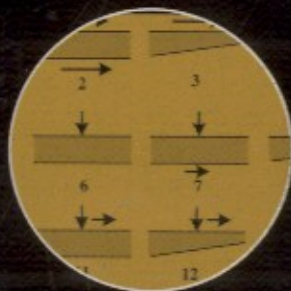
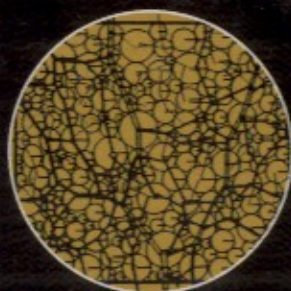


 WILEY



# PRINCIPLES OF POLYMER PROCESSING

SECOND EDITION



ZEHEV TADMOR • COSTAS G. GOGOS

# Contents

- 1 *History, Structural Formulation of the Field Through Elementary Steps, and Future Perspectives, 1***
  - 1.1 Historical Notes, 1
  - 1.2 Current Polymer Processing Practice, 7
  - 1.3 Analysis of Polymer Processing in Terms of Elementary Steps and Shaping Methods, 14
  - 1.4 Future Perspectives: From Polymer Processing to Macromolecular Engineering, 18
  
- 2 *The Balance Equations and Newtonian Fluid Dynamics, 25***
  - 2.1 Introduction, 25
  - 2.2 The Balance Equations, 26
  - 2.3 Reynolds Transport Theorem, 26
  - 2.4 The Macroscopic Mass Balance and the Equation of Continuity, 28
  - 2.5 The Macroscopic Linear Momentum Balance and the Equation of Motion, 32
  - 2.6 The Stress Tensor, 37
  - 2.7 The Rate of Strain Tensor, 40
  - 2.8 Newtonian Fluids, 43
  - 2.9 The Macroscopic Energy Balance and the Bernoulli and Thermal Energy Equations, 54
  - 2.10 Mass Transport in Binary Mixtures and the Diffusion Equation, 60
  - 2.11 Mathematical Modeling, Common Boundary Conditions, Common Simplifying Assumptions, and the Lubrication Approximation, 60
  
- 3 *Polymer Rheology and Non-Newtonian Fluid Mechanics, 79***
  - 3.1 Rheological Behavior, Rheometry, and Rheological Material Functions of Polymer Melts, 80
  - 3.2 Experimental Determination of the Viscosity and Normal Stress Difference Coefficients, 94
  - 3.3 Polymer Melt Constitutive Equations Based on Continuum Mechanics, 100
  - 3.4 Polymer Melt Constitutive Equations Based on Molecular Theories, 122

**4 *The Handling and Transporting of Polymer Particulate Solids, 144***

- 4.1 Some Unique Properties of Particulate Solids, 145
- 4.2 Agglomeration, 150
- 4.3 Pressure Distribution in Bins and Hoppers, 150
- 4.4 Flow and Flow Instabilities in Hoppers, 152
- 4.5 Compaction, 154
- 4.6 Flow in Closed Conduits, 157
- 4.7 Mechanical Displacement Flow, 157
- 4.8 Steady Mechanical Displacement Flow Aided by Drag, 159
- 4.9 Steady Drag-induced Flow in Straight Channels, 162
- 4.10 The Discrete Element Method, 165

**5 *Melting, 178***

- 5.1 Classification and Discussion of Melting Mechanisms, 179
- 5.2 Geometry, Boundary Conditions, and Physical Properties in Melting, 184
- 5.3 Conduction Melting without Melt Removal, 186
- 5.4 Moving Heat Sources, 193
- 5.5 Sintering, 199
- 5.6 Conduction Melting with Forced Melt Removal, 201
- 5.7 Drag-induced Melt Removal, 202
- 5.8 Pressure-induced Melt Removal, 216
- 5.9 Deformation Melting, 219

