

Edited by Robert T. Mathers
and Michael A.R. Meier

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Green Polymerization Methods

Renewable Starting Materials, Catalysis
and Waste Reduction



Edited by Robert T. Matyjaszewski

R. Meier

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Reduction



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Contents

List of Contributors XIII

Part I Introduction 1

1 Why are Green Polymerization Methods Relevant to Society, Industry, and Academics? 3

Robert T. Mathers and Michael A. R. Meier

1.1 Status and Outlook for Environmentally Benign Processes 3

1.2 Importance of Catalysis 4

1.3 Brief Summaries of Contributions 5

References 6

Part II Integration of Renewable Starting Materials 9

2 Plant Oils as Renewable Feedstock for Polymer Science 11

Michael A. R. Meier

2.1 Introduction 11

2.2 Cross-Linked Materials 12

2.3 Non-Cross-Linked Polymers 15

2.3.1 Monomer Synthesis 15

2.3.2 Polymer Synthesis 18

2.4 Conclusion 24

References 25

3 Furans as Offsprings of Sugars and Polysaccharides and Progenitors of an Emblematic Family of Polymer Siblings 29

Alessandro Gandini

3.1 Introduction 29

3.2 First Generation Furans and their Conversion into Monomers 30

3.2.1 Furfural and Derivatives 30

3.2.2 Monomers from Furfural 31

3.2.3 Hydroxymethylfurfural 35

3.3	Polymers from Furfuryl Alcohol	35
3.4	Conjugated Polymers and Oligomers	39
3.5	Polyesters	41
3.6	Polyamides	42
3.7	Polyurethanes	43
3.8	Furyl Oxirane	45
3.9	Application of the Diels–Alder Reaction to Furan Polymers	45
3.9.1	Linear Polymerizations	46
3.9.2	Non-Linear Polymerizations	49
3.9.3	Reversible Polymer Cross-Linking	52
3.9.4	Miscellaneous Systems	52
3.10	Conclusions	53
	References	53
4	Selective Conversion of Glycerol into Functional Monomers via Catalytic Processes	57
	<i>François Jérôme and Joël Barrault</i>	
4.1	Introduction	57
4.2	Conversion of Glycerol into Glycerol Carbonate	58
4.3	Conversion of Glycerol into Acrolein/Acrylic Acid	62
4.4	Conversion of Glycerol into Glycidol	63
4.5	Oxidation of Glycerol to Functional Carboxylic Acid	65
4.5.1	Catalytic Oxidation of Glycerol to Glyceric Acid	65
4.5.2	Oxidative-Assisted Polymerization of Glycerol	68
4.5.2.1	Cationic Polymerization	68
4.5.2.2	Anionic Polymerization	69
4.6	Conversion of Glycerol into Acrylonitrile	71
4.7	Selective Conversion of Glycerol into Propylene Glycol	72
4.7.1	Conversion of Glycerol into Propylene Glycol	72
4.7.1.1	Reaction in the Liquid Phase	73
4.7.1.2	Reaction in the Gas Phase	75
4.7.2	Conversion of Glycerol into 1,3-Propanediol	76
4.8	Selective Coupling of Glycerol with Functional Monomers	78
4.9	Conclusion	84
	References	84

Part III Sustainable Reaction Conditions 89

5	Monoterpenes as Polymerization Solvents and Monomers in Polymer Chemistry	91
	<i>Robert T. Mathers and Stewart P. Lewis</i>	
5.1	Introduction	91
5.2	Monoterpenes as Monomers	92
5.2.1	Terpenic Resins Overview	92
5.2.2	Concepts of Cationic Olefin Polymerization	93

