
List of Figures

Figure No.	Title	Page no.
1.1	Classification of polymeric membranes	2
1.2	Milestones in the development of polymeric membranes	4
1.3	Structure of Polysulphone (PSU)	6
1.4	Structure of Polyether sulphone (PES)	7
1.5	Various membrane preparation methods	9
1.6	Carbon Nanotubes (CNTs)	11
1.7	Single walled carbon nanotubes (SWCNT) and Multiwalled carbon nanotubes (MWCNT)	12
1.8	Methods for the synthesis of Multiwalled carbon nanotubes (MWCNT)	15
1.9	Surface Modification of membrane techniques	21
1.10	Chemical modification techniques	24
2.1	Surface modification of membranes and their characterization	31
3.1	Functionalization of multiwalled carbon nanotubes (MWCNTs)	36
3.2	Preparation of polysulphones mixed matrix membrane via phase inversion process	37
3.3	Scheme for the surface modification of polysulfone/azide-MWCNT mixed matrix membrane via click reaction	38
3.4	Scheme for the surface modification of polysulphones/amine-MWCNT mixed matrix membrane using TMC and CC	40
3.5	Scheme for the surface modification of polysulphones/oxidized-MWCNT mixed matrix membrane with PEI	40
3.6	FTIR spectra of Oxidized-MWCNTs	46
3.7	FTIR spectra of Amine-MWCNTs	47
3.8	FTIR spectra of Azide-MWCNTs	47
3.9	TEM images of (a) Oxidized-MWCNTs, (b) Amine-MWCNTs, (c) Azide-MWCNTs	49
3.10	N1s XPS spectra of modified Polysulphone/azide-MWCNTs mixed matrix membrane via click reaction	50

3.11	N1s XPS spectra of unmodified Polysulphone/azide-MWCNTs mixed matrix membrane via click reaction	51
3.12	Zeta potential values of Polysulphone/azide-MWCNT mixed matrix membrane	52
3.13	Zeta potential values of modified Polysulphone/azide-MWCNT mixed matrix membrane via click reaction	53
3.14	FTIR spectra of Poly ether sulphone/amine-MWCNT mixed matrix membrane, (a) unmodified, (b) modified with trimesoyl chloride (TMC), (c) modified with cyanuric chloride (CC).	54
3.15	FTIR spectra of Polysulphone/amine-MWCNT mixed matrix membrane, (a) unmodified, (b) modified with trimesoyl chloride (TMC), (c) modified with cyanuric chloride (CC)	55
3.16	N1s XPS spectra of Poly ether sulphone/amine-MWCNT mixed matrix membrane	56
3.17	N1s XPS spectra of Polysulphone/amine-MWCNT mixed matrix membrane	56
3.18	N1s XPS spectra of Poly ether sulphone/amine-MWCNT mixed matrix membrane modified using trimesoyl chloride (TMC)	57
3.19	N1s XPS spectra of Polysulphone/amine-MWCNT mixed matrix membrane modified using trimesoyl chloride (TMC)	57
3.20	N1s XPS spectra of Poly ether sulphone/amine-MWCNT mixed matrix membrane modified using cyanuric chloride (CC)	58
3.21	N1s XPS spectra of Polysulphone/amine-MWCNT mixed matrix membrane modified using cyanuric chloride (CC)	58
3.22	Zeta potential values of Polysulphone/amine-MWCNT mixed matrix membrane	60
3.23	Zeta potential values of Polysulphone/amine-MWCNT mixed matrix membrane modified using trimesoyl chloride (TMC)	60
3.24	Zeta potential values of Polysulphone/amine-MWCNT mixed matrix membrane modified using cyanuric chloride (CC)	61
3.25	FTIR spectra of Poly ether sulphone/oxidized-MWCNT mixed matrix membrane, (a) unmodified, (b) modified using polyethylenimine (PEI)	62
3.26	FTIR spectra of Polysulphone/oxidized-MWCNT mixed matrix membrane, (a) unmodified, (b) modified using polyethylenimine (PEI)	62
3.27	O1s XPS spectra of Polyether sulphone/oxidized-MWCNT mixed matrix membrane	64
3.28	O1s XPS spectra of Polysulphone/oxidized-MWCNT mixed matrix membrane	64

