Fabrication of advanced nanofiltration membranes with nanostrand-hybrid morphology mediated by ultrafast Noria-polyethyleneimine co-deposition

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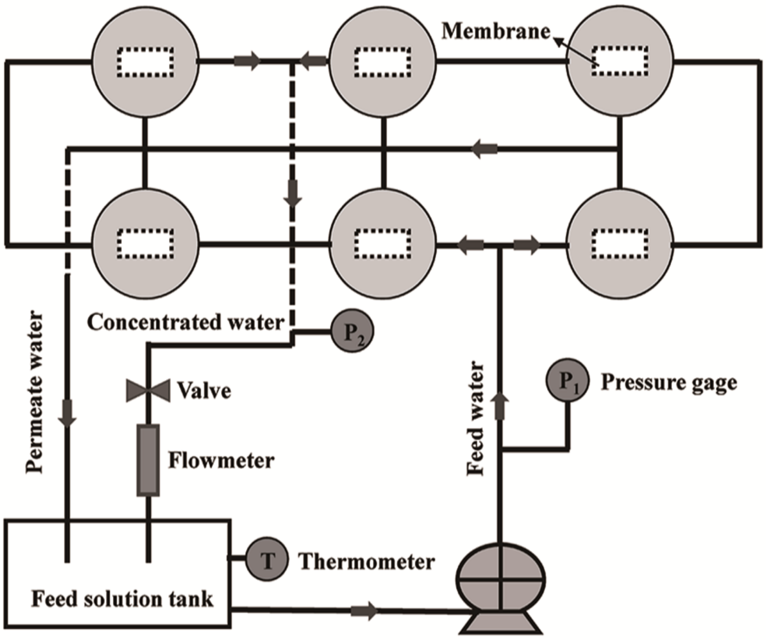

Fig. S1 Scheme of lab-scale cross-flow unit.

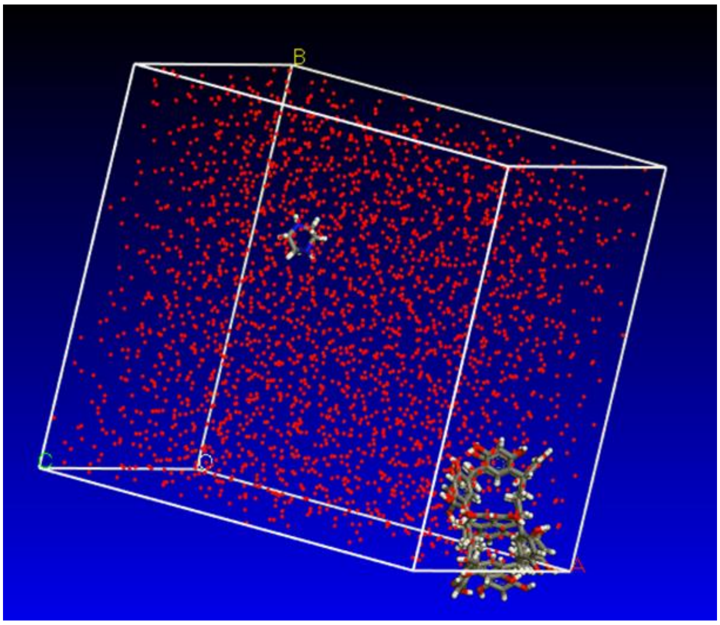

Fig. S2 Model box for MD simulation with dimensions of 42.37Å╳42.37Å╳42.37Å.

