

---

## Table of Contents

<b>1</b>	<b>INTRODUCTION</b> .....	1
	References .....	3
<b>2</b>	<b>SYNTHETIC MEMBRANES FOR MEMBRANE PROCESSES</b> .....	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
<b>3</b>	<b>ATOMIC FORCE MICROSCOPY</b> .....	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
<b>4</b>	<b>NODULAR STRUCTURE OF POLYMERS IN THE MEMBRANE .....</b>	<b>47</b>
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
<b>5</b>	<b>PORE SIZE, PORE SIZE DISTRIBUTION, AND ROUGHNESS AT THE MEMBRANE SURFACE .....</b>	<b>101</b>
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
<b>6</b>	<b>CROSS-SECTIONAL AFM IMAGE .....</b>	<b>141</b>
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
<b>7</b>	<b>ADHESION .....</b>	<b>157</b>
7.1	Introduction .....	157
7.2	Study of Adhesion Forces by AFM .....	160
7.3	Summary .....	166
	References .....	167
<b>8</b>	<b>MEMBRANE SURFACE MORPHOLOGY AND MEMBRANE PERFORMANCE .....</b>	<b>169</b>
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
	<b>SUBJECT INDEX .....</b>	<b>193</b>