

Contents

List of contributors	xi
Woodhead Publishing Series in Energy	xv

Part One Membrane processes and membrane preparation 1

1 Advance membrane separation processes for biorefineries	3
<i>S. Curcio, G. De Luca, K. Saha, S. Chakraborty</i>	
1.1 Introduction	3
1.2 Lignocellulose biomass	4
1.3 Second-generation bioethanol production	6
1.4 Biodiesel	10
1.5 Biogas	10
1.6 Recovery of valuable chemical feedstock from waste biomass and biofuel production	11
1.7 Biocatalytic membrane reactor and principals and application to biorefining	16
1.8 Multiscale modeling of bioreactors aimed at second-generation biofuels from waste biomasses	18
1.9 Future trends in biorefinery	23
1.10 Conclusions	23
List of acronyms	24
References	25
2 Polymeric membranes in biorefinery	29
<i>A. Figoli, T. Marino, F. Galiano</i>	
2.1 Introduction	29
2.2 Preparation of polymeric membranes	30
2.3 Application of polymeric membranes in biorefinery	37
2.4 Conclusions and future challenges	52
List of acronyms	53
References	54
3 Mixed-matrix membranes: preparation and characterization for biorefining	
<i>L. Donato, A. Garofalo, C. Algieri</i>	61
3.1 Introduction	
3.2 Preparation of mixed-matrix membranes	61
3.3 Characterization of mixed-matrix membranes	62
	65

3.4	Mixed-matrix membranes in biorefinery processes	67
3.5	Conclusion and future perspectives	76
	List of symbols	77
	List of acronyms	77
	References	78
4	Organic–inorganic composite membrane preparation and characterization for biorefining	85
	<i>M.S. Seyed Dorraji, V. Vatanpour</i>	
4.1	Introduction	85
4.2	Inorganic–organic composite membranes	85
4.3	Application in biorefineries	92
4.4	Conclusion and future trends	97
	List of acronyms	97
	References	98
Part Two	Integrated membrane operations for the recovery of chemical feedstocks	103
5	Membranes for lignin and hemicellulose recovery in pulp mills	105
	<i>A.-S. Jönsson</i>	
5.1	Introduction	105
5.2	Raw materials for pulp production	106
5.3	Pulping processes	108
5.4	Sulphite pulping	108
5.5	Kraft pulping	109
5.6	Dissolving pulp	116
5.7	Thermomechanical pulping	117
5.8	Chemithermomechanical pulping	123
5.9	Conclusions and future trends	124
	List of acronyms	125
	References	126
6	Membranes for the recovery of organic acids from fermentation broths	135
	<i>C. Jiang, Y. Wang, T. Xu</i>	
6.1	Introduction	135
6.2	Clarification of fermentation broth using microfiltration and nanofiltration	137
6.3	Electro-driven process for organic acid production	140
6.4	Industrialization	150
6.5	Some other classical types of integration of membrane process for organic acid recovery	153
6.6	Challenges and perspective	155

6.7	Conclusion and future trends	156
	List of acronyms	156
	Acknowledgments	157
	References	157
7	Recovery of polyphenols from olive mill wastewaters by membrane operations	163
	<i>A. Cassano, C. Conidi, C.M. Galanakis, R. Castro-Muñoz</i>	
7.1	Introduction	163
7.2	Valorization methods	165
7.3	Integrated membrane processes	173
7.4	Conclusions and future trends	181
	List of acronyms	182
	References	182
8	Recovery of high-added-value compounds from food waste by membrane technology	189
	<i>C.M. Galanakis, R. Castro-Muñoz, A. Cassano, C. Conidi</i>	
8.1	Introduction	189
8.2	Separation of functional micromolecules and macromolecules from food waste	191
8.3	Recovery of high-added-value compounds using ultrafiltration	201
8.4	Recovery of high-added-value compounds by nanofiltration	205
8.5	Economic framework of membrane technology for recovery of valuable solutes	206
8.6	Conclusions and future trends	207
	List of acronyms	210
	References	210
Part Three	Integrated membrane operations for biofuel production	217
9	Membranes for the removal of fermentation inhibitors from biofuel production	219
	<i>X. Qian, M. Malmali, S.R. Wickramasinghe</i>	
9.1	Introduction	219
9.2	Types of inhibitors	221
9.3	Detoxification processes	225
9.4	Membrane-based detoxification processes	226
9.5	Conclusions and future directions	233
	List of symbols	234
	Acknowledgment	234
	References	234