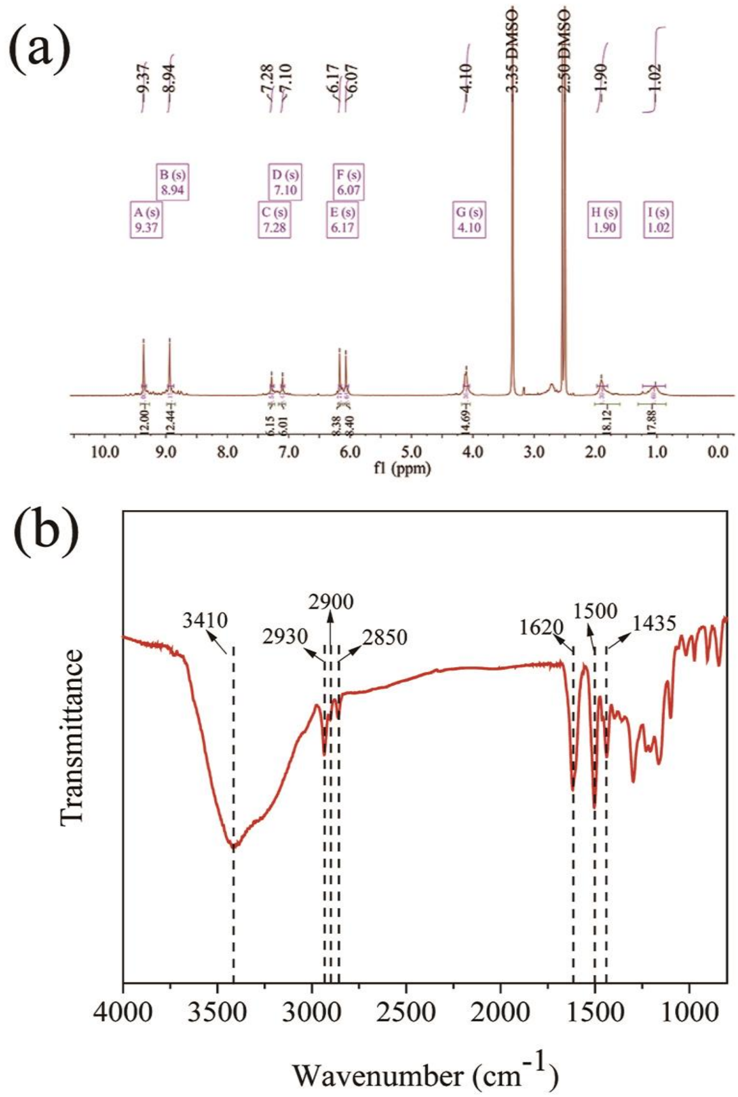

Fig. S3 (a) ^1H NMR and (b) IR spectra of Noria. ^1H NMR: δ=0.86-2.35 ppm (-$CH_2CH_2CH_2$-), 3.98-4.22 ppm (>CH-), 6.01-7.48 ppm (Ar-H), 8.65-9.56 ppm (OH); IR: $\tilde{\nu}$=3410 cm^{-1} (-OH), 2930 cm^{-1}, 2850 cm^{-1} (-CH_2-), 2900 cm^{-1}(CH), 1620 cm^{-1}, 1500 cm^{-1}, 1435 cm^{-1} (aromatic C=C).

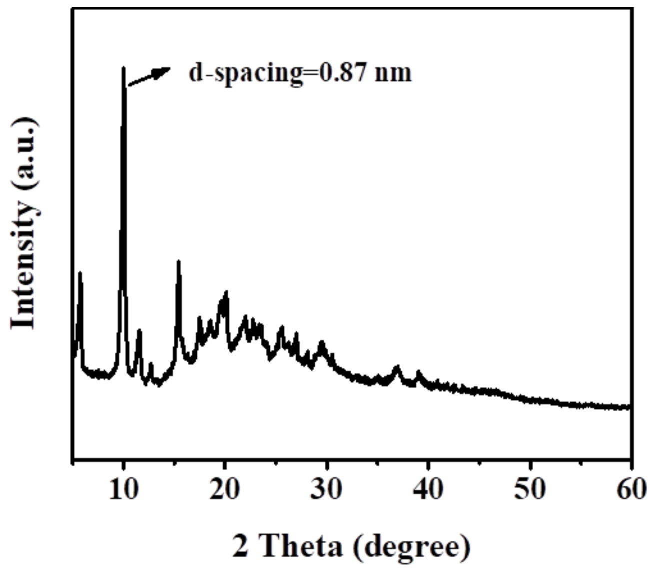

Fig. S4 XRD pattern of Noria.

The strong diffraction peak at $2\theta=10.1^{\circ}$ (d-spacing=0.87 nm) was attributed to the depth of Noria cavity.