**6 *Pressurization and Pumping, 235***

- 6.1 Classification of Pressurization Methods, 236
- 6.2 Synthesis of Pumping Machines from Basic Principles, 237
- 6.3 The Single Screw Extruder Pump, 247
- 6.4 Knife and Roll Coating, Calenders, and Roll Mills, 259
- 6.5 The Normal Stress Pump, 272
- 6.6 The Co-rotating Disk Pump, 278
- 6.7 Positive Displacement Pumps, 285
- 6.8 Twin Screw Extruder Pumps, 298

**7 *Mixing, 322***

- 7.1 Basic Concepts and Mixing Mechanisms, 322
- 7.2 Mixing Equipment and Operations of Multicomponent and Multiphase Systems, 354
- 7.3 Distribution Functions, 357
- 7.4 Characterization of Mixtures, 378
- 7.5 Computational Analysis, 391

**8 *Devolatilization, 409***

- 8.1 Introduction, 409
- 8.2 Devolatilization Equipment, 411
- 8.3 Devolatilization Mechanisms, 413

- 8.4 Thermodynamic Considerations of Devolatilization, 416
  - 8.5 Diffusivity of Low Molecular Weight Components in Molten Polymers, 420
  - 8.6 Boiling Phenomena: Nucleation, 422
  - 8.7 Boiling–Foaming Mechanisms of Polymeric Melts, 424
  - 8.8 Ultrasound-enhanced Devolatilization, 427
  - 8.9 Bubble Growth, 428
  - 8.10 Bubble Dynamics and Mass Transfer in Shear Flow, 430
  - 8.11 Scanning Electron Microscopy Studies of Polymer Melt Devolatilization, 433
- 9 *Single Rotor Machines, 447***
- 9.1 Modeling of Processing Machines Using Elementary Steps, 447
  - 9.2 The Single Screw Melt Extrusion Process, 448
  - 9.3 The Single Screw Plasticating Extrusion Process, 473
  - 9.4 The Co-rotating Disk Plasticating Processor, 506
- 10 *Twin Screw and Twin Rotor Processing Equipment, 523***
- 10.1 Types of Twin Screw and Twin Rotor–based Machines, 525
  - 10.2 Counterrotating Twin Screw and Twin Rotor Machines, 533
  - 10.3 Co-rotating, Fully Intermeshing Twin Screw Extruders, 572
- 11 *Reactive Polymer Processing and Compounding, 603***
- 11.1 Classes of Polymer Chain Modification Reactions, Carried out in Reactive Polymer Processing Equipment, 604
  - 11.2 Reactor Classification, 611
  - 11.3 Mixing Considerations in Multicomponent Miscible Reactive Polymer Processing Systems, 623
  - 11.4 Reactive Processing of Multicomponent Immiscible and Compatibilized Immiscible Polymer Systems, 632
  - 11.5 Polymer Compounding, 635
- 12 *Die Forming, 677***
- 12.1 Capillary Flow, 680
  - 12.2 Elastic Effects in Capillary Flows, 689
  - 12.3 Sheet Forming and Film Casting, 705
  - 12.4 Tube, Blown Film, and Parison Forming, 720
  - 12.5 Wire Coating, 727
  - 12.6 Profile Extrusion, 731
- 13 *Molding, 753***
- 13.1 Injection Molding, 753
  - 13.2 Reactive Injection Molding, 798
  - 13.3 Compression Molding, 811

**14 *Stretch Shaping, 824***

**14.1** Fiber Spinning, 824

**14.2** Film Blowing, 836

**14.3** Blow Molding, 841

**15 *Calendering, 865***

**15.1** The Calendering Process, 865

**15.2** Mathematical Modeling of Calendering, 867

**15.3** Analysis of Calendering Using FEM, 873

**Appendix A *Rheological and Thermophysical Properties of Polymers, 887***

**Appendix B *Conversion Tables to the International System of Units (SI), 914***

**Appendix C *Notation, 918***

**Author Index, 929**

**Subject Index, 944**