

Contents

	Preface	<i>xi</i>
	Editor Biography	<i>xiii</i>
1	Introduction to Polymer Crystallization	1
	<i>N.M. Nurazzi, M.N.F. Norrrahim, S.S. Shazleen, M.M. Harussani, F.A. Sabaruddin, and M.R.M. Asyraf</i>	
1.1	Introduction	1
1.2	Degree of Crystallinity	3
1.3	Thermodynamics on the Crystallization of Polymers Characteristics	4
1.4	Polymer Crystallization Mechanism	5
1.4.1	Strain-Induced Crystallization of Polymer	5
1.4.2	Crystallization of Polymer from Solution	7
1.5	Applications of Crystalline Polymer	8
	References	10
2	Characterization of Polymer Crystallization by Using Thermal Analysis	13
	<i>Kai Yang, Xiuling Zhang, Mohanapriya Venkataraman, Jakub Wiener, and Jiri Militky</i>	
2.1	Introduction	13
2.2	Basic Principle	14
2.2.1	General Idea	14
2.2.2	Application of DSC Method	15
2.3	Characterization of Polymer Crystallization According to Isothermal Crystallization Process	16
2.3.1	Performance of Isothermal Crystallization Process	16
2.3.2	Analysis of Isothermal Crystallization Process	16
2.3.2.1	Crystal Geometry	17
2.3.2.2	Characterization of Crystallization Rate	18
2.3.2.3	Characterization of Crystallization Activation Energy	18
2.3.3	Isothermal Crystallization of Some Polymer Composites	19
2.4	Characterization of Polymer Non-isothermal Crystallization Process	20
2.4.1	Basics of Nonlinear Crystallization Modeling	20

2.4.2	Performance of Non-isothermal Crystallization Process	20
2.4.3	Analysis of Crystal Geometry During Non-isothermal Crystallization Process	21
2.4.3.1	Jeziorny-Modified Avrami Equation	21
2.4.3.2	Ozawa Model	21
2.4.3.3	Mo model	25
2.4.4	Determination of Crystallization Activation Energy (E)	26
2.4.5	Analysis of Relative Crystallinity	27
2.5	Conclusion	27
	Acknowledgment	28
	Abbreviations	28
	References	28

3 Crystallization Behavior of Polypropylene and Its Blends and Composites 33

Daniela Mileva, Davide Tranchida, Enrico Carmeli, Dietrich Gloger, and Markus Gahleitner

3.1	Introduction – Polypropylene Crystallinity in Perspective	33
3.2	Chain Structure and Molecular Weight Effects for iPP Crystallinity and Polymorphism	37
3.3	Nucleation of iPP	42
3.4	Crystallization in Multiphase Copolymers, Blends, and Composites	47
3.5	Processing Effects and Resulting Properties	54
3.6	Investigation Methods for PP Crystallization and Morphology	60
	Acknowledgments	64
	References	65

4 Crystallization of PE and PE-Based Blends, and Composites 87

Amirhosein Sarafpour, Gholamreza Pircheraghi, Farzad Gholami, Rouhollah Shami-Zadeh, and Farzad Jani

4.1	An Introduction to Polyethylene, Its Crystallization, and Kinetics	87
4.1.1	Basics of Structure and Morphology	87
4.1.2	Theory of Crystallization and Its Kinetics	92
4.2	Experimental Study on Crystallization Kinetics of Polyethylene	93
4.2.1	Isothermal Crystallization	93
4.2.2	Non-isothermal Crystallization	96
4.3	Nucleation Theory	99
4.4	Crystal Growth	100
4.5	PE Blends and Co-crystallization	103
4.6	PE Nanocomposites	109
4.7	Summary	112
	References	112