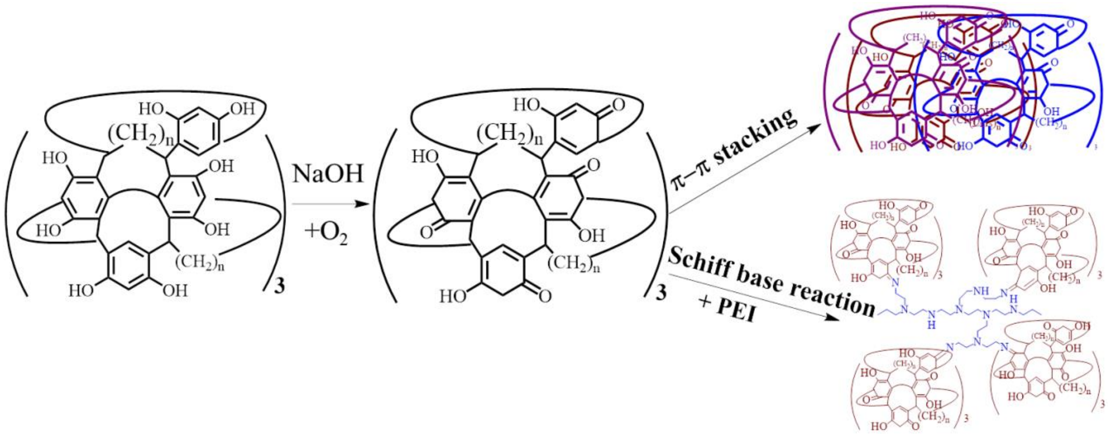

Fig. S5 The possible reaction mechanism for Noria and PEI in alkaline solution.

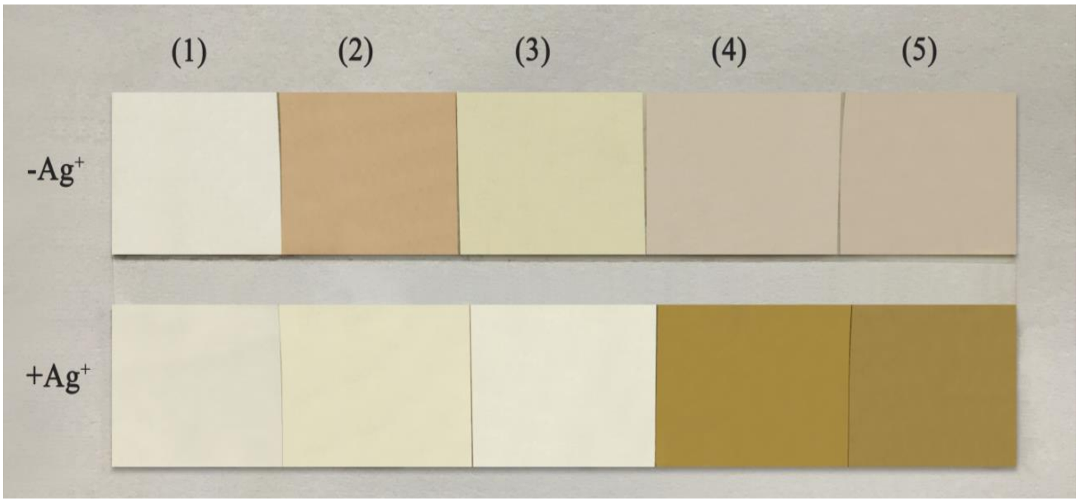

Fig. S6 Digital photographs of various PSF membranes before (-Ag^+) and after (-Ag^+) immersion in $AgNO_3$ solution (1) Nascent (2) Modified by Noria before rinsing (3) Modified by Noria after rinsing (4) Modified by Noria-PEI 70000 before rinsing (5) Modified by Noria-PEI 70000 after rinsing (The modification time was 20 s and the immersion time in 0.1 M $AgNO_3$ solution wa 5 h at 25℃).

