

Contents

List of contributors	xiii
Woodhead Publishing Series in Biomaterials	xix
Preface	xxv
 Part One Chemistry, processing and applications of polyurethane biomaterials	 1
 1 Hierarchal structure–property relationships of segmented polyurethanes	 3
<i>T.J. Touchet and E.M. Cosgriff-Hernandez</i>	
1.1 Introduction	3
1.2 Structure of segmented polyurethanes	3
1.3 Soft segment chemistry	5
1.4 Hard segment chemistry	8
1.5 Microphase separation	10
1.6 Compositional effects on mechanical properties	12
1.7 Compositional effects on degradation rate	15
1.8 Summary and future perspectives	16
References	17
 2 Surface characterization techniques for polyurethane biomaterials	 23
<i>H. Zhang</i>	
2.1 Friction measurement	23
2.2 Contact angle	25
2.3 X-ray photoelectron spectroscopy	30
2.4 Secondary ion mass spectrometry	37
2.5 Scanning electron microscopy	38
2.6 Protein adsorption test	44
2.7 Hemocompatibility measurement	49
2.8 Antimicrobial efficacy test	51
2.9 Antibiofilm efficacy	56
Acknowledgments	64
References	64

3	Design of biodegradable polyurethanes and the interactions of the polymers and their degradation by-products within <i>in vitro</i> and <i>in vivo</i> environments	75
	<i>X. Zhang, K.G. Battiston, J.E. McBane, L.A. Matheson, R.S. Labow and J. Paul Santerre</i>	
3.1	Fundamentals of polyurethane degradation	75
3.2	Design of new degradable polyurethanes inspired by biodegradation mechanisms	77
3.3	<i>In vivo</i> testing of polyurethanes from 2005 to 2015	80
3.4	Coculture using degradable polyurethanes from 2005 to 2015	84
3.5	Degradable polyurethanes cultured with stem cells for tissue engineering applications	85
3.6	Degradable polyurethanes used in drug delivery systems	87
3.7	Physical forms and processing of degradable polyurethanes	89
3.8	Monomers and oligomers used in degradable polyurethanes	93
3.9	Summary	93
	References	104
4	Novel applications of urethane/urea chemistry in the field of biomaterials	115
	<i>G.B. Kim, J. Guo, J. Hu, D. Shan and J. Yang</i>	
4.1	Introduction	115
4.2	Citrate-based urethane-doped polyesters	116
4.3	Waterborne polyurethane biomaterials	130
4.4	Functionalization of polyurethanes and novel applications of urethane/urea chemistry	135
4.5	Conclusions and outlook	140
	Acknowledgments	141
	References	141
5	3D printing of polyurethane biomaterials	149
	<i>K.-C. Hung, C.-S. Tseng and S.-H. Hsu</i>	
5.1	Polyurethane as a candidate material for 3D printing	149
5.2	Applications of polyurethanes in 3D printing	156
5.3	Applications of biodegradable polyurethanes in 3D printing	158
5.4	Low-temperature printing process of waterborne biodegradable polyurethanes	160
5.5	Conclusion	162
	References	162
6	Nanoparticle-induced phenomena in polyurethanes	171
	<i>D.K. Patel, A. Biswas and P. Maiti</i>	
6.1	Introduction	171
6.2	Preparation of composites	173

6.3	Morphology	174
6.4	Structure	176
6.5	Nanoparticle-induced self-assembly	177
6.6	Mechanical behavior	178
6.7	Thermal behavior	182
6.8	Flame retardancy	184
6.9	Antimicrobial activity	184
6.10	Biomedical application of nanocomposites	185
6.11	Conclusions	187
	Acknowledgments	187
	References	188
7	Polyurethane nanoparticles, a new tool for biomedical applications?	195
	<i>G. Morral-Ruiz, P. Melgar-Lesmes, C. Solans and M.J. García-Celma</i>	
7.1	Introduction	195
7.2	Synthesis of polyurethane nanoparticles	196
7.3	Polyurethane nanoparticles as drug delivery systems	201
7.4	Polyurethane nanoparticles as diagnosis tools	207
7.5	Polyurethane nanoparticles as theranostic tools	208
7.6	Future trends	210
	References	211
8	Polyurethanes for controlled drug delivery	217
	<i>A. Basu, S. Farah, K.R. Kunduru, S. Doppalapudi, W. Khan and A.J. Domb</i>	
8.1	Introduction	217
8.2	Chemistry of polyurethanes	219
8.3	Use in drug delivery	220
8.4	Conclusion and future directions	238
	Abbreviations	239
	References	240
9	Antibacterial polyurethanes	247
	<i>L.-C. Xu and C.A. Siedlecki</i>	
9.1	Introduction	247
9.2	Antiadhesive polyurethanes	248
9.3	Bactericidal polyurethanes	258
9.4	Other strategies of antibacterial polyurethanes and future perspectives	271
	Acknowledgment	273
	References	273

