

Contents

| | |
|---|-------------|
| Preface | xiii |
| Part 1 Graphene, Carbon Nanotubes and Fullerenes | 1 |
| 1 Synthesis, Characterization and Functionalization of Carbon Nanotubes and Graphene: A Glimpse of Their Application | 3 |
| <i>Mahe Talat and O.N. Srivastava</i> | |
| 1.1 Introduction | 4 |
| 1.2 Synthesis and Characterization of Carbon Nanotubes | 5 |
| 1.3 Synthesis and Characterization of Graphene | 11 |
| 1.3.1 Micromechanical Cleavage of Highly Oriented Pyrolytic Graphite | 11 |
| 1.3.2 Chemical Vapor Deposition Growth of Graphene either as Stand Alone or on Substrate | 11 |
| 1.3.3 Chemical and Thermal Exfoliation of Graphite Oxide | 13 |
| 1.3.4 Arc-Discharge Method | 14 |
| 1.4 Methods Used in Our Lab: CVD, Thermal Exfoliation, Arc Discharge and Chemical Reduction | 14 |
| 1.4.1 Raman Spectra | 16 |
| 1.4.2 Electrochemical Exfoliation | 18 |
| 1.5 Functionalization of Carbon Nanotubes and Graphene | 19 |
| 1.5.1 Covalent Functionalization | 20 |
| 1.5.2 Non-Covalent Functionalization | 21 |
| 1.5.3 FTIR Analysis of CNTs and FCNTs | 23 |
| 1.6 Applications | 24 |
| 1.7 Conclusion | 29 |
| Acknowledgements | 29 |
| References | 30 |

| | | |
|----------|---|------------|
| 2 | Surface Modification of Graphene | 35 |
| | <i>Tapas Kuila, Priyabrata Banerjee and Naresh Chandra Murmu</i> | |
| 2.1 | Introduction | 36 |
| 2.2 | Surface-Modified Graphene from GO | 39 |
| 2.2.1 | Covalent Surface Modification | 39 |
| 2.2.2 | Non-covalent Surface Modification | 60 |
| 2.3 | Application of Surface-Modified Graphene | 70 |
| 2.3.1 | Polymer Composites | 71 |
| 2.3.2 | Sensors | 72 |
| 2.3.3 | Drug Delivery System | 73 |
| 2.3.4 | Lubricants | 73 |
| 2.3.5 | Nanofluids | 74 |
| 2.3.6 | Supercapacitor | 75 |
| 2.4 | Conclusions and Future Directions of Research | 75 |
| | Acknowledgement | 77 |
| | References | 77 |
| 3 | Graphene and Carbon Nanotube-based Electrochemical Biosensors for Environmental Monitoring | 87 |
| | <i>G. Alarcon-Angeles, G.A. Álvarez-Romero and A. Merkoçi</i> | |
| 3.1 | Introduction | 88 |
| 3.1.1 | Carbon Nanotubes (CNTs) | 88 |
| 3.1.2 | Graphene (GR) | 91 |
| 3.1.3 | Electrochemical Sensors | 93 |
| 3.1.4 | Sensors and Biosensors Based on CNT and GR | 94 |
| 3.2 | Applications of Electrochemical Biosensors | 97 |
| 3.2.1 | Heavy Metals | 97 |
| 3.2.2 | Phenols | 103 |
| 3.2.3 | Pesticides | 109 |
| 3.3 | Conclusions and Future Perspectives | 121 |
| | References | 121 |
| 4 | Catalytic Application of Carbon-based Nanostructured Materials on Hydrogen Sorption Behavior of Light Metal Hydrides | 129 |
| | <i>Rohit R Shahi and O.N. Srivastava</i> | |
| 4.1 | Introduction | 130 |
| 4.2 | Different Carbon Allotropes | 133 |