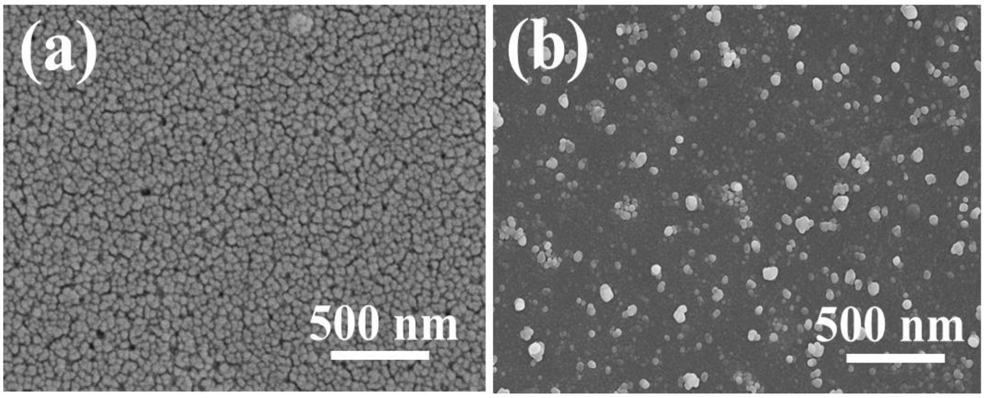

Fig. S7 SEM images of (a) PSF membrane modified by Noria-PEI for 20 s (b) Modified membrane after immersion in 0.1 M $AgNO_3$ solution at 25℃ for 5 h.

