
Table of Contents

1	INTRODUCTION	1
	References	3
2	SYNTHETIC MEMBRANES FOR MEMBRANE PROCESSES	5
2.1	Introduction	5
2.2	Membrane Preparation	6
2.2.1	Membranes with Symmetric Structure	6
2.2.2	Membranes with Asymmetric Structure	6
2.2.2.1	Phase Inversion Technique for Preparation of Integrally Skinned Asymmetric Membranes ...	7
2.2.2.2	Preparation of Composite Membranes	8
2.2.2.3	Membrane Surface Modification	9
2.2.3	Membrane Drying	10
2.3	Membranes for Separation Processes	11
2.3.1	Membranes for the Separation of Solutions and Solvent Mixtures	11
2.3.1.1	Reverse Osmosis Membranes	11
2.3.1.2	Nanofiltration Membranes	11
2.3.1.3	Ultrafiltration Membranes	11
2.3.1.4	Microfiltration Membranes	12
2.3.2	Membranes for Gas and Vapor Separation	12
2.3.3	Membranes for Pervaporation and Membrane Distillation .	14
2.3.3.1	Pervaporation	14
2.3.3.2	Membrane Distillation	14
2.3.4	Membranes for Other Separation Processes	15
2.3.4.1	Electrodialysis	15
2.3.4.2	Dialysis	15
2.4	Membrane Applications	15
2.5	Membrane Characterization	17
	References	18
3	ATOMIC FORCE MICROSCOPY	19
3.1	Introduction	19
3.1.1	Terms and Abbreviations	22

3.1.2	Advantages and Disadvantages of AFM	22
3.2	AFM: Principles and Applications	23
3.2.1	AFM Principles	23
3.2.2	Components of AFM Equipment	26
3.2.3	Different AFM Modes	30
3.2.3.1	Forces Working in AFM	30
3.2.3.2	AFM Modes of Operation	31
3.2.3.3	Contact Mode	32
3.2.3.4	Non-contact Mode	32
3.2.3.5	Tapping Mode	33
3.2.4	More Information about the Cantilever	34
3.2.5	Phase Imaging and Roughness Parameters	38
3.2.5.1	Image Display by AFM	38
3.2.5.2	AFM Imaging	38
3.2.5.3	Phase Imaging	38
3.2.5.4	Roughness Parameters	38
3.2.5.5	Key Measurements from AFM	39
3.3	Instructions for AFM Experiments	39
3.4	AFM Applications for Synthetic Membranes	43
3.5	Summary	43
	References	45
4	NODULAR STRUCTURE OF POLYMERS IN THE MEMBRANE	47
4.1	Introduction	47
4.1.1	Nodular Structure on the Membrane Surface: Images of Transmission Electron Microscopy and Scanning Electron Microscopy	50
4.1.2	Studies of Nodules by AFM	51
4.2	Flat Sheet Membranes	52
4.2.1	Nodular Structure of the Top Surface	52
4.2.2	Nodular Structure under the Top Surface: Plasma Treatment	62
4.2.2.1	Functionalization of Surface by Plasma Treatment	62
4.2.2.2	Plasma Etching	69
4.3	Hollow Fiber Membranes	73
4.4	Effects of Membrane Preparation and Posttreatment Parameters on the Nodular Size	84
4.5	Summary	94
	References	99
5	PORE SIZE, PORE SIZE DISTRIBUTION, AND ROUGHNESS AT THE MEMBRANE SURFACE	101
5.1	Introduction	101
5.1.1	Porous Structure of the Membrane Surface, SEM	102
5.1.2	Porous Structure of Membrane Surface, AFM	103
5.2	Pore Size and Pore Size Distribution at the Membrane Surface	104

5.2.1	Determination of Pore Size and Pore Size Distribution by AFM	104
5.2.2	Comparison with Other Methods	116
5.2.3	Effects of Membrane Preparation and Posttreatment Parameters on Pore Size and Pore Size Distribution	123
5.3	Roughness of the Membrane Surface	128
5.3.1	Roughness Parameters	128
5.3.2	Effects of Membrane Preparation and Posttreatment Parameters on Roughness Parameters	129
5.4	Summary	138
	References	138
6	CROSS-SECTIONAL AFM IMAGE	141
6.1	Introduction	141
6.2	Cross-sectional Images	141
6.2.1	Cross-sectional Images of Membranes by SEM	141
6.2.2	Cross-sectional Images of Membranes by AFM	147
6.3	Summary	154
	References	154
7	ADHESION	157
7.1	Introduction	157
7.2	Study of Adhesion Forces by AFM	160
7.3	Summary	166
	References	167
8	MEMBRANE SURFACE MORPHOLOGY AND MEMBRANE PERFORMANCE	169
8.1	Introduction	169
8.2	Relationship Between Membrane Morphology and Membrane Performance	170
8.2.1	Reverse Osmosis and Nanofiltration Membranes	170
8.2.2	Ultrafiltration Membranes	172
8.2.3	Pervaporation membranes	174
8.2.4	Gas separation membranes	174
8.2.5	Membranes for Other Membrane Processes	180
8.3	Surface Roughness and Membrane Fouling	183
8.4	AFM Study of the Dry and Wet Surfaces of the Membrane	188
8.5	Summary	189
	References	190
	SUBJECT INDEX	193