

Contents

Preface	<i>ix</i>
About the Authors	<i>xi</i>
Acknowledgment	<i>xiii</i>
Abbreviations and Symbols	<i>xv</i>

1	Introduction	1
1.1	Membrane Development at a Glance	1
1.2	Two-Dimensional Membranes	1
1.3	Separation Mechanisms of 2D Membranes	2
1.4	Fabrication Methods for 2D Membranes	4
1.5	Applications of 2D Membranes	6
	References	6
2	Types of 2D Material-Based Membranes	9
2.1	Porous Two-Dimensional Nanosheet-Based Membranes	9
2.1.1	Zeolite 2D Membranes	9
2.1.2	Metal–Organic Framework 2D Membranes	10
2.1.3	Covalent Organic Framework (COF) 2D Membranes	11
2.1.4	Graphitic Carbon Nitride (g-C ₃ N ₄) Membranes	12
2.2	Nonporous 2D Nanosheet-Based Membranes	13
2.2.1	Graphene-Based Membranes	13
2.2.2	Layered Double Hydroxide (LDH) Membranes	15
2.2.3	Transition Metal Dichalcogenide (TMD) Membranes	15
2.2.4	MXene Membranes (Typically Ti ₃ C ₂ T _x)	16
	References	18
3	MXene Nanosheets and Membranes	25
3.1	Preparation and Characterization of MXene Nanosheets	25
3.1.1	Top-down Synthesis	25
3.1.2	Bottom-up Synthesis	31
3.2	Preparation and Characterization of MXene Membranes	34
	References	40

4	MXene Membranes for Nanofiltration	43
4.1	Introduction	43
4.2	Separation Performance of MXene-Based Nanofiltration Membranes	44
4.3	Summary	57
	References	57
5	MXene Membranes for the Isolation of Antibiotics	61
5.1	Introduction	61
5.2	Physical Adsorption	62
5.3	Advanced Oxidation	68
5.4	Membrane Separation	72
5.5	Summary	84
	References	84
6	MXene-Based Membranes for Gas Separation	89
6.1	Introduction	89
6.2	Gas Separation Performance of MXene-Based Membranes	90
6.3	Summary	101
	References	102
7	MXene Membranes for Ion Separation	105
7.1	Introduction	105
7.2	Self-cross-linked MXene Membranes for Monovalent Metal Ion Sieving	106
7.2.1	Preparation of Self-cross-linked MXene Membranes	106
7.2.2	Monovalent Metal Ion-sieving Performance of Self-cross-linked MXene Membranes	107
7.2.3	Characterization of Self-cross-linked MXene Membranes	109
7.3	Thermally Cross-Linked MXene Membranes for Heavy Metal Ion Separation by a Voltage-supported Process	112
7.3.1	Mixed-ion Sieving and Exclusion of the Heavy Metal Ion Pb^{2+}	113
7.3.2	Characterization of Thermally Cross-Linked MXene Membranes	115
7.4	Ultrathin MXene-Derived Membranes by Sinter-cross-linking with Tunable Interlayer Spacing	117
7.4.1	Properties and Ion-rejection Performance of Sinter-cross-linked MXene Membranes	117
7.4.2	Characterization of Sinter-cross-linked MXene Membranes and MXene Nanosheets at Different Sintering Temperatures	120
7.5	Al^{3+} -cross-linked MXene Membranes	121
7.5.1	Preparation and Characterization of Al^{3+} -cross-linked MXene Membranes	122
7.5.2	Ion-sieving Performance of Al^{3+} -cross-linked MXene Membranes	123
7.6	Summary	126
	References	126

8	MXene Membrane for Oil/Water Emulsion Separation	129
8.1	Introduction	129
8.2	Functional Polymer Layer on Support	130
8.3	Low-Dimensional Materials	134
8.4	Summary	151
	References	151
9	MXene Membranes for Salinity Gradient Energy Conversion	157
9.1	Introduction	157
9.2	Performance of MXene Membranes for Salinity Gradient Energy Conversion	158
9.3	Summary	169
	References	170
10	Scale-Up of MXene Membranes	175
10.1	Introduction	175
10.2	Scale-Up of 2D Membranes	176
10.2.1	Spin Coating	177
10.2.2	Spray Coating	177
10.2.3	Drop Coating and Dip Coating	179
10.2.4	Doctor Blade Method	179
10.2.5	Electrophoretic Deposition (EPD)	181
10.3	Summary	191
	References	192
11	Perspectives	197
11.1	Further Applications of MXene Nanosheets	197
11.2	Challenges and Outlook for MXene Membranes	198
11.2.1	Stability of MXene Nanosheets Must Be Improved	198
11.2.2	Scalable Fabrication of MXene Membranes with Suitable Interlayer Channels Is Required	198
11.2.3	Operating Time of MXene Membranes under Realistic Operation Conditions Must Be Extended	199
11.2.4	Fundamentals of Mass Transport Mechanisms in Confined Nanochannels/Sub-nanochannels Within MXene Membranes Has to Be Studied	199
	References	200
	Index	203