

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 Grohens
 - 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(ϵ -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(ϵ -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
	<i>Zdeněk Starý</i>	
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
	<i>Yingfeng Yu</i>	
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
	<i>Petr Svoboda</i>	
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(ϵ -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(ϵ -Caprolactone)/Poly(Styrene-co-Acrylonitrile) Blend	172
5.5.7	Crystallization Kinetics by Optical Microscopy and by H_v 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
	<i>Jitendra Sharma</i>	
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
	<i>Kell Mortensen</i>	
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

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
	<i>Sangmook Lee and Jae Wook Lee</i>	
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
	<i>Éva Kiss</i>	
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 Compatibilization	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
	<i>Kasylda Milczewska and Adam Voelkel</i>	
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
	<i>Ramesh T. Subramaniam and R. Shanti Rajanathan</i>	
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
	<i>José-David Badia, Laura Santonja-Blasco, Alfonso Martínez-Felipe, and Amparo Ribes-Greus</i>	
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
	<i>Suchart Siengchin</i>	
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
	<i>Fatemeh Sabzi</i>	
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	TLC/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
	<i>Yingrui Shang and David Kazmer</i>	
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

- 15.1.4 Numerical Method 465
- 15.2 Numerical Simulation of Phase Separation of Immiscible Polymer Blends on a Heterogeneously Functionalized Substrate 466
 - 15.2.1 Fundamentals 467
 - 15.2.2 Numerical Method 468
 - 15.2.3 Implementation 470
 - 15.2.4 Results and Discussion 471
 - 15.2.5 Summary 479
- 15.3 Numerical Simulation of the Self-Assembly of a Polymer–Polymer–Solvent Ternary System on a Heterogeneously Functionalized Substrate 481
 - 15.3.1 Introduction 481
 - 15.3.2 Thermodynamics 481
 - 15.3.3 Numerical Method 484
 - 15.3.4 Implementation 485
 - 15.3.5 Results and Discussion 486
 - 15.3.6 Summary 496
- 15.4 Verification of Numerical Simulation of the Self-Assembly of a Polymer–Polymer–Solvent Ternary System on a Heterogeneously Functionalized Substrate 497
 - 15.4.1 Experiment 498
 - 15.4.2 Implementation 499
 - 15.4.3 Results and Discussion 501
 - 15.4.4 Summary 511
- 15.5 Effects of Pattern Shapes and Block Copolymer 513
- 15.6 Conclusions 515
 - Acknowledgments 517
 - References 517

Volume 2

- 16 Optical Microscopy (Polarized, Interference, and Phase-Contrast Microscopy) and Confocal Microscopy 523**
Muruganathan Ramanathan and Seth B. Darling
 - 16.1 Introduction 523
 - 16.2 Optical and Confocal Microscopy: A Brief Overview 524
 - 16.3 Mesoscale Morphologies in Polymer Blends: Spherulites and Microcrystallites 526
 - 16.4 Optical Characterization of Mesoscale Morphologies in Polymer Blends 528
 - 16.4.1 Crystalline–Crystalline Blend 528
 - 16.4.2 Crystalline–Amorphous Blend 531
 - 16.4.3 Role of Polymer Tacticity on Polymer Blend Morphologies 535

- 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
	<i>Hiroyuki Aoki</i>	
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
	<i>Ufana Riaz and Syed Marghoob Ashraf</i>	
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

20.7	Characterization of Natural Polymer Blends Using FTIR Spectroscopy	663
20.7.1	Collagen Blends	663
20.7.2	Chitosan Blends	664
20.8	Study of Blends by Polarization Modulation and 2D-FTIR Spectroscopy	665
20.9	Analysis of Polymer Blends Using FTIR Microspectroscopy	668
20.10	Conclusions	669
	Acknowledgments	670
	Abbreviations	670
	References	671
21	Characterization of Polymer Blends with Solid-State NMR Spectroscopy	679
	<i>Mohammad Mahdi Abolhasani and Vahid Karimkhani</i>	
21.1	Introduction	679
21.2	Miscibility	680
21.3	Proton Spin-Lattice Relaxation Experiments	680
21.4	Experiments for the Direct Observation of Proton Spin-Diffusion	688
21.5	Molecular Dynamics	692
21.5.1	² H NMR Line Shape Analysis	692
21.5.2	Polarization Inversion Spin Exchange at the Magic Angle (PISEMA) Experiment	694
21.5.3	Two-Dimensional Wideline Separation (WISE) NMR	695
21.6	Organic Solar Cells	696
21.7	Conclusions	700
	References	702
22	Characterization of Polymer Blends by Infrared, Near-Infrared, and Raman Imaging	705
	<i>Harumi Sato, Miriam Unger, Dieter Fischer, Yukihiro Ozaki, and Heinz W. Siesler</i>	
22.1	Instrumentation for Mid-Infrared and Near-Infrared Imaging	705
22.2	Raman Microspectroscopy	709
22.3	Characterization of Polymer Blends by FT-IR Imaging	711
22.3.1	Investigation of Phase Separation in Biopolymer Blends	711
22.3.1.1	Poly((3-Hydroxybutyrate)(PHB)/Poly(L-Lactic Acid)(PLA) Blends	711
22.3.1.2	FT-IR Imaging of Anisotropic PHB/PLA Blend Films	714
22.3.1.3	Variable-Temperature FT-IR and Raman Imaging Spectroscopy of a Phase-Separated PHB/PLA 50/50 wt% Blend Film	717
22.3.1.4	FT-IR Imaging of the State of Order of PHB/PCL Blend Films	720
22.3.1.5	FT-IR and FT-NIR Imaging of the Spherulitic Structure of Poly(3-Hydroxy-Butyrate) and Cellulose Acetate Butyrate Blends	724

- 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
	<i>Gabriel Bernardo and Jorge Morgado</i>	
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
	<i>Samy A. Madbouly and Michael R. Kessler</i>	
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
	<i>Chikkakuntappa Ranganathaiah</i>	
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