Contents

List of Contributors XXI

Volume 1

1 Polymer Blends: State of the Art, New Challenges, and Opportunities 1
Jyotishkumar Parameswaranpillai, Sabu Thomas, and Yves Crohens
1.1 Introduction 1
1.2 Miscible and Immiscible Polymer Blends 2
1.3 Compatibility in Polymer Blends 3
1.4 Topics Covered in this Book 3
References 5

2 Miscible Blends Based on Biodegradable Polymers 7
Emilio Meaurio, Natalia Hernandez-Montero, Ester Zuza, and Jose-Ramon Sarasua
2.1 Introduction 7
2.2 Thermodynamic Approach to the Miscibility of Polymer Blends 8
2.2.1 Introduction 8
2.2.2 Molecular Size and Entropy 8
2.2.3 The Regular Solution 10
2.2.4 The Flory–Huggins Model 13
2.2.5 The Hildebrand Approach 17
2.2.6 Extension of the Flory–Huggins Model to Systems with Specific Interactions 19
2.2.7 The Dependence of Miscibility on Blend Composition and Temperature 24
2.2.8 The Painter–Coleman Association Model (PCAM) 25
2.2.9 Analysis of the Miscibility Using Molecular Modeling Calculations 26
2.2.10 Classification of Miscible Systems 27
2.2.10.1 Entropically Driven Miscible Systems 27
2.2.10.2 Enthalpically Driven Miscible Systems 28
2.3 Revision of Polymer Blends Based on Biodegradable Polyesters 29
2.3.1 Blends Containing Poly(lactic acid) or Poly(lactide) (PLA) 29
2.3.1.1 PLA/PLA Blends 30
2.3.1.2 PLA Blended with Poly(ethylene glycol) (PEG) and Poly(ethylene oxide) (PEO) 34
2.3.1.3 PLA Blended with Poly(vinyl alcohol) (PVA) and Poly(vinyl acetate) 36
2.3.1.4 PLA/Poly(e-caprolactone) (PCL) Blends 37
2.3.1.5 PLA/Poly((R)-3-Hydroxybutyric acid)) (PHB) Blends 40
2.3.1.6 PLA Blended with Poly(methyl methacrylate) (PMMA) and Poly(methyl acrylate) (PMA) 41
2.3.1.7 PLA/Poly(4-vinylphenol) (PVPh) Blends 43
2.3.1.8 PLA Blended with Poly(butylene succinate) (PBS) and Poly(ethylene succinate) (PESu) 45
2.3.1.9 PLA Blended with Poly(propylene carbonate) (PPC) and Poly(trimethylene carbonate) (PTMC) 47
2.3.1.10 PLA/Poly(styrene) (PS) Blends 48
2.3.1.11 PLA Blended with Other Polymers 48
2.3.1.12 PLA Blended with Other Copolymers 50
2.3.2 Blends Containing Poly(e-caprolactone) (PCL) 50
2.3.3 Blends Containing Poly(hydroxy butyrate) (PHB) 50
2.3.4 Blends Containing Poly(p-dioxanone) (PPDO) 51
2.3.5 Blends Containing Poly(glycolic acid) (PGA) or Polyglycolide 52
2.4 Revision of Blends Based on Natural Polymers 52
2.4.1 Blends Containing Starch 52
2.4.2 Blends Containing Cellulose 54
2.4.3 Blends Containing Chitosan 55
2.4.4 Blends Containing Collagen 56
Appendix 2.A Relevant Research Papers 57
Appendix 2.B List of Abbreviations and Nomenclature 83
2.B.1 Chemical Terms 83
2.B.2 Polymers and Copolymers 83
2.B.3 Notations 84
2.B.4 Symbols 85
2.B.5 Greek Letters 86
Acknowledgments 86
References 86