3.29	O1s XPS spectra of Polyether sulphone/oxidized-MWCNT mixed matrix membrane modified using polyethylenimine (PEI)	65
3.30	O1s XPS spectra of Polysulphone/oxidized-MWCNT mixed matrix membrane modified using polyethylenimine (PEI)	65
3.31	N1s XPS spectra of Polyether sulphone/oxidized-MWCNT mixed matrix membrane modified using polyethylenimine (PEI)	66
3.32	N1s XPS spectra of Polysulphone/oxidized-MWCNT mixed matrix membrane modified using polyethylenimine (PEI)	66
3.33	Zeta potential values of Polysulphone/oxidized-MWCNT mixed matrix membrane	67
3.34	Zeta potential values of Polysulphone/oxidized-MWCNT mixed matrix membrane modified using polyethylenimine (PEI)	68
4.1	Pure water flux of pristine Polysulphone, unmodified and modified polysulphone/azide-MWCNTs mixed matrix membrane via click reaction	70
4.2	Pure water flux of pristine Polyether sulphone, unmodified and modified polyether sulphone/amine-MWCNTs mixed matrix membrane using trimesoyl chloride (TMC) and cyanuric chloride (CC)	71
4.3	Pure water flux of pristine Polysulphone, unmodified and modified polysulphone/amine-MWCNTs mixed matrix membrane using trimesoyl chloride (TMC) and cyanuric chloride (CC)	72
4.4	Pure water flux of pristine Polyether sulphone, unmodified and modified polyether sulphone/oxidized-MWCNTs mixed matrix membrane using polyethylenimine (PEI)	74
4.5	Pure water flux of pristine Polysulphone, unmodified and modified polysulphone/oxidized-MWCNTs mixed matrix membrane using polyethylenimine (PEI)	75
4.6	Flux recovery ratio (FRR) and Irreversible Fouling ratio (R _{ir}) of Pristine Polysulphone, unmodified polysulphone/azide-MWCNTs mixed matrix membrane and modified polysulphone/azide-MWCNTs mixed matrix membrane via click reaction	76
4.7	Bovine serum albumin rejection of Pristine Polysulphone, unmodified polysulphone/azide-MWCNTs mixed matrix membrane and modified polysulphone/azide-MWCNTs mixed matrix membrane via click reaction	77
4.8	Flux recovery ratio (FRR) and Irreversible Fouling ratio (R _{ir}) of Pristine Polyether sulphone, unmodified polyether sulphone/amine-MWCNTs mixed matrix membrane and modified polyether sulphone/amine-MWCNTs mixed matrix membrane using trimesoyl chloride (TMC) and cyanuric chloride (CC)	79

4.9	Flux recovery ratio (FRR) and Irreversible Fouling ratio (R _{ir}) of Pristine Polysulphone, unmodified polysulphone/amine-MWCNTs mixed matrix membrane and modified polysulphone/amine-MWCNTs mixed matrix membrane using trimesoyl chloride (TMC) and cyanuric chloride (CC)	80
4.10	Bovine serum albumin rejection of Pristine Polyether sulphone, unmodified polyether sulphone/amine-MWCNTs mixed matrix membrane and modified polyether sulphone/amine-MWCNTs mixed matrix membrane using trimesoyl chloride (TMC) and cyanuric chloride (CC)	80
4.11	Bovine serum albumin rejection of Pristine Polysulphone, unmodified polysulphone/amine-MWCNTs mixed matrix membrane and modified polysulphone/amine-MWCNTs mixed matrix membrane using trimesoyl chloride (TMC) and cyanuric chloride (CC)	81
4.12	Flux recovery ratio (FRR) and Irreversible Fouling ratio (R _{ir}) of Pristine Polyether sulphone, unmodified polyether sulphone/oxidized-MWCNTs mixed matrix membrane and modified polyether sulphone/oxidized-MWCNTs mixed matrix membrane using polyethylenimine (PEI)	83
4.13	Flux recovery ratio (FRR) and Irreversible Fouling ratio (R _{ir}) of Pristine Polysulphone, unmodified polysulphone/oxidized-MWCNTs mixed matrix membrane and modified polysulphone/oxidized-MWCNTs mixed matrix membrane using polyethylenimine (PEI)	83
4.14	Bovine serum albumin rejection of Pristine Polyether sulphone, unmodified polyether sulphone/oxidized-MWCNTs mixed matrix membrane and modified polyether sulphone/oxidized-MWCNTs mixed matrix membrane using polyethylenimine (PEI)	84
4.15	Bovine serum albumin rejection of Pristine Polysulphone, unmodified polysulphone/oxidized-MWCNTs mixed matrix membrane and modified polysulphone/oxidized-MWCNTs mixed matrix membrane using polyethylenimine (PEI)	84
4.16	Representation of heavy metal rejection thorough modified polysulphone/azide-MWCNTs membrane via click reaction due to adsorption as well as complexation	87
4.17	Representation of heavy metal rejection thorough modified polyether sulphone/amine-MWCNTs membrane using TMC and CC due to adsorption as well as complexation	90
4.18	Representation of heavy metal rejection thorough modified polysulphone/amine-MWCNTs membrane using TMC and CC due to adsorption as well as complexation	91