5	Crystallization of PLA and Its Blends and Composites	121
	<i>Jesús M. Quiroz-Castillo, Ana D. Cabrera-González, Luis A. Val-Félix, and Tomás J. Madera-Santana</i>	
5.1	Introduction	121
5.2	Crystallization of Macromolecules	123
5.2.1	Improvement of PLA Crystallization Kinetics	126
5.3	Poly(lactic Acid) Nucleation	130
5.3.1	Inorganic Nucleating Agents	130
5.3.2	Organic Nucleating Agents	133
5.4	Poly(lactic Acid) Blends	136
5.4.1	Poly(lactic Acid) Binary Blends with Biopolymers–Starch and PHAs	136
5.4.2	Poly(lactic Acid) Binary Blends with Biodegradable Polymers – PCL, PBAT, and PBS	138
5.5	Poly(lactic Acid) Composites	139
5.5.1	Poly(lactic Acid) – Natural Fiber Composites	139
5.5.2	Poly(lactic Acid) – Nanocomposites	140
5.6	Conclusions	143
	References	144
6	Crystallization in PLLA-Based Blends, and Composites	161
	<i>Pratick Samanta and Bhanu Nandan</i>	
6.1	Introduction	161
6.2	Chemical and Crystal Structure of PLLA	162
6.3	PLLA Properties: Glass Transition and Melting Temperature	162
6.3.1	Glass Transition Temperature	162
6.3.2	Melting Temperature	163
6.4	PLLA Crystallization	163
6.4.1	PLLA Crystallization Study Through Spherulite Growth	163
6.4.2	Lauritzen and Hoffman Theory in PLLA Crystallization	164
6.4.3	Crystallization Kinetics Through Calorimetry Study	166
6.5	Crystallization of PLLA in Blends	168
6.6	Crystallization of PLLA in Nanocomposites	172
6.7	Crystallization of PLLA in Block Copolymer	175
6.8	Crystallization of PLLA After Adding Nucleating Agents	178
6.9	PLLA Plasticization	182
6.10	Conclusion and Future Outlook	182
	References	183
7	Crystallization in PCL-Based Blends and Composites	195
	<i>Madhushree Hegde, Akshatha Chandrashekar, Mouna Nataraja, Jineesh A. Gopi, Niranjana Prabhu, and Jyotishkumar Parameswaranpillai</i>	
7.1	Introduction	195

- 7.2 Crystallinity of PCL and the Factors Affecting Crystallinity 195
- 7.3 Crystalline Behavior of PCL-Based Multiphase Polymer Systems 199
 - 7.3.1 Crystallization Behavior of Blends of PCL 199
 - 7.3.2 Crystallization Behavior of Block Copolymers of PCL 202
 - 7.3.3 Effect of Fillers on the Crystalline Behavior of PCL 203
- 7.4 Conclusion 207
- References 208

8 Crystallization and Shape Memory Effect 215

Shiji Mathew

- 8.1 Introduction 215
- 8.2 Shape Memory Cycle 216
- 8.3 Mechanism of Shape Memory Effect 217
- 8.4 Types of Shape Memory Polymers 218
- 8.5 Biomedical Applications of Shape Memory Polymers 218
 - 8.5.1 Tissue Engineering 218
 - 8.5.2 Bone Engineering 220
 - 8.5.3 Medical Stents 221
 - 8.5.4 Drug Delivery Application 222
 - 8.5.5 SMPs as Self-Healing Materials 222
 - 8.5.6 Vascular Embolization 226
- 8.6 Conclusion 227
- References 227

9 3D Printing of Crystalline Polymers 233

Hiriyalu S. Ashrith, Tamalapura P. Jeevan, and Hanume Gowda V. Divya

- 9.1 Introduction 233
- 9.2 3D Printing Materials and Processes 234
 - 9.2.1 Nylon and Polyamides 234
 - 9.2.2 Polyethylene 238
 - 9.2.3 Polyethylene Terephthalate 240
 - 9.2.4 Polypropylene 241
 - 9.2.5 Polylactic Acid 243
- 9.3 Characterization of 3D-Printed Crystalline Polymers 244
 - 9.3.1 Mechanical Properties/Mechanical Characteristics 244
 - 9.3.2 Thermal Properties/Thermal Characteristics 246
 - 9.3.3 Tribological Properties/Tribological Characteristics 247
- 9.4 Conclusion 248
- References 250

10 Crystallization from Anisotropic Polymer Melts 255

Daniel P. da Silva, James J. Holt, Supatra Pratumshat, Paula Pascoal-Faria, Artur Mateus, and Geoffrey R. Mitchell

