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Review

Surface modification methods of organic solvent nanofiltration membranes

M. Amirilargani [a], M. Sadrzadeh [b], E.J.R. Sudhölter [a], L.C.P.M. de Smet [a,*]

[a] Department of Chemical Engineering, Delft University of Technology, The Netherlands
[b] Department of Mechanical Engineering, University of Alberta, Canada

HIGHLIGHTS

- Review recent of progress in the surface modification of OSN membranes.
- Molecular focus on controlling the properties of the selective layer.
- Effects of surface modification on separation performance.
- Critical comparison of the OSN reviewed surface modification techniques.

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ABSTRACT

Organic solvent nanofiltration (OSN) is an emerging technology in which membranes are used for organic solvent separation and purifications. Its fields of applications range from pharmacy, catalyst regeneration, to oil and solvent treatments. A major challenge is to maintain a high stability of these (modified) membranes under different feed conditions. Tailoring the selective layer of OSN membranes is the main approach to develop functionalized membranes which show stable high selectivities and permeabilities. During the past decade, methods such as grafting, light-induced modification, plasma treatment, and polyelectrolyte modification have been intensively studied. This paper reviews the recent progress in this field of surface modification of different types of polymeric and also of ceramic OSN membranes. First, the most crucial surface layer properties that affect the OSN membranes properties are described in detail. Next, different surface modification methods and their effects on membrane selectivity and permeability are reviewed and compared. Finally, a perspective is given on expected future trends in this highly challenging and important field of current research.

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* Corresponding author. Tel.: +31 15 27 82686.
E-mail address: l.c.p.m.desmet@tudelft.nl (L.C.P.M. de Smet).

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Abbreviations

AEMA	aminoethyl methacrylate
AF	acid fuchsin
AFM	atomic force microscopy
APTES	(3-aminopropyl)triethoxysilane
APTMS	(3-aminopropyl)trimethoxysilane
BTB	bromothymol blue
CA	cellulose acetate
CSA	camphor sulfonic acid
CVD	chemical vapor deposition
DCM	dichloromethane
DEA	diethanolamine
DLC	diamond-like carbon
DMAc	N,N-dimethylacetamide
DMF	N,N-dimethylformamide
DMSO	dimethyl sulfoxide
DR	disperse red 1
EA	ethyl acetate
EtOH	ethanol
GNPs	gold nanoparticles
GO	graphene oxide
H-PAN	hydrolized-polyacrylonitrile
HNSA	6-hydroxy-2-naphthalenesulfonic acid
IPA	*iso*-propyl alcohol
IPD	*iso*-phthaloyl dichloride
ISA	integrally skinned asymmetric
LbL	layer-by-layer
MA	methylacrylate
MEK	methyl ethyl ketone
MeOH	methanol
MMM	mixed matrix membrane
MO	methyl orange
MOF	metal-organic framework
MPD	M-phenylenediamine
MPTES	(3-mercaptopropyl)triethoxysilane
MWCO	molecular weight cut-off
MWNTs	multi-walled carbon nanotubes
NF	nanofiltration
NMP	N-methylpyrrolidinone
OSN	organic solvent nanofiltration
PA	polyamide
PAA	polyacrylic acid
PAN	polyacrylonitrile
PDMS	polydimethylsiloxane
PDDA	poly(diallyldimethylammonium chloride)
PEC	polyelectrolyte complex
PEI	polyethylene imine
PEG	polyethylene glycol
PEM	polyelectrolyte multilayer
PEO	polyethylene oxide
PI	polyimide
PIB	polyisobutylene
PNIPAM	poly(*N*-isopropyl acrylamide)
PPy	polypyrrole
PS	polystyrene
PSf	polysulfone
PSS	poly(sodium styrene sulfonate)
PTMSP	poly[1-(trimethylsilyl)-1-propyne]
RB	Rose Bengal
RO	reverse osmosis
Sa	average roughness
SDS	sodium dodecyl sulphate
SPEEK	sulfonated poly(ether ether ketone)
SPN	segmented polymer network
SRNF	solvent resistant nanofiltration
Sq	root mean square of the roughness data
Sz	difference between the highest peaks and the lowest valleys
TEA	triethylamine
TFC	thin film composite
TFN	thin film nanocomposite
TGA	thermogravimetric analysis
THF	tetrahydrofuran
TMC	trimesoylchloride
TPO	2,4,6-trimethylbenzoyl-diphenyl-phosphine oxide
UF	ultrafiltration

Greek symbol

ε_r	relative dielectric constant

1. Introduction

Nowadays chemical separations are playing crucial roles in processes of the chemical, petrochemical, pharmaceutical and food industries [1]. Membrane-based separation processes have attracted significant attention in industrial applications due to their distinct advantages over traditional separation processes like distillation and extraction. This is primarily due to their better separation performance, the lower size and costs of the equipment used, and a much improved energy efficiency [2–4]. Nanofiltration (NF) membranes with separation properties between those of ultrafiltration (UF) and reverse osmosis (RO) membranes (pore size < 0.5 nm), were first explored in the late 1980's [5,6]. Although NF membranes have been widely applied for water and wastewater treatment processes [7], their application for organic solvent nanofiltration (OSN), sometimes also referred to as solvent-resistant nanofiltration (SRNF) or organophilic NF, is a rather new technology [1]. OSN has a great potential to be employed in a wide range of processes related to, e.g. food [8–10], fine chemical [11–13], pharmaceutical [14–16] and petrochemical industries [17–19] for the treatment of organic solvents. Within the Scopus database a total number of 335 papers in indexed journals was found on keywords related to the topic of OSN membranes as of 2005 (Fig. 1). More than two third of these papers appeared over the last five years, showing the growing interest in OSN membranes.

The compatibility of these membranes under extreme operating conditions like harsh and aggressive media, elevated pH and high temperatures, while maintaining a reasonable long-term separation performance and reproducibility is the main challenge in the further development of OSN membranes. In such membranes,