| | | |
|----------|---|------------|
| 4.3 | Carbon Nanomaterials as Catalyst for Different Storage Materials | 135 |
| 4.4 | Key Results with MgH_2 , $NaAlH_4$ and Li-Mg-N-H Systems | 137 |
| 4.4.1 | Magnesium Hydride | 137 |
| 4.4.2 | Sodium Alanate | 148 |
| 4.4.3 | Amides/Imides | 157 |
| 4.5 | Summary | 164 |
| | Acknowledgements | 165 |
| | References | 165 |
| 5 | Carbon Nanotubes and Their Applications | 173 |
| | <i>Mohan Raja and J. Subha</i> | |
| 5.1 | Introduction | 173 |
| 5.2 | Carbon Nanotubes Structure | 174 |
| 5.3 | Carbon Nanotube Physical Properties | 176 |
| 5.4 | Carbon Nanotube Synthesis and Processing | 177 |
| 5.5 | Carbon Nanotube Surface Modification | 178 |
| 5.6 | Applications of Carbon Nanotubes | 179 |
| 5.6.1 | Composite Materials | 179 |
| 5.6.2 | Nano Coatings – Antimicrobials and Microelectronics | 182 |
| 5.6.3 | Biosensors | 184 |
| 5.6.4 | Energy Storages | 185 |
| 5.7 | Conclusion | 187 |
| | References | 187 |
| 6 | Bioimpact of Carbon Nanomaterials | 193 |
| | <i>A. Djordjevic, R. Injac, D. Jovic, J. Mrdjanovic and M. Seke</i> | |
| 6.1 | Biologically Active Fullerene Derivatives | 194 |
| 6.1.1 | Introduction | 194 |
| 6.1.2 | Functionalization/Derivatization of Fullerene C_{60} | 196 |
| 6.1.3 | Biological Activity of Non-Derivatized Fullerene C_{60} | 196 |
| 6.1.4 | Biological Activity of Derivatized Fullerene C_{60} | 197 |
| 6.1.5 | Chemical Synthesis of Fullerenol $C_{60}(OH)_n$ | 201 |
| 6.1.6 | Fullerenol and Biosystems | 202 |

| | | |
|-----------------------------------|---|------------|
| 6.2 | Biologically Active Graphene Materials | 219 |
| 6.2.1 | Chemical Synthesis and Characterization of Important Biologically Active Graphene Materials | 219 |
| 6.2.2 | Biologically Active Graphene Materials | 222 |
| 6.3 | Bioimpact of Carbon Nanotubes | 230 |
| 6.3.1 | Introduction | 230 |
| 6.3.2 | Properties of CNTs | 231 |
| 6.3.3 | Classification of CNTs | 231 |
| 6.3.4 | Synthesis of CNTs | 231 |
| 6.3.5 | Functionalization of CNTs | 232 |
| 6.3.6 | Drug (Molecule/Gene/ Antibody) Delivery, Targeting, Drug Release | 232 |
| 6.3.7 | Toxicity | 236 |
| 6.3.8 | The Fate of CNTs | 237 |
| 6.4 | Genotoxicity of Carbon Nanomaterials | 238 |
| 6.4.1 | Genotoxicity of Graphene in <i>In Vitro</i> and <i>In Vivo</i> Models | 239 |
| 6.4.2 | Genotoxicity of SWNT and MWNT | 242 |
| 6.4.3 | Genotoxicity of Polyhydroxylated Fullerene Derivatives | 244 |
| 6.4.4 | Conclusion | 246 |
| 6.5 | Ecotoxicological Effects of Carbon Nanomaterials | 247 |
| | References | 251 |
| Part 2 Composite Materials | | 273 |
| 7 | Advanced Optical Materials Modified with Carbon Nano-Objects | 275 |
| | <i>Natalia V. Kamanina</i> | |
| 7.1 | Introduction | 275 |
| 7.2 | Photorefractive Features of the Organic Materials with Carbon Nanoparticles | 279 |
| 7.3 | Homeotropic Alignment of the Nematic Liquid Crystals Using Carbon Nanotubes | 297 |
| 7.4 | Thin Film Polarization Elements and Their Nanostructurization via CNTs | 303 |
| 7.5 | Spectral and Mechanical Properties of the Inorganic Materials via CNTs Application | 307 |

| | | |
|----------|--|------------|
| 7.6 | Conclusion | 310 |
| | Acknowledgments | 311 |
| | References | 312 |
| 8 | Covalent and Non-Covalent Functionalization of Carbon Nanotubes | 317 |
| | <i>Tawfik A. Saleh and Vinod K. Gupta</i> | |
| 8.1 | Introduction | 317 |
| 8.2 | Functionalization of Carbon Nanotubes | 318 |
| 8.3 | Covalent Functionalization | 318 |
| 8.4 | Non-Covalent Functionalization | 320 |
| 8.5 | Functionalization of CNT with Nanoparticles | 320 |
| | 8.5.1 Applications of the CNT-Based Nanocomposites | 324 |
| | 8.5.2 Nanocomposites as Photocatalysts | 324 |
| | 8.5.3 Nanocomposites as Adsorbents | 325 |
| 8.6 | Conclusion | 326 |
| | Acknowledgment | 327 |
| | References | 327 |
| 9 | Metal Matrix Nanocomposites Reinforced with Carbon Nanotubes | 331 |
| | <i>Praveennath G. Koppad, Vikas Kumar Singh, C.S. Ramesh, Ravikiran G. Koppad and K.T. Kashyap</i> | |
| 9.1 | Introduction | 332 |
| 9.2 | Carbon Nanotubes | 333 |
| 9.3 | Processing and Microstructural Characterization of Metal Matrix Nanocomposites | 338 |
| | 9.3.1 Powder Metallurgy | 339 |
| | 9.3.2 Electroless and Electrodeposition Techniques | 343 |
| | 9.3.3 Spray Forming | 346 |
| | 9.3.4 Liquid Metallurgy | 349 |
| | 9.3.5 Other Techniques | 350 |
| 9.4 | Mechanical Properties of Carbon Nanotube Reinforced Metal Matrix Nanocomposites | 353 |
| | 9.4.1 CNT/Al Nanocomposites | 353 |
| | 9.4.2 CNT/Cu Nanocomposites | 356 |
| | 9.4.3 CNT/Mg Nanocomposites | 359 |
| | 9.4.4 CNT/Ti Nanocomposites | 360 |