3 Thermodynamics and Morphology and Compatibilization of Polymer Blends 93
Zdeněk Starý
3.1 Introduction 93
3.2 Thermodynamics of Polymer Blends 95
3.2.1 Enthalpy of Mixing 95
3.2.2 Entropy of Mixing 96
3.2.3 Flory–Huggins Theory 98
3.3 Phase Behavior of Polymer Blends 100
3.3.1 Phase Diagrams 101
3.3.2 Phase Separation 104
3.3.3 Interfaces in Polymer Blends 107
3.4 Morphology of Polymer Blends 111
3.4.1 Morphology Development During Melt Processing 114
3.4.2 Stability of Blend Morphology 119
3.5 Compatibilization of Polymer Blends 120
3.5.1 Morphology Development in Compatibilized Blends 121
3.5.2 Compatibilization Techniques 123
3.5.2.1 Addition of Preprepared Copolymer 124
3.5.2.2 Addition of Reactive Polymer 125
3.5.2.3 Addition of Reactive Low-Molecular-Weight Compounds 125
3.5.2.4 Other Compatibilization Techniques 126

References 126

4 Characterization of Polymer Blends: Rheological Studies 133
Yingfeng Yu
4.1 Introduction 133
4.1.1 General Description of Thermoset Rheological Behaviors 133
4.1.2 Thermosetting Resins: Gelation, Vitrification, and Viscoelasticity 134
4.1.3 Methods of Rheological Measurement 137
4.2 Thermosetting Blend Systems with Rubbers and Thermoplastics 138
4.2.1 Phase Separation and Rheological Behavior of Rubber-Modified Systems 138
4.2.2 Phase Separation and Rheological Behavior of Thermoplastic-Modified Systems 140
4.2.3 Viscoelastic Properties of the Blends 143
4.2.4 Gelation Behaviors of the Blends 148
4.3 Thermosetting Systems with Nanostructures 150
4.4 Conclusions 153
References 153

5 Characterization of Phase Behavior in Polymer Blends by Light Scattering 159
Petr Svoboda
5.1 Introduction 159
5.2 Amorphous/Crystalline Polymer Blends 160
5.3 Light Scattering 161
5.4 Cloud-Point Determination 162
5.5 Time-Resolved Light Scattering 165
5.5.1 Immiscible Blends 165
5.5.2 Spinodal Decomposition 166
5.5.3 Crystallization by \( H_v \) Light Scattering 169
5.5.4 Model Blend of Poly(e-Caprolactone) (PCL) and Poly(Styrene-co-Acrylonitrile) (SAN) 170
5.5.5 Samples Preparation 171
5.5.6 Phase Separation and Phase Dissolution in Poly(e-Caprolactone)/Poly(Styrene-co-Acrylonitrile) Blend 172
5.5.7 Crystallization Kinetics by Optical Microscopy and by H_2 Light Scattering 181
5.5.8 Competition of Phase Dissolution and Crystallization 190
5.6 Determination of Virtual UCST Behavior 197
5.6.1 Evaluation of Particle Size in Immiscible Blends 204
Acknowledgments 205
References 205

6 Characterization of Polymer Blends by X-Ray Scattering: SAXS and WAXS 209
Jitendra Sharma
6.1 Introduction 209
6.1.1 Development of SAXS Techniques for Polymers 212
6.1.2 Instrumentation and the Synchrotron Advantage 212
6.2 Basics of X-Ray Scattering 213
6.2.1 Elastic Scattering of Electromagnetic Radiation by Single Electron 213
6.2.2 Scattering by Assembly of Electrons: Scattering Geometry and Interference 215
6.2.3 Scattered Intensity 216
6.3 Small- and Wide-Angle X-Ray Scattering (SAXS and WAXS) 218
6.4 Polymer Blend Morphology 219
6.4.1 Blends of Homopolymers 219
6.4.1.1 Structural Characterization: SAXS Data 220
6.4.1.2 Crystallinity: WAXS Data 224
6.4.2 Blends of Block Copolymers 224
6.4.3 Time-Resolved Studies: Kinetics of Crystallization and Melting 228
6.5 Conclusions 231
References 232

7 Characterization of Polymer Blends and Block Copolymers by Neutron Scattering: Miscibility and Nanoscale Morphology 237
Kell Mortensen
7.1 Introduction 237
7.2 Small-Angle Scattering 237
7.2.1 Contrast 239
7.2.2 Scattering Function 242
7.2.3 Gaussian Chain 244
### Contents

7.3 Thermodynamics of Polymer Blends and Solutions. Flory-Huggins Theory 246
7.4 The Scattering Function and Thermodynamics 249
7.4.1 The Forward Scattering 250
7.4.2 Random Phase Approximation (RPA) 254
7.4.3 Beyond Mean Field 258
7.5 Block Copolymers 260
7.5.1 Ordered Phases 264
References 268