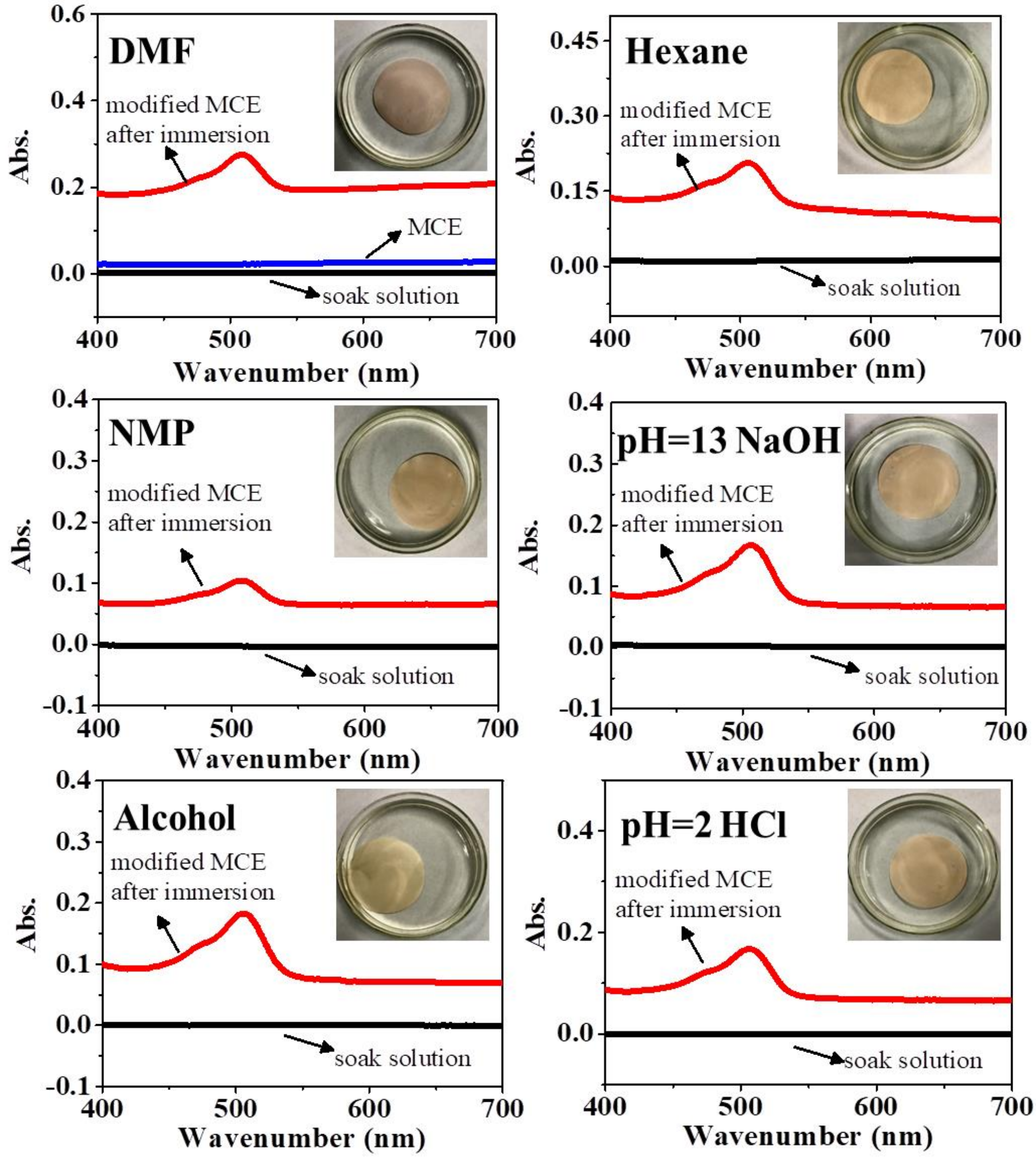

Fig. S8 Digital photographs and UV-vis spectra for soak solution and modified MCE after immersion in various solvents for 3 h (The modification time was 20 s).

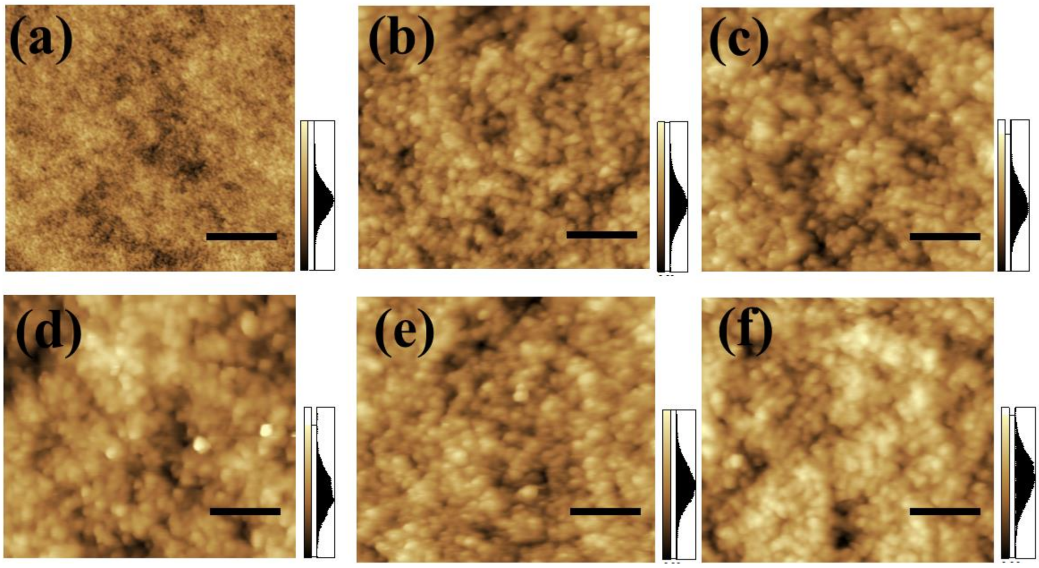

Fig. S9 AFM topography images of (a) PSF-0 (b) PSF-1 (c) PSF-2 (d) PSF-3 (e) PSF-4 and (f) PSF-5 (The scale bar was 1 um).

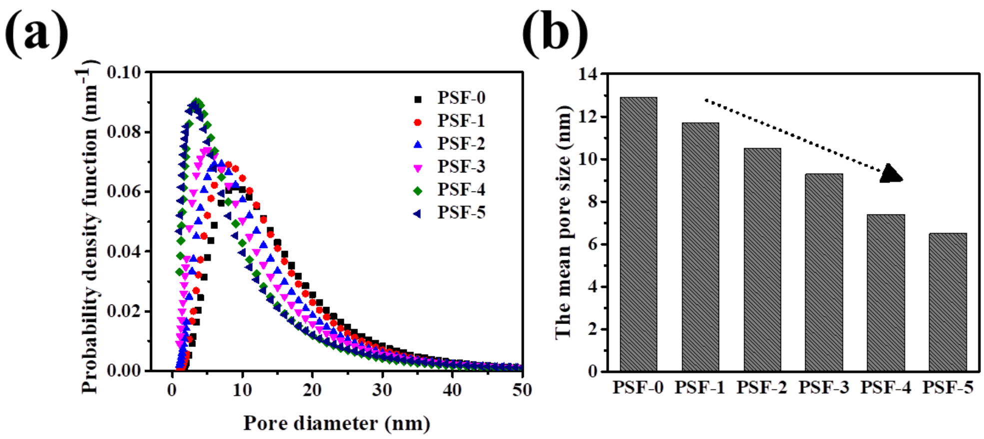

Fig. S10 The pore size distribution curves of various PSF support membranes (b) The mean pore sizes for PSF support membranes.