5.2.3	Cationic Polymerization of β -Pinene	98
5.2.4	Cationic Polymerization of Dipentene	104
5.2.5	Cationic Polymerization of α -Pinene	106
5.2.6	Characteristics of Terpenic Resins	112
5.2.7	Applications of Terpenic Resins	113
5.2.8	Commercial Production and Markets of Terpenic Resins	113
5.2.9	Environmental Aspects of Terpenic Resin Production	115
5.3	Monoterpenes as Solvents and Chain Transfer Agents	116
5.3.1	Possibilities for Replacing Petroleum Solvents	116
5.3.2	Ring-Opening Polymerizations in Monoterpenes	117
5.3.3	Metallocene Polymerizations in Monoterpenes	121
5.4	Conclusion	124
	Acknowledgments	124
	References	125
6	Controlled and Living Polymerization in Water: Modern Methods and Application to Bio-Synthetic Hybrid Materials	129
	<i>Debasis Samanta, Katrina Kratz, and Todd Emrick</i>	
6.1	Introduction	129
6.2	Ring-Opening Metathesis Polymerization (ROMP)	130
6.2.1	Water Soluble ROMP Catalysts	133
6.3	Living Free Radical Methods for Bio-Synthetic Hybrid Materials	136
	Acknowledgments	141
	References	141
7	Towards Sustainable Solution Polymerization: Biodiesel as a Polymerization Solvent	143
	<i>Marc A. Dubé and Somaieh Salehpour</i>	
7.1	Introduction	143
7.2	Solution Polymerization and Green Solvents	144
7.3	Biodiesel as a Polymerization Solvent	144
7.4	Experimental Section	146
7.4.1	Materials	146
7.4.2	Polymerization	147
7.4.3	Characterization	148
7.5	Effect of FAME Solvent on Polymerization Kinetics	148
7.5.1	Chain Transfer to Solvent Constant	149
7.5.2	Rate Constant	151
7.6	Effect of Biodiesel Feedstock	155
7.6.1	Polymerization Kinetics	157
7.6.2	Polymer Composition	158
7.7	Conclusion	160
	References	160

Part IV Catalytic Processes 163

- 8 Ring-Opening Polymerization of Renewable Six-Membered Cyclic Carbonates. Monomer Synthesis and Catalysis 165**
Donald J. Darensbourg, Adriana I. Moncada, and Stephanie J. Wilson
- 8.1 Introduction 165
- 8.2 Preparation of 1,3-Propanediol from Renewable Resources 166
- 8.3 Preparation of Dimethylcarbonate from Renewable Resources 169
- 8.4 Synthesis of Trimethylene Carbonate 171
- 8.5 Six-Membered Cyclic Carbonates: Thermodynamic Properties of Ring-Opening Polymerization 171
- 8.6 Catalytic Processes Using Green Catalysts Methods 172
- 8.6.1 Cationic Ring-Opening Polymerization 173
- 8.6.2 Anionic Ring-Opening Polymerization 176
- 8.6.3 Enzymatic Ring-Opening Polymerization 178
- 8.6.4 Coordination–Insertion Ring-Opening Polymerization 181
- 8.6.4.1 Groups 13- and 14 Based Catalysts 182
- 8.6.4.2 Groups 4–12 Based Catalysts 186
- 8.6.4.3 Lanthanide-Based Catalysts 190
- 8.6.4.4 Groups 1 and 2 Based Catalysts 191
- 8.6.5 Organocatalytic Ring-Opening Polymerization 193
- 8.7 Thermoplastic Elastomers and their Biodegradation Processes 194
- 8.8 Concluding Remarks 197
- Acknowledgments 197
- References 197
- 9 Poly(lactide)s as Robust Renewable Materials 201**
Jan M. Becker and Andrew P. Dove
- 9.1 Introduction 201
- 9.1.1 The Lactide Cycle 202
- 9.2 Ring-Opening Polymerization of Lactide 204
- 9.2.1 Coordination–Insertion Polymerization 205
- 9.2.2 Organocatalytic Ring-Opening Polymerization 208
- 9.3 Poly(lactide) Properties 210
- 9.3.1 PLA Properties and Processing Effects 211
- 9.3.2 Polymer Blends 213
- 9.3.2.1 Poly(Lactide)/Poly(ϵ -Caprolactone) Blends 213
- 9.3.2.2 Other Biodegradable/Renewable Polyesters 214
- 9.4 Thermoplastic Elastomers 214
- 9.5 Future Developments/Outlook 216
- References 216