4.19	Representation of heavy metal rejection thorough modified PES or PSU/amine-MWCNTs membrane using PEI due to adsorption as well as complexation	94
5.1	Cross-section SEM images of pristine polysulphone, polysulphone/azide-MWCNTs, and click reaction modified polysulphone/azide-MWCNTs mixed matrix membranes	97
5.2	AFM images of pristine polysulphone, polysulphone/azide-MWCNTs, and click reaction modified polysulphone/azide-MWCNTs mixed matrix membranes	98
5.3	Contact angle measurement of pristine polysulphone, polysulphone/azide-MWCNTs, and click reaction modified polysulphone/azide-MWCNTs mixed matrix membranes	99
5.4	SANS profile of (a) polysulphone/azide-MWCNTs mixed matrix membrane and (b) modified polysulphone/azide-MWCNTs mixed matrix membrane via click reaction	100
5.5	Cross-section SEM images of pristine polyether sulphone, polyether sulphone/amine-MWCNTs, and modified polyether sulphone/amine-MWCNTs mixed matrix membranes using trimesoyl chloride (TMC) and cyanuric chloride (CC)	102
5.6	Cross-section SEM images of pristine polysulphone, polysulphone/amine-MWCNTs, and modified polysulphone/amine-MWCNTs mixed matrix membranes using trimesoyl chloride (TMC) and cyanuric chloride (CC)	103
5.7	AFM images of pristine polyether sulphone, polyether sulphone/amine-MWCNTs, and modified polyether sulphone/amine-MWCNTs mixed matrix membranes using trimesoyl chloride (TMC) and cyanuric chloride (CC)	104
5.8	AFM images of pristine polysulphone, polysulphone/amine-MWCNTs, and modified polysulphone/amine-MWCNTs mixed matrix membranes using trimesoyl chloride (TMC) and cyanuric chloride (CC)	105
5.9	Contact angle measurement of pristine polyether sulphone, polyether sulphone/amine-MWCNTs, and modified polyether sulphone/amine-MWCNTs mixed matrix membranes using trimesoyl chloride (TMC) and cyanuric chloride (CC)	108
5.10	Contact angle measurement of pristine polysulphone, polysulphone/amine-MWCNTs, and modified polysulphone/amine-MWCNTs mixed matrix membranes using trimesoyl chloride (TMC) and cyanuric chloride (CC)	109
5.11	SANS profile of (a) polysulphone/amine-MWCNTs mixed matrix membrane and (b) polyether sulphone/amine-MWCNTs mixed matrix membrane (c) modified polysulphone/amine-MWCNTs mixed matrix membrane using trimesoyl chloride (TMC) (d) modified polyether sulphone/amine-MWCNTs mixed matrix	112

	membrane using trimesoyl chloride (TMC) (e) modified polysulphone/amine-MWCNTs mixed matrix membrane using cyanuric chloride (CC) (f) modified polyether sulphone/amine-MWCNTs mixed matrix membrane using cyanuric chloride (CC)	
5.12	Cross-section SEM images of pristine polysulphone, pristine polyether sulphone, polysulphone/oxidized-MWCNTs and polyether sulphone/ oxidized -MWCNTs mixed matrix membrane and modified polysulphone/ oxidized -MWCNTs and polyether sulphone/ oxidized -MWCNTs mixed matrix membrane using polyethylenimine (PEI)	113
5.13	AFM images of pristine polyether sulphone, polyether sulphone/oxidized-MWCNTs, and modified polyether sulphone/ oxidized -MWCNTs mixed matrix membranes using polyethylenimine (PEI)	114
5.14	AFM images of pristine polysulphone, polysulphone/oxidized-MWCNTs, and modified polysulphone/ oxidized -MWCNTs mixed matrix membranes using polyethylenimine (PEI)	115
5.15	Contact angle measurement of pristine polysulphone, pristine polyether sulphone, polysulphone/oxidized-MWCNTs, polyether sulphone/oxidized-MWCNTs and modified polysulphone/ oxidized -MWCNTs and polyether sulphone/oxidized-MWCNTs mixed matrix membranes using polyethylenimine (PEI)	118
5.16	SANS profile of (a) polysulphone/oxidized-MWCNTs, (b) polyether sulphone/oxidized-MWCNTs and (c) modified polysulphone/ oxidized -MWCNTs and (d) polyether sulphone/oxidized-MWCNTs mixed matrix membranes using polyethylenimine (PEI)	120
