Contents

Preface *xi*

1 Introduction: Scope of the Book *1*
Anil Kumar Nallajarla and Anandarup Goswami
1.1 Introduction: Green Chemistry, Solvent-free Synthesis, and Nanocatalysts *1*
1.2 Topics Covered in this Book *5*
1.3 Solvent-Free Synthesis of Nanocatalysts *6*
1.4 Solvent and Catalyst-Free Organic Transformations *8*
1.5 Solvent-Free Reactions Using NCs *10*
1.5.1 Different Metal Oxides as a Catalyst/Support in Solvent-Free Reaction *12*
1.5.1.1 Titanium Oxide *12*
1.5.1.2 Tin Oxide *13*
1.5.1.3 Manganese Oxide (MnO_x) *14*
1.5.1.4 Zinc Oxide *14*
1.5.1.5 Aluminum Oxide *15*
1.5.1.6 Iron Oxide *15*
1.5.2 Silica-Based Materials as Catalysts/Supports in Solvent-Free Organic Reactions *15*
1.5.3 Carbon-Based Materials as Catalysts/Supports in Solvent-Free Organic Reactions *16*
1.5.4 Nitride-Based Materials as Catalysts/Supports in Solvent-Free Organic Reactions *17*
1.5.5 Ionic Liquid-Based Materials as Catalysts/Supports in Solvent-Free Organic Reactions *18*
1.6 Present Status and Future Direction *20*
References *22*

2 Strategies for the Preparation of Nanocatalysts and Supports Under Solvent-Free Conditions *31*
Rahul P. Gaikwad, Arun D. Kute, and Manoj B. Gawande
2.1 Introduction *31*

2.2 Mechanochemistry *32*
2.2.1 Ball Milling *33*
2.2.2 Mortar and Pestle *38*
2.3 Thermal Treatment *44*
2.3.1 Simple Thermal Treatment *44*
2.3.2 Thermal Decomposition *50*
2.3.3 Microwave Heating Energy *51*
2.4 Plasma-Assisted Methods *52*
2.4.1 Thermal Plasma Method *53*
2.4.2 Cold Thermal Plasma Method *56*
2.5 Deposition Method *59*
2.5.1 Atomic Layer Deposition (ALD) Method *59*
2.5.2 Chemical Vapor Deposition (CVD) Method *63*
2.6 Conclusion and Future Perspective *64*
Acknowledgments *65*
References *65*

3 Solvent- and Catalyst-Free Organic Transformation *69*
Fatemeh Majidi Arlan and Farzad Zamani
3.1 Introduction *69*
3.2 Solvent- and Catalyst-Free Organic Transformations *69*
3.2.1 Mechanochemistry *70*
3.2.2 Microwave Irradiation *80*
3.2.3 Classical Heating *91*
3.2.4 Ultrasound Irradiation *103*
3.3 Conclusion *109*
References *109*

4 Metal Oxides as Catalysts/Supports in Solvent-Free Organic Reactions *121*
Manishkumar S. Tiwari, Saravana Kumaran, and Haresh G. Manyar
4.1 Introduction *121*
4.2 Different Metal Oxides as a Catalyst/Support in Solvent-Free Reactions *123*
4.2.1 Titanium Dioxide-Based Catalysts *123*
4.2.2 Tin Oxide-Based Catalysts *127*
4.2.3 Manganese Oxide-Based Catalysts *132*
4.2.4 Zinc Oxide-Based Catalysts *135*
4.2.5 Aluminum Oxide-Based Catalysts *137*
4.2.6 Iron Oxide-Based Catalysts *142*
4.2.6.1 Fe_3O_4-Based Catalyst/Support *143*
4.2.6.2 Fe_2O_3-Based Catalyst/Support *148*
4.3 Conclusion *150*
References *150*

5 Silica-Based Materials as Catalysts or Supports in Solvent-Free Organic Reactions *163*
Gianvito Vilé and Christophe Len
5.1 Solvent-Free Reactions Over Silica Gel *163*
5.2 Silica Nanoparticles and its Applications *168*
5.3 Zeolites and Hierarchical Zeolite Structures *171*
5.4 Conclusion *175*
References *175*