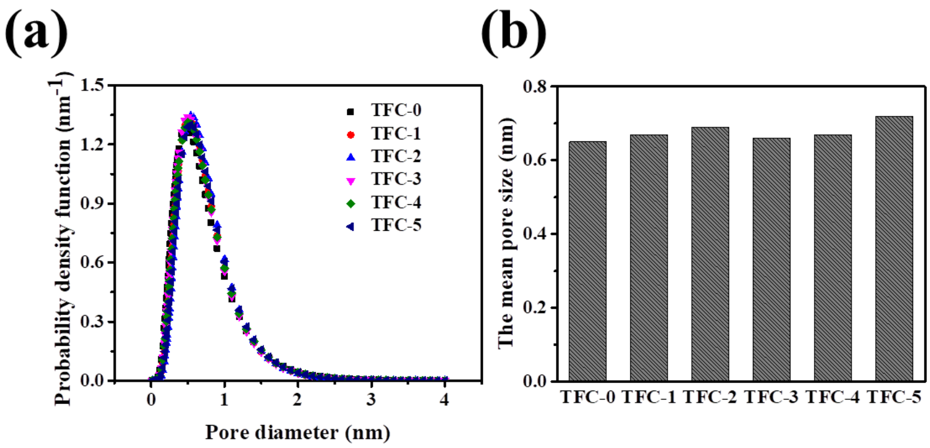

Fig. S11 (a) The pore size distribution curves of various TFC membranes (b) The mean pore sizes for TFC membranes.