8 Ultrasound in Polymer Blends 269
* Sangmook Lee and Jae Wook Lee*

8.1 Introduction 269
8.2 High-Frequency Ultrasound 270
8.2.1 Static Characterization 270
8.2.1.1 Miscibility of Solution Blends 270
8.2.1.2 Compatibility 273
8.2.1.3 Density 274
8.2.1.4 Phase Inversion 275
8.2.1.5 Molecular Orientation 276
8.2.2 In-Line Monitoring 278
8.2.2.1 Morphology 278
8.3 Power Ultrasound 280
8.3.1 Injection Molding 280
8.3.1.1 Weld Line Strength Improvement 280
8.3.2 Batch Melt Mixing 281
8.3.2.1 Compatibilization 282
8.3.3 Extrusion 283
8.3.3.1 Molecular Weight Control 284
8.3.3.2 Tensile Properties Enhancement 284
8.3.3.3 Compatibilization 286
8.3.3.4 Rheological Modification 287
8.3.3.5 Morphology Control 289
8.3.3.6 Die Swell Reduction 290
8.4 Summary 292
References 293

9 Characterization of Polymer Blends: Ellipsometry 299
* Éva Kiss*

9.1 Ellipsometry 299
9.1.1 Principles of Ellipsometry 299
9.1.2 Thickness and Optical Properties of Layers on Solid Supports 300
9.1.2.1 Linear EMA 301
9.1.2.2 Maxwell-Garnett EMA 301
9.1.2.3 Bruggeman EMA 302
9.1.3 Depth Profiling 303
9.1.4 Sample Preparation 303
9.1.5 Types of Instrument and Measurements 303
9.1.5.1 Spectroscopic Ellipsometry, Real-Time Measurement 304
9.2 Applications in the Characterization of Polymer Blend Films 304
9.2.1 Phase Separation in Thin Polymer Blend Films 304
9.2.2 Analysis of Interfacial Thickness and Interfacial Reaction 305
9.2.2.1 Miscibility 305
9.2.2.2 Reactive Compatabilization 308
9.2.3 Morphology, Roughness, and Pattern Formation in Nanolayers 309
9.2.4 Biomaterial Surfaces 312
9.2.5 Surface Modification, Adsorption from Solution 312
9.2.5.1 Biomaterial Blends 313
9.2.5.2 Distribution and Release of Drugs 315
9.2.6 Composite Layers for Organic Solar Cells 317
9.3 Concluding Remarks 322
Acknowledgments 322
References 323

10 Inverse Gas Chromatography 327
Kasylda Milczewska and Adam Voelkel
10.1 Concept and History of Inverse Gas Chromatography (IGC) 327
10.2 Theoretical Background 328
10.3 Thermodynamic Aspects: Parameters Used for Polymer Blend Characterization 330
10.3.1 Flory–Huggins Interaction Parameter for Polymer–Test Solute Systems 331
10.3.2 Flory–Huggins Interaction Parameter for “Multiple” Systems 333
10.4 Procedures Used in IGC Experiments Leading to the Determination of Polymer Blend Characteristics 334
10.5 Application of Chemometric Methods 336
10.6 Transport Properties of Polymeric Mixtures 337
10.7 Usefulness of IGC: Applications of IGC-Derived Parameters in the Characterization of Various Systems 340
10.8 Advantages and Drawbacks of IGC 341
References 342