10	Membranes for ethanol dehydration	241
	<i>I.T. Meireles, C. Brazinha, I.M. Coelho, J.G. Crespo</i>	
10.1	Introduction	241
10.2	Hydrophilic pervaporation	243
10.3	Pervaporation membranes	244
10.4	Conclusions and future trends	257
	List of symbols	257
	List of acronyms	258
	References	259
11	Bio-oil production and upgrading: new challenges for membrane applications	263
	<i>V. Piemonte, M. Capocelli, G. Orticello, L. Di Paola</i>	
11.1	Introduction	263
11.2	Thermal conversion of biomass to liquid	267
11.3	Separation processes	274
11.4	Membrane-based separation processes	275
11.5	Bio-oil upgrading	278
11.6	Conclusions and future trends	283
	References	284
12	Biodiesel production and purification using membrane technology	289
	<i>M.H.M. Reis, V.L. Cardoso</i>	
12.1	Introduction	289
12.2	Biodiesel production process	290
12.3	Biodiesel purification by wet and dry washing	294
12.4	Membrane separation processes for biodiesel purification	295
12.5	Intensified process: membrane reactors	299
12.6	Conclusions and future trends	302
	References	303
13	Algae harvesting	309
	<i>S. Cheruvu, S. Van Ginkel, X. Wei, X. Zhang, D. Steiner, S.H. Rego De Oliveira, C. Xu, L.H. Kalil Duarte, E. Salvi, Z. Hu, H.J. Lee, R. Gijon-Felix, Y. Chen</i>	
13.1	Introduction	309
13.2	Algae harvesting	310
13.3	Membrane filtration: advantages and disadvantages	319
13.4	Current membrane design	322
13.5	Water and nutrient recycling	322
13.6	Conclusion and future trends	325
	References	325

Part Four	Membrane reactors	329
14	Pervaporation membrane reactors: biomass conversion into alcohols	331
	<i>A. Amelio, B. Van der Bruggen, C. Lopresto, A. Verardi, V. Calabro, P. Luis</i>	
14.1	Introduction	331
14.2	Production of bioalcohols	332
14.3	Biobutanol	336
14.4	Industrial processes	342
14.5	Application of PV for bioalcohol production	349
14.6	Current alternatives to membrane reactors	357
14.7	Other applications of membrane PV reactors	358
14.8	Conclusions and future trends	359
	List of acronyms	361
	Acknowledgments	363
	References	363
15	Membrane reactors for methanol synthesis from forest-derived feedstocks	383
	<i>M.R. Rahimpour, Z. Dehghani</i>	
15.1	Introduction	383
15.2	Biomass feedstocks	384
15.3	Issues confronting biomass	386
15.4	Biomass-to-energy conversion technologies	386
15.5	Types of biomass gasifiers	390
15.6	Methanol	393
15.7	Synthesis gas-to-methanol conversion	395
15.8	Conventional methanol synthesis reactor	396
15.9	Process deficiencies and modifications	398
15.10	Membrane technology	398
15.11	Membrane reactor for methanol synthesis	399
15.12	Parameters affecting methanol synthesis in a membrane reactor	401
15.13	Economic evaluations	403
15.14	Conclusion and future trends	403
	References	404
16	Hydrogen production from pyrolysis-derived bio-oil using membrane reactors	411
	<i>M.R. Rahimpour, M. Nategh</i>	
16.1	Introduction	411
16.2	Conventional methods for hydrogen production	412

16.3	Major drawbacks of conventional methods	416
16.4	Hydrogen production from pyrolysis-derived bio-oil	416
16.5	Membrane technology	420
16.6	Hydrogen-selective membrane materials	420
16.7	Desired hydrogen-selective membrane material	423
16.8	Membrane reactor configuration	423
16.9	Factors affecting hydrogen production in a membrane reactor	425
16.10	Conclusion and future trends	426
	List of acronyms	426
	References	427
17	Membrane reactors for hydrogen production from biomass-derived oxygenates	435
	<i>K. Ghasemzadeh, S.M. Sadati Tilebon, A. Basile</i>	
17.1	Introduction	435
17.2	Different technologies of hydrogen production from biomass-derived oxygenates	436
17.3	Membrane reactors for hydrogen production from biomass-derived oxygenates	438
17.4	Conclusion and future trends	458
	List of acronyms	459
	References	461
18	Biomethane production by biogas with polymeric membrane module	465
	<i>A. Molino, P. Iovane, M. Migliori</i>	
18.1	Introduction	465
18.2	Production of biomethane	467
18.3	Applications of biomethane	473
18.4	Conclusions and future trends	479
	References	480
	Index	483