| | | |
|--|---|------------|
| 9.5 | Strengthening Mechanisms | 361 |
| 9.6 | Thermal Properties of Carbon Nanotube Reinforced Metal Matrix Nanocomposites | 363 |
| 9.7 | Tribological Properties of Carbon Nanotube Reinforced Metal Matrix Nanocomposites | 366 |
| 9.8 | Challenges | 368 |
| 9.9 | Concluding Remarks | 371 |
| | References | 371 |
| Part 3 Fly Ash Engineering and Cryogels | | 377 |
| 10 | Aluminum/Fly Ash Syntactic Foams: Synthesis, Microstructure and Properties | 379 |
| | <i>Dung D. Luong, Nikhil Gupta and Pradeep K. Rohatgi</i> | |
| 10.1 | Introduction | 380 |
| 10.2 | Hollow Particles | 382 |
| 10.2.1 | Fly Ash Cenospheres | 382 |
| 10.2.2 | Engineered Hollow Particles | 384 |
| 10.3 | Synthesis Methods | 388 |
| 10.3.1 | Stir Mixing | 388 |
| 10.3.2 | Infiltration Methods | 389 |
| 10.3.3 | Comparison of Synthesis Methods | 391 |
| 10.4 | Microstructure of Aluminum/Fly Ash Composites | 393 |
| 10.5 | Properties of Aluminum/Fly Ash Syntactic Foams | 398 |
| 10.6 | Applications | 409 |
| 10.7 | Conclusion | 411 |
| | Acknowledgments | 412 |
| | References | 412 |
| 11 | Engineering Behavior of Ash Fills | 419 |
| | <i>Ashutosh Trivedi</i> | |
| 11.1 | Background | 420 |
| 11.1.1 | Physico-Chemical Characterization | 420 |
| 11.1.2 | Engineering Characteristics | 421 |
| 11.2 | Engineering Evaluation of Cemented Ash Fill | 439 |
| 11.2.1 | Measurement of Cemented Ash Characteristics: Application of RQD | 439 |
| 11.2.2 | Concept of Strength Ratio and Modulus Ratio | 440 |

| | | |
|-----------|---|------------|
| 11.2.3 | Evaluation of Joint Parameters | 442 |
| 11.2.4 | Relationship of RQD and Joint Parameters | 443 |
| 11.2.5 | Steps to Obtain Deformations from the Present Technique | 444 |
| 11.3 | Problems of Uncemented Ash Fill | 446 |
| 11.3.1 | Collapse, Piping and Erosion, Liquefaction | 446 |
| 11.3.2 | Collapse Behavior of Ash Fills | 448 |
| 11.4 | Ash as a Structural Fill | 453 |
| 11.4.1 | Penetration Test | 454 |
| 11.4.2 | Load Test | 455 |
| 11.4.3 | Test Setup for Ash Fills and Testing Technique | 457 |
| 11.4.4 | Bearing Capacity of Ash Fill | 460 |
| 11.4.5 | Settlement of Ash Fills by PLT | 463 |
| 11.4.6 | Settlement on Ash Fills by PLT, CPT and SPT | 464 |
| 11.4.7 | Settlement of Footings on Ash Deposit | 466 |
| 11.5 | Conclusions | 470 |
| | Salutations, Acknowledgement and Disclaimer | 470 |
| | References | 471 |
| 12 | Carbon-Doped Cryogel Thin Films Derived from Resorcinol Formaldehyde | 475 |
| | <i>Z. Marković, D. Kleut, B. Babić, I. Holclajtner-Antunović, V. Pavlović and B. Todorović-Marković</i> | |
| 12.1 | Introduction | 476 |
| 12.2 | Experimental Procedure | 476 |
| 12.3 | Results and Discussion | 477 |
| 12.3.1 | FTIR Analysis | 477 |
| 12.3.2 | Raman Analysis | 478 |
| 12.3.3 | Surface Morphology of Carbon-Doped RF Cryogel Thin Films | 481 |
| 12.4 | Conclusion | 483 |
| | Acknowledgements | 484 |
| | References | 484 |
| | Index | 487 |