11 Thermal Analysis in Polymer Blends 347
Ramesh T. Subramaniam and R. Shanti Rajantharan
11.1 Introduction to Polymer Blends 347
11.1.1 The Principle of Polymer Blending 348
11.2 Experimental 349
11.2.1 System 1: PVC/PEO Blends 349
11.2.2 System 2: PVC/PEO:LiCF$_3$SO$_3$ Blends 350
11.2.3 System 3: PVC/PEO-LiCF$_3$SO$_3$·DBP:EC Blends 351
11.2.4 System 4: PVC/PEO-LiCF$_3$SO$_3$-DBP-EC:SiO$_2$ Blends 351
11.3 Instrumentation 351
11.3.1 Sample Weight 352
11.3.2 Testing Temperature Range 352
11.3.3 Gas Environment 352
11.3.4 Heating Rate 353
11.4 Thermal Analysis 353
11.4.1 Information Obtained from TGA 353
11.4.2 Thermal Process 353
11.4.3 The Value of the TGA Information 354
11.5 Results and Discussion: Thermal Analysis 355
11.5.1 Pure PVC 355
11.5.2 Pure PEO 359
11.5.3 System 1: PVC/PEO Blends 359
11.5.4 System 2: PVC/PEO-LiCF$_3$SO$_3$ Blends 360
11.5.5 System 3: PVC/PEO-LiCF$_3$SO$_3$-DBP-EC Blends 361
11.5.6 System 4: PVC-PEO-LiCF$_3$SO$_3$-DBP-EC:SiO$_2$ Blends 362
11.6 Conclusion 362

References 363

12 Dynamic Mechanical Thermal Analysis of Polymer Blends 365
José-David Badia, Laura Santonja-Blasco,
Alfonso Martínez-Felipe, and Amparo Ribes-Greus
12.1 Dynamic Mechanical Thermal Analysis (DMTA) 365
12.1.1 The DMTA Analyzers 366
12.1.2 Using DMTA to Analyze the Viscoelastic Behavior of Polymers 368
12.1.3 Description of DMTA Results: The Viscoelastic Spectra 369
12.1.3.1 The Glassy State 369
12.1.3.2 The Glass–Rubber Relaxation 371
12.1.3.3 Rubbery Plateau 372
12.1.3.4 Recrystallization or Curing 372
12.1.3.5 Flowing 373
12.1.4 Modeling the Viscoelastic Behavior 373
12.2 Miscibility Studies 373
12.2.1 Binary Systems 374
12.2.2 Ternary Systems 376
12.2.3 Influence of Type of Processing 376
12.2.4 Recovering Plastic Waste by Polymer Blending 377
12.2.5 Influence of Nanoparticles 377
12.2.6 The Study of the Rubbery Plateau as an Indicator of Miscibility 378
12.2.7 Theoretical Approaches to Calculating the Glass–Rubber Relaxation Temperature 379
12.3 Segmental Dynamics, Fragility Index, and Free-Volume 379
12.4 Effects of Plasticizers and Chemical and Physical Crosslinks 381
12.4.1 Influence of Plasticizers on Viscoelastic Performance of Polymer Blends 382
12.4.2 Influence of Chemical and Physical Crosslinkers on the Viscoelastic Performance of Polymer Blends 383
12.4.3 Strategies to Tune the Heat Distortion Temperature by Polymer Blending 384
12.5 Summary 386
References 387

13 Thermomechanical Analysis and Processing of Polymer Blends 393
Suchart Siengchin
13.1 Introduction 393
13.2 Polymer Toughness 394
13.3 Thermomechanical Analysis and Manufacture of Polymer Blends 395
13.3.1 Theoretical Background 396
13.3.1.1 Dynamic Mechanical Thermal Analysis (DMTA) 396
13.3.1.2 Creep Response 397
13.3.1.3 Thermogravimetric Analysis 399
13.3.2 Latex and Online-Manufacturing Concept of Polymer Blends 399
13.3.3 Materials Systems Studied 402
13.4 Results and Discussion 403
13.4.1 POM/PU Blend 403
13.4.2 PA-6/HNBR Blend 408
13.5 Summary 412
13.5.1 Greek Symbols 413
Acknowledgment 413
References 413

