	253
9.1	Introduction —	253
9.2	Quinodimethane-Based Open-Shell Polycyclic Hydrocarbons —	256
9.2.1	<i>o</i> -QDM-Embedded Diradicaloids —	256
9.2.2	<i>m</i> -Xylylene-Based Systems —	257
9.2.3	<i>p</i> -QDM-Embedded Systems and Its π -Extended Derivatives —	259
9.3	Open-Shell Anthenes and <i>Peri</i> -Fused Acenes —	265
9.3.1	Anthenes —	265
9.3.2	Periacenes —	267
9.4	Phenalenyl-Based Open-Shell PHs —	270
9.4.1	Phenalenyl-Based Monoradicals —	270
9.4.2	Phenalenyl-Based Diradicaloids —	275
9.5	Miscellaneous Open-Shell PHs —	281
9.6	Conclusion —	282
	Acknowledgments —	283
	References —	283
10	Synthesis and Use of Reactive Molecular Precursors for the Preparation of Carbon Nanomaterials —	289
10.1	Introduction —	289
10.2	Reactivity of Oligoynes —	291
10.3	Synthetic Approaches toward Oligoynes —	292
10.4	Carbonization of Non-Preorganized Oligoynes —	296
10.5	Topochemical Polymerization of Oligoynes —	299
10.6	Self-Assembly and Carbonization of Functionalized Oligoynes —	301
10.7	Conclusions and Outlook —	307
	Acknowledgments —	308
	References —	308