Part Two	Polyurethanes for vascular applications	285
10	Regulating blood cell adhesion via surface modification of polyurethanes	287
	<i>J. Clauser, K. Gester, U. Steinseifer and S.J. Sonntag</i>	
10.1	Introduction	287
10.2	Blood-material interactions	288
10.3	Surface-liquid interactions	290
10.4	Chemical surface modification	292
10.5	Physical surface modification	301
10.6	Conclusion	312
	References	312
11	Enhancing polyurethane blood compatibility	319
	<i>K. Ishihara, Y. Liu and Y. Inoue</i>	
11.1	Introduction	319
11.2	Structural characteristics of segmented polyurethanes as blood-compatible materials	319
11.3	Utilizing bioactive molecules for surface modification to prevent thrombus formation	322
11.4	Modification of PU with functional groups	323
11.5	Blending of a polymer with a PC group to improve blood compatibility	334
11.6	Concluding remarks	340
	References	341
12	Antimicrobial polyurethanes for intravascular medical devices	349
	<i>I. Francolini and A. Piozzi</i>	
12.1	Introduction	349
12.2	PU's in intravascular applications	350
12.3	Infections associated with intravascular devices	353
12.4	Pathogenesis of intravascular device-related infections	358
12.5	Prevention of intravascular device-related infections	362
12.6	Future perspectives	372
	References	373
13	Polyurethanes for cardiac applications	387
	<i>M. Boffito, S. Sartori, C. Mattu and G. Ciardelli</i>	
13.1	Introduction: cardiovascular diseases	387
13.2	Polyurethanes in cardiovascular applications	389
13.3	Polyurethanes in heart valve replacement	389
13.4	Cardiac tissue engineering/regenerative medicine	394
13.5	Polyurethane devices for drug delivery in cardiovascular applications	405
13.6	General conclusions	407
	References	408

14 Nitric oxide-releasing polyurethanes	417
<i>J. Pant, M.J. Goudie, E.J. Brisbois and H. Handa</i>	
14.1 Introduction	417
14.2 Nitric oxide-releasing/generating polyurethanes	421
14.3 Biomedical applications of nitric oxide-releasing polyurethanes	423
14.4 Conclusion	437
References	438
15 Mechanical behavior of polyurethane-based small-diameter vascular grafts	451
<i>F. Montini-Ballarin, G.A. Abraham and P.C. Caracciolo</i>	
15.1 Vascular tissues: structure, diseases, and current treatments	451
15.2 The importance of a biomimetic mechanical response	452
15.3 Characterization of mechanical behavior	454
15.4 Polyurethanes for vascular tissue engineering	456
15.5 Future trends and perspectives	471
References	471
Part Three Polyurethane scaffolds for tissue engineering	479
16 Polyurethanes for bone tissue engineering	481
<i>S. Fernando, M. McEnery and S.A. Guelcher</i>	
16.1 Introduction	481
16.2 Chemistry of polyurethane bone grafts	481
16.3 Bone grafting	483
16.4 Osteoconductive bone grafts	486
16.5 Biologically active bone grafts	492
References	496
17 Antimicrobial nanostructured polyurethane scaffolds	503
<i>S. Chung and T.J. Webster</i>	
17.1 Introduction	503
17.2 Techniques for constructing polyurethanes scaffolds	503
17.3 Strategies to impart antibacterial activity to polyurethanes	509
17.4 Conclusions and future directions	513
References	514
18 Interaction of cells with polyurethane scaffolds	523
<i>Y. Xu and J. Guan</i>	
18.1 Introduction	523
18.2 Interaction of cells with fibrous polyurethane scaffolds	523
18.3 Interaction of stem cells with microporous polyurethane scaffolds	532
18.4 Interaction of cells with other types of polyurethane scaffolds	535

18.5	Current challenges to understanding the effect of polyurethane scaffold properties on cell fate	536
18.6	Future perspectives	537
	References	538
19	Electrospun fibrous polyurethane scaffolds in tissue engineering	543
	<i>Y. Hong</i>	
19.1	Introduction	543
19.2	Electrospinning technique and apparatus	543
19.3	Factors that affect the electrospinning process	545
19.4	Methods to enhance cellular infiltration of electrospun scaffolds	548
19.5	Electrospun polyurethane scaffolds in tissue engineering applications	552
19.6	Summary and future trends	556
	Acknowledgments	557
	References	557
20	Embolic applications of shape memory polyurethane scaffolds	561
	<i>T.L. Landsman, A.C. Weems, S.M. Hasan, R.S. Thompson, T.S. Wilson and D.J. Maitland</i>	
20.1	Introduction	561
20.2	Embolization and occlusion	569
20.3	Why shape memory polymer scaffolds?	579
20.4	The future of shape memory polymer scaffolds	584
	References	588
21	Scaffolds of biodegradable block polyurethanes for nerve regeneration	599
	<i>K.T. Xu, Y.Q. Niu, Y.H. Zhu, X.Y. Liu and C. Liu</i>	
21.1	Introduction	599
21.2	Experimental procedures	601
21.3	Results and discussion	607
21.4	Conclusions	626
	Acknowledgments	626
	References	626
22	The use of biodegradable polyurethane in the development of dermal scaffolds	631
	<i>J.E. Greenwood and M.J.D. Wagstaff</i>	
22.1	Introduction	631
22.2	Why are dermal substitutes necessary?	631
22.3	Skin structure and function	634
22.4	The ideal dermal substitute	634
22.5	Development history of NovoSorb™ biodegradable temporizing dermal matrix for major burn injury	638

22.6	Proof of concept of cultured composite skin on biodegradable temporizing dermal matrix	642
22.7	Human trials	648
22.8	The first use of biodegradable temporizing dermal matrix in moderate to severe burn repair	654
22.9	Conclusions	661
	References	661
Index		663