14 Water Sorption and Solvent Sorption Behavior 417
Fatemeh Sabzi
14.1 Introduction 417
14.2 Water Sorption 418
14.2.1 Chitosan Blends 418
14.2.2 PVP/Polysulfone Blend 420
14.2.3 PEOX Blends 422
14.2.4 PES/PEO Blend 422
14.2.5 Phenoxy Blends 423
14.2.6 Poly(ethylene terephthalate) (PET) Nanocomposites 423
14.2.7 PMMA/HHIS and PMMA/HS 424
14.2.8 PVC/EVAc 425
14.2.9 PBI/PI 428
14.2.10 PP/EVA 428
14.2.11 PVA/P(AA-AMPS) 430
14.2.12 PVP/PEG 431
14.2.13 iPHB/aPHB and iPHB/PECH 431
14.2.14 Epoxy Resin/PEI 432
14.2.15 PMMA/PEO 433
14.3 Pervaporation 434
14.3.1 THF/Water Mixtures 434
14.3.2 Acetic Acid/Water Mixture 435
14.3.3 Ethanol/Water Mixture 435
14.3.4 DMF/Water Mixtures 436
14.3.5 1,4-Dioxane/Water 436
14.4 Vapor Permeation 437
14.4.1 Chitosan/CPA 437
14.4.2 Natural Rubber Blends 437
14.4.3 NBR Blends 440
14.4.4 LCP Blends 441
14.4.5 PU/PDMS 442
14.4.6 EEA-CB 442
14.4.7 PVC/EVAc 443
14.4.8 PHB/PEO and PHB/PMMA 443
14.4.9 PVA/PAA 443
14.5 Gas Permeation 444
14.5.1 PVA/PEI/PEG 444
14.5.2 PS/PC 444
14.5.3 PS/PPO 445
14.5.4 PS/PTMPS 445
14.5.5 Matrimid/PSF 446
14.5.6 Matrimid/P84 446
14.5.7 Matrimid/PBI 447
14.5.8 CA/PMMA 447
14.5.9 PU/PMMA 448
14.5.10 EVA-45/H-48 448
14.5.11 PS/PVME 448
14.5.12 TLCP/PET 449
14.5.13 CELL/PVA 449
14.5.14 Trogamid Blends 449
14.5.15 TPX/Siloxane 450
14.5.16 PTMSMMA/3-Methylsulfolane 450
14.5.17 BCPC/PMMA 450
14.6 Conclusions 451
References 451

15 Modeling and Simulation 457
Yingrui Shang and David Kazmer
15.1 Introduction 457
15.1.1 Numerical Models for Polymer Blends 457
15.1.2 Spinodal Decomposition 461
15.1.3 Cahn–Hilliard Equation 464
| 16.4.4 | Crystallization Morphologies in Stereocomplexationable Chiral Blends | 537 |
| 16.4.5 | Mesoscale Morphologies in Conducting Polymer Blends | 540 |
| 16.5 | Confocal Microscopy Characterization of Polymer Blends | 543 |
| 16.6 | Summary | 547 |
| | Acknowledgments | 547 |
| | References | 548 |

| 17 | Electron Microscopic Analysis of Multicomponent Polymers and Blends | 551 |
| | Rameshwar Adhikari |
| 17.1 | Introduction and Overview | 551 |
| 17.2 | Sample Preparation Techniques | 552 |
| 17.2.1 | Thin-Film Preparation | 552 |
| 17.2.2 | Staining of Thin Sections | 553 |
| 17.2.3 | Etching of the Surface | 554 |
| 17.2.4 | Specimens for Fracture Behavior Analysis | 554 |
| 17.3 | Morphological Characterization | 555 |
| 17.3.1 | Blends of Semicrystalline Polymers | 555 |
| 17.3.2 | Blends of Amorphous Polymers | 561 |
| 17.3.3 | Nanostructured Copolymers and Blends | 563 |
| 17.4 | Special Techniques and Applications | 567 |
| 17.5 | Deformation Studies on Polymer Blends | 571 |
| 17.6 | Concluding Notes | 574 |
| | Acknowledgments | 575 |
| | References | 575 |

| 18 | Characterization of Polymer Blends Using SIMS and NanoSIMS | 579 |
| | Vanna Torrisi |
| 18.1 | Introduction | 579 |
| 18.2 | Thin Films and Ultrathin Films of Polymer Blends | 580 |
| 18.2.1 | Phase-Separation Phenomena | 583 |
| 18.2.2 | Technological Applications of Thin and Ultrathin Films of Polymer Blends | 586 |
| 18.2.3 | The Necessity of Compositional Information | 588 |
| 18.3 | SIMS: The Techniques and Outputs | 589 |
| 18.3.1 | ToF-SIMS: The Technique | 592 |
| 18.3.1.1 | Spectra, Profiling, and Imaging Mode | 592 |
| 18.3.1.2 | ToF-SIMS: Spatially Resolved Molecular Information | 593 |
| 18.3.1.3 | Multivariate Analysis of ToF-SIMS Images | 595 |
| 18.3.2 | NanoSIMS: The Technique | 597 |
| 18.3.2.1 | NanoSIMS: Ion Optical Set-Up | 597 |
| 18.3.2.2 | NanoSIMS: The Mass Spectrometer | 597 |
18.3.2.3 NanoSIMS: Highly Spatially Resolved Elemental Information 598
18.4 3D Imaging of Polymer Blends 599
18.5 Conclusions and Perspectives 602
References 603