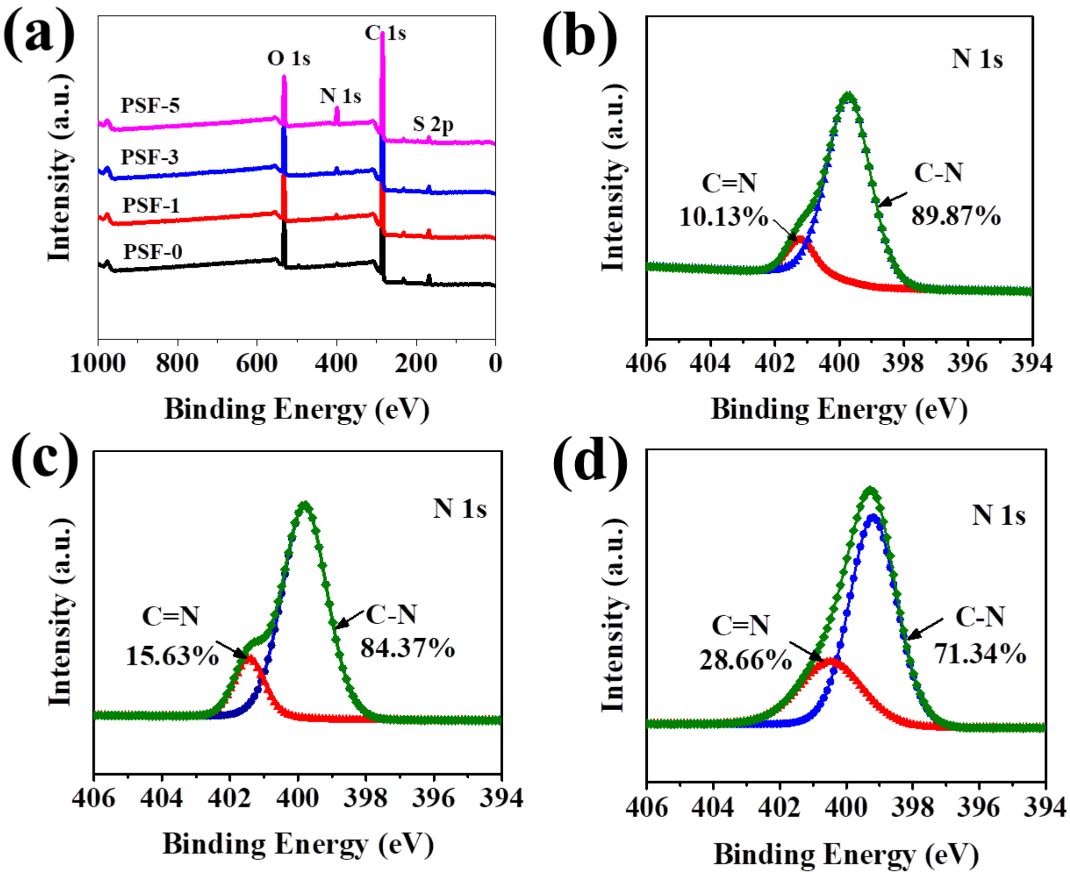

Fig. S12 (a) XPS spectra of PSF-0, PSF-1, PSF-3 and PSF-5; High resolution spectra of N 1s for (b) PSF-1 (c) PSF-3 and (d) PSF-5.

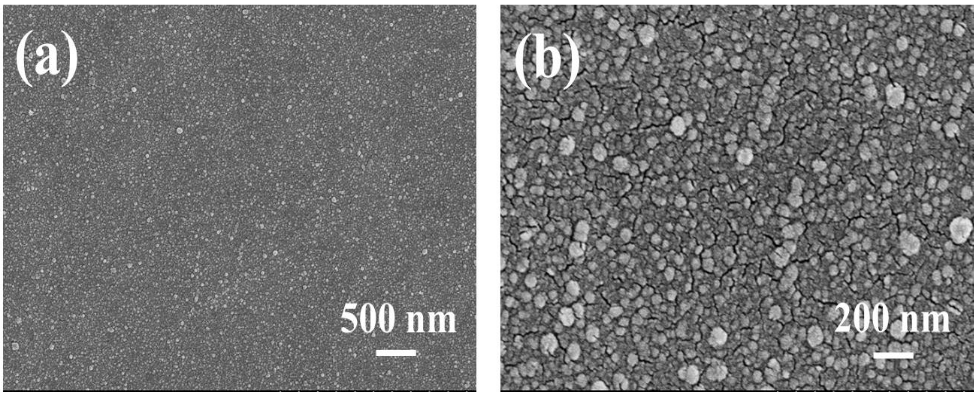

Fig. S13 Surface morphology of PIP-TMC TFC membranes fabricated on nascent PSF support (a) SEM image at low magnification (b) SEM image at high magnification.

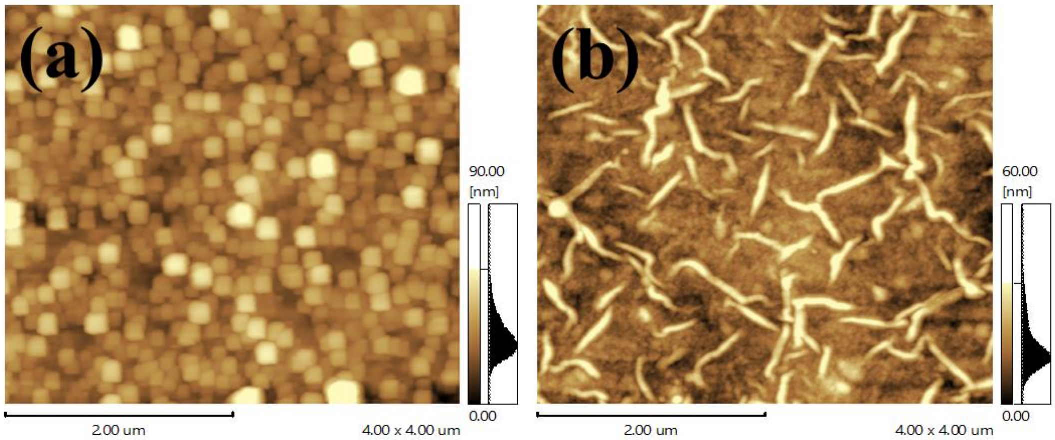

Fig. S14 AFM topography images of PIP-TMC membranes fabricated on (a) Nascent PSF support (b) Support membrane modified by Noria for 40 s (without washing) (PIP-1.0 wt%; TMC- 0.1wt%; IP time-30 s).