10	Synthesis of Saccharide-Derived Functional Polymers	221
	<i>Julian Thimm and Joachim Thiem</i>	
10.1	Introduction	221
10.2	Polyethers	223
10.3	Polyamides	226
10.4	Polyurethanes and Polyureas	229
10.5	Glycosilicones	230
	References	234
11	Degradable and Biodegradable Polymers by Controlled/Living Radical Polymerization: From Synthesis to Application	235
	<i>Nicolay V. Tsarevsky</i>	
11.1	Introduction	235
11.2	(Bio)degradable Polymers by CRP	238
11.2.1	Linear (Bio)degradable Polymers	239
11.2.1.1	Polymers with a Degradable Functional Group	239
11.2.1.2	Polymers with a Degradable Polymeric Segment	242
11.2.1.3	Polymers with Multiple Cleavable Groups or Polymeric Segments	243
11.2.2	Degradable Star Polymers	244
11.2.3	Degradable Graft Polymers (Polymer Brushes)	245
11.2.4	Hyperbranched Degradable Polymers	250
11.2.5	Cross-Linked Degradable Polymers	252
11.3	Conclusions	254
	Abbreviations	254
	References	255
	Part V Biomimetic Methods and Biocatalysis	263
12	High-Performance Polymers from Phenolic Biomonomers	265
	<i>Tatsuo Kaneko</i>	
12.1	Introduction	265
12.2	Coumarates as Phytomonomers	266
12.3	LC Properties of Homopolymers	267
12.3.1	Syntheses and Structures	267
12.3.2	Solubility	268
12.3.3	Thermotropic Property	269
12.3.4	Ordered Structures	270
12.3.5	Cell Compatibility	273
12.4	LC Copolymers for Biomaterials	274
12.4.1	Lithocholic Acid as Co-monomer	274
12.4.2	Cholic Acid as Co-monomer	276
12.5	LC Copolymers for Photofunctional Polymers	279
12.5.1	Syntheses of P(4HCA-co-DHCA)s	279
12.5.2	Phototunable Hydrolyzes	279

12.5.3	Photoreaction of Nanoparticles	282
12.6	LC Copolymers for High Heat-Resistant Polymers	282
12.6.1	P(4HCA-co-DHCA) Bioplastics	282
12.6.2	Biohybrids	286
12.7	Conclusion	288
	Acknowledgments	289
	References	289
13	Enzymatic Polymer Synthesis in Green Chemistry	291
	<i>Andreas Heise and Inge van der Meulen</i>	
13.1	Introduction	291
13.2	Polymers	292
13.2.1	Polycondensates	292
13.2.1.1	Polyesters by Ring-Opening Polymerization	293
13.2.1.2	Polyesters by Condensation Polymerization	296
13.2.2	Polyphenols	298
13.2.3	Vinyl Polymers	300
13.2.4	Polyanilines	301
13.3	Green Media for Enzymatic Polymerization	303
13.3.1	Ionic Liquids	303
13.3.2	Supercritical Carbon Dioxide	304
13.4	Conclusions and Outlook	306
	References	307
14	Green Cationic Polymerizations and Polymer Functionalization for Biotechnology	313
	<i>Judit E. Puskas, Chengching K. Chiang, and Mustafa Y. Sen</i>	
14.1	Introduction	313
14.2	Enzyme Catalysis	313
14.2.1	Lipases	315
14.2.2	<i>Candida antarctica</i> Lipase B	321
14.2.3	CALB-Catalyzed Transesterification Reactions	323
14.3	“Green” Cationic Polymerizations and Polymer Functionalization Using Lipases	325
14.3.1	Ring-Opening Polymerization	325
14.3.2	Enzyme-Catalyzed Polymer Functionalization	328
14.4	Natural Rubber Biosynthesis – the Ultimate Green Cationic Polymerization	330
14.4.1	Anatomy of the NR Latex, and Structure of Natural Rubber	331
14.4.1.1	Structure of Natural Rubber	332
14.4.2	Biochemical Pathway of NR Biosynthesis	333
14.4.2.1	Monomer	333
14.4.2.2	Initiators	334
14.4.2.3	Catalyst: Rubber Transferase	335
14.4.3	Chemical Mechanism of Natural Rubber Biosynthesis	337

14.4.4	<i>In vitro</i> NR Biosynthesis	339
14.5	Green Synthetic Cationic Polymerization and Copolymerization of Isoprene	341
	Acknowledgments	342
	References	342
	Index	349

Part I

Introduction

1

Why are Green Polymerization Methods Relevant to Society, Industry, and Academics?