19 Fluorescence Microscopy Techniques for the Structural Analysis of Polymer Materials 609
Hiroyuki Aoki
19.1 Introduction 609
19.2 Fundamentals of Fluorescence Microscopy 609
19.3 Fluorescence Imaging of Polymer Blend Systems 612
19.3.1 Real-Space Measurement of 3D Structure 612
19.3.2 Spectroscopic Information 614
19.4 Fluorescence Microscopy Beyond the Diffraction Barrier 615
19.4.1 Near-Field Optical Microscopy 615
19.4.2 Super-Resolution Optical Microscopy 617
19.4.3 Conformational Analysis of Single Polymer Chain 620
19.5 Summary 621
References 622

20 Characterization of Polymer Blends with FTIR Spectroscopy 625
Ufana Riaz and Syed Marghoob Ashraf
20.1 Introduction 625
20.2 Methods of Investigating Miscibility 626
20.2.1 FTIR as a Spectroscopic Tool for the Characterization of Polymer Blends 626
20.2.2 Determination of Miscibility Through Hydrogen Bonding 628
20.3 Characterization of Vinyl Polymer Blends using FTIR Spectroscopy 628
20.3.1 Poly(vinylphenol) (PVPh) Blends 628
20.3.2 Poly(vinylpyrrolidone) (PVP) Blends 632
20.3.3 Poly(vinyl alcohol) (PVA) Blends 637
20.4 Characterization of Blends of Polyethers (PE) using FTIR Spectroscopy 643
20.4.1 Polyethylene Oxide (PEO) Blends 643
20.4.2 Poly (vinyl methyl ether) (PVME) Blends 650
20.5 Characterization of Acrylate Blends with FTIR Spectroscopy 655
20.5.1 Poly(methylmethacrylate) (PMMA) Blends 655
20.5.2 Poly-(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) Blends 657
20.6 Characterization of Synthetic Rubber using FTIR Spectroscopy 661
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.7 Characterization of Natural Polymer Blends Using FTIR Spectroscopy</td>
<td>663</td>
</tr>
<tr>
<td>20.7.1 Collagen Blends</td>
<td>663</td>
</tr>
<tr>
<td>20.7.2 Chitosan Blends</td>
<td>664</td>
</tr>
<tr>
<td>20.8 Study of Blends by Polarization Modulation and 2D-FTIR Spectroscopy</td>
<td>665</td>
</tr>
<tr>
<td>20.9 Analysis of Polymer Blends Using FTIR Microspectroscopy</td>
<td>668</td>
</tr>
<tr>
<td>20.10 Conclusions</td>
<td>669</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>670</td>
</tr>
<tr>
<td>Abbreviations</td>
<td>670</td>
</tr>
<tr>
<td>References</td>
<td>671</td>
</tr>
<tr>
<td>21 Characterization of Polymer Blends with Solid-State NMR Spectroscopy</td>
<td>679</td>
</tr>
<tr>
<td>Mohammad Mahdi Abolhasani and Vahid Karimkhani</td>
<td></td>
</tr>
<tr>
<td>21.1 Introduction</td>
<td>679</td>
</tr>
<tr>
<td>21.2 Miscibility</td>
<td>680</td>
</tr>
<tr>
<td>21.3 Proton Spin-Lattice Relaxation Experiments</td>
<td>680</td>
</tr>
<tr>
<td>21.4 Experiments for the Direct Observation of Proton Spin-Diffusion</td>
<td>688</td>
</tr>
<tr>
<td>21.5 Molecular Dynamics</td>
<td>692</td>
</tr>
<tr>
<td>21.5.1 $^2$H NMR Line Shape Analysis</td>
<td>692</td>
</tr>
<tr>
<td>21.5.2 Polarization Inversion Spin Exchange at the Magic Angle (PISEMA) Experiment</td>
<td>694</td>
</tr>
<tr>
<td>21.5.3 Two-Dimensional Wideline Separation (WISE) NMR</td>
<td>695</td>
</tr>
<tr>
<td>21.6 Organic-Solar Cells</td>
<td>696</td>
</tr>
<tr>
<td>21.7 Conclusions</td>
<td>700</td>
</tr>
<tr>
<td>References</td>
<td>702</td>
</tr>
<tr>
<td>22 Characterization of Polymer Blends by Infrared, Near-Infrared, and Raman Imaging</td>
<td>705</td>
</tr>
<tr>
<td>Harumi Sato, Miriam Unger, Dieter Fischer, Yukihiro Ozaki, and Heinz W. Siesler</td>
<td></td>
</tr>
<tr>
<td>22.1 Instrumentation for Mid-Infrared and Near-Infrared Imaging</td>
<td>705</td>
</tr>
<tr>
<td>22.2 Raman Microspectroscopy</td>
<td>709</td>
</tr>
<tr>
<td>22.3 Characterization of Polymer Blends by FT-IR Imaging</td>
<td>711</td>
</tr>
<tr>
<td>22.3.1 Investigation of Phase Separation in Biopolymer Blends</td>
<td>711</td>
</tr>
<tr>
<td>22.3.1.1 Poly((3-Hydroxybutyrate)(PHB)/Poly(L-Lactic Acid)(PLA) Blends</td>
<td>711</td>
</tr>
<tr>
<td>22.3.1.2 FT-IR Imaging of Anisotropic PHB/PLA Blend Films</td>
<td>714</td>
</tr>
<tr>
<td>22.3.1.3 Variable-Temperature FT-IR and Raman Imaging Spectroscopy of a Phase-Separated PHB/PLA 50/50 wt% Blend Film</td>
<td>717</td>
</tr>
<tr>
<td>22.3.1.4 FT-IR Imaging of the State of Order of PHB/PCL Blend Films</td>
<td>720</td>
</tr>
<tr>
<td>22.3.1.5 FT-IR and FT-NIR Imaging of the Spherulitic Structure of Poly(3-Hydroxy-Butyrate) and Cellulose Acetate Butyrate Blends</td>
<td>724</td>
</tr>
</tbody>
</table>
22.3.1.6 Raman Mapping Measurements of the Influence of a Compatibilizer on Phase Separation of the Polymer Blend Polypropylene/Polyamide 6 728