- 10.1 Introduction 255
- 10.2 Evaluating Anisotropy 256

10.3	Crystallization During Deformation of Networks	258
10.4	Sheared Polymer Melts	260
10.5	Crystallization During Injection Molding	264
10.6	Sheared Polymer Melts with Nucleating Agents	266
10.7	Sheared Polymer Melts with Nanoparticles	271
10.8	3D Printing Using Extrusion	272
10.8.1	In-Situ Studies of Polymer Crystallization During 3D Printing	273
10.9	Morphology Mapping	275
10.10	Discussion	276
	Acknowledgments	277
	References	277
11	Molecular Simulations of Polymer Crystallization	283
	<i>Yijing Nie and Jianlong Wen</i>	
11.1	Introduction	283
11.2	Establishment of Polymer Simulation Systems	283
11.2.1	MC Simulations	284
11.2.2	MD Simulations	284
11.2.2.1	United Atom Chain Model	285
11.2.2.2	Coarse-Grained Polymer Model	285
11.3	Polymer Crystallization at Quiescent State	285
11.3.1	Crystal Nucleation	285
11.3.2	Intramolecular Nucleation Model	287
11.4	Nanofiller-Induced Polymer Crystallization	288
11.4.1	Nanofiller-Induced Homopolymer Crystallization	288
11.4.2	Nanofiller-Induced Copolymer Crystallization	291
11.4.2.1	Nanofiller-Induced Block Copolymer Crystallization	291
11.4.2.2	Random Copolymer Nanocomposite Crystallization	293
11.4.3	Crystallization of Polymers Grafted on Nanofillers	293
11.5	Effect of Grafting Density	293
11.6	Effect of Chain Length	293
11.7	Effect of Interfacial Interactions	295
11.8	Stereocomplex Crystallization of Polymer Blends	295
11.8.1	Simulation Details	296
11.8.2	Effects of Different Methods	297
11.8.2.1	Effect of Chain Length	297
11.8.2.2	Effect of Stretching	298
11.8.2.3	Effect of Nanofillers	298
11.8.2.4	Effect of Chain Topology	299
11.8.2.5	Effect of Chain Structure	300
11.9	Flow-Induced Polymer Crystallization	301
11.9.1	Flow-Induced Polymer Nucleation	301
11.9.2	Stretch-Induced Crystalline Structure Changes	306
11.10	Summary	308
	References	309

12	Application, Recycling, Environmental and Safety Issues, and Future Prospects of Crystalline Polymer Composites	323
	<i>Busra Cetiner, Havva Baskan-Bayrak, and Burcu S. Okan</i>	
12.1	Introduction	323
12.2	Crystalline Polymers and Composites	324
12.2.1	Crystalline Polymers	324
12.2.2	Crystalline Polymer Composites	326
12.2.2.1	Crystalline Polymer Composites with Organic Reinforcements	328
12.2.2.2	Crystalline Polymer Composites with Inorganic Reinforcements	329
12.2.2.3	Crystalline Polymer Composites with Natural Reinforcements	330
12.3	Applications of Crystalline Polymer Composites	331
12.3.1	Automotive Applications of Crystalline Polymer Composites	331
12.3.2	Biomedical Applications of Crystalline Polymer Composites	334
12.3.3	Defense and Aerospace Applications of Crystalline Polymer Composites	335
12.3.4	Other Applications of Crystalline Polymer Composites	339
12.4	Recycling, Environmental, and Safety Issues of Crystalline Polymer Composites	340
12.4.1	Recycling of Glass Fiber-Reinforced Crystalline Polymer Composites	340
12.4.2	Recycling of Carbon Fiber-Reinforced Crystalline Polymer Composites	341
12.4.3	Recycling of Carbon Nanotubes-Reinforced Crystalline Polymer Composites	342
12.4.4	Recycling of Natural Fiber-Reinforced Crystalline Polymer Composites	343
12.4.5	Environmental Impact and Safety Issues of Crystalline Polymer Composites	343
12.5	Future Prospects of Crystalline Polymer Composites	344
12.6	Conclusions	345
	References	345
	Index	359