Robert T. Mathers and Michael A. R. Meier

1.1

Status and Outlook for Environmentally Benign Processes

In June 1992, the “Rio Declaration on Environment and Development” (*Rio declaration*) of the United Nations Conference on Environment and Development (UNCED) announced in Principle 1 [1] that human beings are at the center of concerns for sustainable development and that they are entitled to a healthy and productive life in harmony with nature. Since the Rio declaration, the necessity for *sustainable development* has become obvious [2]. Most frequently, sustainable development is defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs [3]. Much has happened since then and the principles of *green chemistry* [4] are now known and applied by chemists worldwide. Recently, Paul T. Anastas stated in his keynote speech at the 2010 ACS (American Chemical Society) national meeting in San Francisco: “Building a sustainable world is the most taxing intellectual exercise we have ever engaged in. It is also the most important for the future of our world” [5]. Thus, great challenges remain and in the field of green chemistry there are plenty of possibilities in the future for innovation and environmentally friendlier consumer products.

As the use of polymers is becoming increasingly more common for many applications in modern society, *polymer science* is able to make diverse contributions to the rapidly growing field of green chemistry. In particular, polymer science offers manifold possibilities for the sustainable use of renewable raw materials. Even though utilizing renewable resources to meet current needs without creating adverse health or environmental impacts can be challenging, renewable resources offer potentially less toxic products as these resources can be expected to be biodegradable and, more importantly, biocompatible. However, we are fully aware that this is a generalization and a careful case by case evaluation is absolutely necessary! Moreover, nature offers a great synthetic potential to the polymer chemist, and it is up to us to develop new methods to incorporate renewable resources into polymeric materials. This development has to begin now in order to be ready to apply these methods industrially in a few decades, as fossil reserves continue to

deplete and become more expensive. Equally important, we need more sustainable routes toward known polymeric products in order to avoid waste, contamination, high energy consumption, and many other environmental concerns. In the United States, the *National Research Council*, in its report entitled “Sustainability in the Chemical Industry: Grand Challenges and Research Needs,” has advocated that all areas of the chemical industry focus on long-term strategies to minimize toxicity and environmental impact while creating sustainable processes [6].

Therefore, we are certain that this edited volume will assist in *training a future generation* of scientists and engineers to consider green chemistry and sustainability within the field of polymer science as the most beneficial long-term strategy. Because these peer-reviewed chapters come from departments of polymer science, chemical engineering, chemistry, and materials science, we anticipate that this volume will build upon previous polymer science [7, 8] and green chemistry [9] books to provide a *state-of-the-art resource for industry and academia*. Moreover, this variety clearly reflects the need for collaboration between these (and other) disciplines to reach our final goal of *sustainability*. Specifically, new catalytic and biomimetic methods, alternative reaction media, and the utilization of renewable resources are described in this edited volume. Additionally, these discussions cover emerging areas in condensation, controlled free radical, anionic, cationic, and metathesis polymerizations. Based on the excellent contributions in this volume, which originate from a number of science and engineering venues, we can only assume that the idea of a *green polymerization method* will continue to be an important part of polymer science for many years.

1.2

Importance of Catalysis

In 1836, Berzelius described his newly coined concept of “*catalysis*” and “*catalytic power*” in an article for *The Edinburgh New Philosophical Journal* entitled “Considerations respecting a New Power which acts in the Formation of Organic Bodies”. He described these new idioms as “a power, which is capable of effecting chemical reactions in unorganized substances, as well as organized bodies” [10]. Years later, Karl Zeigler and Giudio Natta received the 1963 Nobel Prize for catalysis research related to polyolefins. More recently, Nobel prizes have been awarded for asymmetric catalysis (2001) and olefin metathesis catalysts (2005).

At the present time, refined ideas regarding catalysis have become very common in science and engineering disciplines, as evidenced by the large number of journal articles devoted to this subject each year. From an industrial standpoint, catalysts have played an integral role in the manufacture of chemical raw materials [11], polyolefins [12], and many other polymeric materials. To gain a perspective on the importance of catalysis in *green polymer chemistry*, it is helpful to mention that during the formulation of the principles of green chemistry [4], catalysis was described as a foundational pillar [13]. Since that time, major advances in organocatalysis and biocatalysis have continued to emerge as complementary methods to traditional