References 730

23 Electron Paramagnetic Resonance Spectroscopy and Forward Recoil Spectrometry 731
Krzysztof Kruczała and Ewa Szajdzińska-Piętek

23.1 Introduction 731
23.2 Electron Paramagnetic Spectroscopy 732
23.2.1 EPR Background 732
23.2.1.1 Multifrequency EPR 736
23.2.1.2 Pulsed EPR 737
23.2.1.3 EPR Imaging 738
23.2.1.4 Simulation of EPR Spectra 741
23.2.1.5 Spin Probes and Spin Labels 744
23.2.2 EPR Applications in Studies of Polymer Blends 747
23.2.2.1 Spin Probing of the Structure and Dynamics 747
23.2.2.2 Radical Processes Induced by Ionizing Radiation 755
23.2.2.3 Conductive Materials 761
23.3 Forward Recoil Spectrometry 766
23.3.1 FRES Fundamentals 767
23.3.2 Technique Developments 769
23.3.2.1 Time-of-Flight FRES 770
23.3.2.2 Low-Energy FRES 771
23.3.2.3 Heavy Ion FRES 772
23.3.3 Applications to Polymer Blend Studies 773
23.3.3.1 Tracer Diffusion 773
23.3.3.2 Reaction Kinetics 775
23.3.3.3 Surface and Interfaces 776
23.3.3.4 Phase Separation 778
Acknowledgments 782
References 783