6 Carbon-Based Materials as Catalysts/Supports in Solvent-Free Organic Reactions *181*
Nagy L. Torad, Ahmed A.M. El-Amir, Fathy M. Hassan, Amira A. El-Maddah, Wael A. Amer, and Mohamad M. Ayad
6.1 Introduction *181*
6.2 Solvent-Free Catalysis Using Carbon-Based Materials *182*
6.2.1 Activated Carbons (ACs) *183*
6.2.1.1 Acetylation Reactions *183*
6.2.1.2 Oxidation of Cyclohexane *184*
6.2.2 Carbon-Based Solid Acid (CBSA) Catalysts *185*
6.2.2.1 Cross-Aldol Condensation of Ketones with Aromatic Aldehydes *185*
6.2.2.2 Substituted Imidazoles *188*
6.2.2.3 Amidoalkyl Naphthols *188*
6.2.2.4 Reductive Amination of Aldehydes and Ketones *190*
6.2.2.5 Xanthenes and Dibenzoxanthenes *192*
6.2.2.6 Dihydropyrimidinone Compounds (Biginelli Reaction) *192*
6.2.2.7 Acylation, Acetalization, Thioacetalization of Aldehydes *194*
6.2.3 Carbon Nanotubes (CNTs) *195*
6.2.3.1 Esterification of Alcohols *195*
6.2.3.2 Benzyl Alcohol Oxidation *197*
6.2.3.3 Phenol Derivatives Antioxidants *199*
6.2.3.4 Acrylonitrile Derivatives *200*
6.2.4 Graphene Oxide (GO) *200*
6.2.4.1 Alkylaminophenols Derivatives *201*
6.2.4.2 N-Arylation Reactions *202*
6.2.4.3 Oxidation of Benzylic Alcohols *203*
6.2.4.4 Aldol and Konevenagel Condensation Reaction *204*
6.2.4.5 Oxidation of Cyclohexene *205*
6.2.4.6 Oxidation of Hydrazide and Pyrazole Derivatives *207*
6.2.5 Porous Carbon Materials *208*
6.2.5.1 Oxidation of Alcohol and Hydrocarbons *209*
6.2.5.2 Coupling of Amines *210*
6.3 Summary and Future Perspectives *213*
References *214*

7 Nitride-Based Nanostructures for Solvent-Free Catalysis *229*
Fatemeh Majidi Arlan, Ahmed A.M. El-Amir, Amira A. El-Maddah, Nagy L. Torad, and Esmail Doustkhah
7.1 Carbon Nitride *229*
7.1.1 Introduction *229*
7.1.2 Synthesis of Carbon Nitride *232*
7.1.3 Modification of Carbon Nitrides *232*
7.1.4 Solvent-Free Catalysis with Carbon Nitrides *234*
7.2 Boron Nitride *245*
7.2.1 Introduction *245*
7.2.2 Synthesis and Modification of Boron Nitride *246*
7.3 Molybdenum Nitride *247*
7.3.1 Introduction *247*
7.3.2 Synthesis of Molybdenum Nitride *247*
7.3.3 Solvent-Free Catalytic Application of Molybdenum Nitride *248*
7.4 Aluminum Nitride *249*
7.4.1 Introduction *249*
7.4.2 Synthesis of Aluminum Nitride *249*
7.4.2.1 Solvent-Free Synthesis *250*
7.4.3 Solvent-Free Application of Aluminum Nitride *250*
7.5 Conclusion *251*
References *251*

8 Supported Ionic Liquids for Solvent-Free Catalysis *261*
Vahid Khakyzadeh and Sahra Sheikhaleslami
8.1 Introduction *261*
8.2 Supported Ionic Liquids *263*
8.3 Building Blocks of SILs *264*
8.3.1 Ionic Segment *265*
8.3.2 Solid-Support Segment *265*
8.3.2.1 Silica Gels *267*
8.3.2.2 Ordered Mesoporous Silicas *267*
8.3.2.3 Carbon Nanotubes (CNTs) *268*
8.3.2.4 Silica-Coated Magnetic Nanoparticles (SMNPs) *269*
8.4 SIL Catalytic Systems *269*
8.5 Supported IL Solvent-Free Catalysis *272*
8.6 Solvent-Free Hydrogenation of Olefins *272*
8.7 Solvent-Free Heck Reaction *273*
8.8 Solvent-Free Multicomponent Reactions *275*
8.8.1 Synthesis of Pyran-Based Heterocycles *275*
8.8.2 Synthesis of 1,4-Dihydropyridine (Hantzsch Reaction) *279*
8.8.3 Synthesis of 3,4-Dihydropyrimidine-2(1*H*)-One/Thiones (Biginelli Reaction) *280*
8.8.4 Synthesis of 1-Amidoalkyl Naphthol *282*
8.8.5 Miscellaneous Solvent-Free Multicomponent Reactions *283*

8.9 Solvent-Free Condensation Reactions *285*
8.9.1 Solvent-Free Friedländer Condensation *285*
8.9.2 Solvent-Free Knoevenagel Condensation *286*
8.9.3 Esterification *286*
8.10 Solvent-Free CO_2 Conversion Reactions *287*
8.11 Solvent-Free Oxidation Reactions *290*
8.12 Miscellaneous Solvent-Free Organic Reactions *291*
8.13 Conclusion *296*
References *296*

9 Present Status and Future Outlook *305*
Elka Kraleva, Maria L. Saladino, and Izabela S. Pieta
9.1 Summary *305*
9.2 Future Outlook *322*
Acknowledgments *323*
References *323*

Index *329*