

# Contents

<b>Résumé</b>	<b>i</b>
<b>Zusammenfassung</b>	<b>v</b>
<b>Abstract</b>	<b>ix</b>
<b>Table of Contents</b>	<b>xii</b>
<b>List of Figures</b>	<b>xvii</b>
<b>List of Tables</b>	<b>xxviii</b>
<b>Nomenclature</b>	<b>xxxi</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Main Objectives . . . . .	6
1.2 Organization of Thesis . . . . .	7
1.3 Flow Kinematics and Stress Tensor of Deformable Bodies . . . . .	8
1.3.1 Simple Shear . . . . .	9
1.3.2 Uniaxial Extension . . . . .	10
1.4 Supplementary Characterization Techniques . . . . .	10
1.4.1 Differential Scanning Calorimetry (DSC) . . . . .	11
1.4.2 Light Scattering . . . . .	11
1.4.3 Gel Permeation Chromatography (GPC) . . . . .	12
1.4.4 Scanning Electron Microscopy (SEM) . . . . .	13
<b>2 Constitutive Models to Predict the Linear and Nonlinear Viscoelastic Response of Polymer Melts</b>	<b>15</b>

## **Contents**

---

2.1	Constitutive Models for the prediction of Linear Viscoelastic Properties . . . . .	17
2.1.1	Maxwell Model . . . . .	19
2.1.2	Models Based on the Tube Theory . . . . .	20
2.2	Constitutive Models for Prediction of the Non-linear Viscoelastic Properties . . . . .	23
2.2.1	Dumbbell Theory: Giesekus Model . . . . .	24
2.2.2	Models Based on the Tube Theory . . . . .	24
2.3	Concluding Remarks on Various Constitutive Models Discussed in the Chapter 2	29
<b>3</b>	<b>FT-Rheology and Stress-Decomposition Techniques For the Analysis of LAOS Responses</b>	<b>31</b>
3.1	FT-Rheology . . . . .	32
3.1.1	Shear Stress . . . . .	35
3.1.2	Normal Stress Difference . . . . .	41
3.2	Stress Decomposition . . . . .	44
3.3	Conclusions of Chapter 3 . . . . .	51
<b>4</b>	<b>Linear and Non-linear Viscoelasticity of Polystyrene Melts and its Blends using FT-Rheology</b>	<b>53</b>
4.1	Materials and Methods . . . . .	54
4.1.1	Materials . . . . .	54
4.1.2	Rheological Measurement Protocol . . . . .	55
4.2	Results and Discussion . . . . .	56
4.3	Concluding Remarks on the Characterization of Monodisperse PS melts and its Blends using FT-Rheology . . . . .	65
<b>5</b>	<b>LAOS and Uniaxial Extensional Rheology of Blends from Linear and Long-Chain Branched Polyolefins</b>	<b>67</b>
5.1	Materials and Methods . . . . .	70
5.1.1	Materials . . . . .	70
5.1.2	Molecular Characterization . . . . .	71
5.1.3	Rheological Characterization Methods . . . . .	71
5.2	Results and Discussion . . . . .	72
5.2.1	Linear Viscoelasticity . . . . .	72
5.2.2	Non-linear Viscoelasticity: Large Amplitude Oscillatory Shear (LAOS) . . . . .	75

---

5.2.3 Nonlinear Viscoelasticity: Uniaxial Extensional Experiments and Molecular Stress Function (MSF) Model Simulations . . . . .	89
5.3 Concluding Remarks on the Characterization of LCB Using Oscillatory Shear and Uniaxial Extensional Rheology . . . . .	96
<b>6 Non-linear Viscoelasticity of Polymer Composites with Carbon Nanotubes Using FT-Rheology</b>	<b>97</b>
6.1 Materials and Experimental Protocols . . . . .	99
6.1.1 Materials: . . . . .	99
6.1.2 Nanocomposites Preparation: . . . . .	99
6.1.3 Rheological Characterization Method . . . . .	100
6.2 Results and Discussion . . . . .	100
6.3 Concluding Remarks on the Characterization of Polymer Composites using FT-Rheology . . . . .	107
<b>7 Solution Electrospinning: Fabrication of Scaffolds for the Tissue Engineering Applications</b>	<b>109</b>
7.1 Solution Electrospinning Process . . . . .	110
7.2 Parameters Affecting Diameter and Morphology of Electrospun Fibers . . . . .	113
7.2.1 Solution parameters . . . . .	113
7.2.2 Process parameters . . . . .	115
7.2.3 Environmental parameters . . . . .	117
7.3 New Way to Fabricating 3D cm-thick Hierarchical Foams via Solution Electrospinning . . . . .	118
7.3.1 Materials and Methods . . . . .	120
7.3.2 Self-assembly of electrospun fibers . . . . .	122
7.3.3 Temporal evolution of a self-assembled honeycomb patterns . . . . .	123
7.3.4 Mechanism of self-assembly and its temporal evolution . . . . .	126
7.3.5 Fabrication of 3D foams and physical characterization . . . . .	128
7.3.6 Mechanical characterization of 3D foam . . . . .	131
7.4 Conclusion and Future Perspective . . . . .	132
<b>8 Melt Electrospinning: Influence of Material and Process Parameters on Fiber Diameters and Morphology</b>	<b>135</b>

## Contents

---

8.1	Material and Methods . . . . .	137
8.1.1	Materials . . . . .	137
8.1.2	Rheological Characterization . . . . .	138
8.1.3	Configuration of Melt Electrospinning . . . . .	138
8.2	Results and Discussion . . . . .	140
8.3	Conclusion . . . . .	150
<b>9</b>	<b>Summary and Outlook</b>	<b>153</b>
<b>Appendix A</b>	<b>Analytical Solution of MSF Model Under MAOS Flow</b>	<b>157</b>
<b>Appendix B</b>	<b>Analysis of PP and PE Blends Using Steady Shear and Lissajous-Bowditch Curves</b>	<b>159</b>
B.1	Validity of Cox-Merz and Laun Rule for the PP and PE blends . . . . .	159
B.2	Lissajous-Bowditch Curves . . . . .	161
<b>Bibliography</b>		<b>165</b>
<b>Acknowledgment</b>		<b>181</b>
<b>CV</b>		<b>183</b>