24 Characterization of Polymer Blends Using UV-Visible Spectroscopy 789
Mamdouh H. Abou-Taleb

24.1 Introduction 789
24.2 Electromagnetic Radiation 791
24.3 Interaction of Radiation (UV/VIS) with Matter 792
24.4 The Nature of Electronic Excitations in Matter (Polymer Blends) 793
24.5 Relationship of Structure of Matter to the Electronic Absorption Spectrum 796
24.6 The Correspondence of Color and Transparent Spectrum 796
24.7 Relationship of Polymer Blends to Material Characterization 798
24.8 Optical Properties of Semiconductors (Polymers and Polymer Blends) 801
24.9 Optical Absorption Spectra of Materials 802
24.9.1 Extended-to-Extended State Transitions 803
24.9.2 Extended-to-Localized and Localized-to-Extended State Transitions 803
24.9.3 Localized-to-Localized State Transitions 804
24.9.4 Exciton Absorption 807
24.9.5 Free Carrier Absorption 807
24.10 Instrumentation 809
24.10.1 Single-Beam Spectrophotometry 809
24.10.2 Double-Beam Spectrophotometry 810
24.11 Radiation Sources 811
24.11.1 Xenon Lamp (Xenon Arc Lamp) 811
24.11.2 Deuterium Lamp 811
24.12 Monochromator 811
24.12.1 Wavelength Selection 812
24.13 Detection Area and Detectors 812
24.13.1 Photomultiplier 812
24.13.2 Silicon Photodiode 813
24.13.3 Photodiode Array 813
24.14 Data Acquisition 814
24.15 Classification of Errors in Spectrophotometry 814
24.15.1 Spectral Band Width and Slit Width 815
24.15.2 Slit Height 816
24.15.3 Stray Light 816
24.15.4 Solvents 817
References 817

25 Fluorescence Spectroscopy 821
Gabriel Bernardo and Jorge Morgado
25.1 Introduction 821
25.2 Fundamentals of Fluorescence Spectroscopy 822
25.2.1 Theory 822
25.2.2 Steady-State Fluorescence 823
25.2.3 Time-Resolved Fluorescence 823
25.2.4 Fluorescence Quenching 827
25.2.5 Fluorescence Microscopy 830
25.3 Intrinsically Fluorescent Polymer Blends 830
25.4 Systems Requiring Extrinsic Fluorescent Labels 840
25.5 Conclusions 844
Nomenclature 844
Acknowledgments 845
References 846
26 Characterization of Polymer Blends by Dielectric Spectroscopy and Thermally Simulated Depolarization Current 849
Samy A. Madbouly and Michael R. Kessler

26.1 Introduction 849
26.1.1 Dielectric Relaxation Spectroscopy and Thermally Stimulated Depolarization Current 849
26.1.2 Analysis of Relaxation Spectrum 850
26.1.3 Effect of Temperature on Relaxation Spectrum 852
26.2 Dielectric Relaxation Spectroscopy of Amorphous Polymer Blends 853
26.3 Dielectric Relaxation Spectroscopy of Semicrystalline Polymer Blends 862
26.4 Dielectric Relaxation Spectroscopy of Chemically Reactive Polymer Blends 868
26.5 Conclusions 872
References 873

27 Positron Annihilation Spectroscopy: Polymer Blends and Miscibility 877
Chikkakuntappa Ranganathaiah

27.1 Introduction 877
27.2 Positron Annihilation Spectroscopy 878
27.2.1 The Positron Annihilation Process 878
27.2.2 Positronium 880
27.2.2.1 Positron and Positronium Sensitivity to Defects and Free Volume 882
27.2.2.2 Models Predicting Positronium Formation 883
27.3 Free Volume Theory 884
27.3.1 Free Volume Model and Positronium Lifetime Connection 885
27.4 Characterization of Polymer Blends by PAS 887
27.5 Experimental Methods of PAS 888
27.5.1 Positron Annihilation Lifetime Spectroscopy (PALS) 888
27.5.1.1 Free Volume Distribution-Lifetime Analysis by Laplace Transform Method 891
27.5.1.2 Free-Volume Distributions in Polymer Blends 892
27.5.1.3 Angular Correlation of Annihilation Radiation (ACAR) Method 893
27.5.1.4 Doppler Broadening of the Annihilation Radiation (DBAR) Method 894
27.6 Miscibility in Polymer Blends and Free Volume 896
27.6.1 Free Volume and Miscibility Studies in Blends 901
27.7 Future Outlook 916
Acknowledgments 916
References 916

Index 921