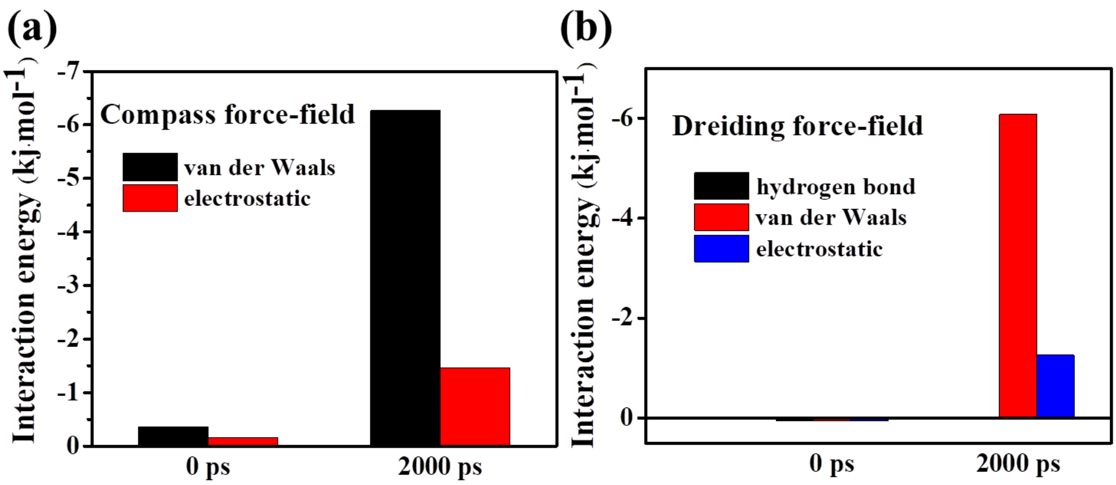

Fig. S15 The interaction energy between PIP and Noria molecules calculated by (a) Compass force-field (b) Dreiding force-field.

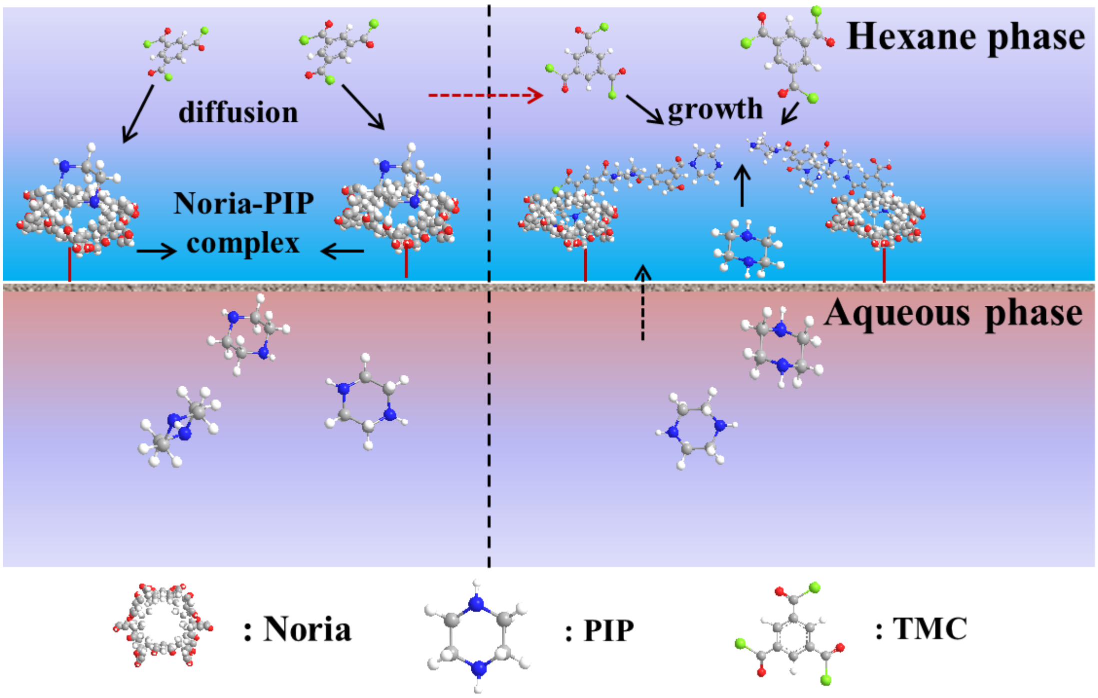

Fig. S16 Schematic illustration of the formation mechanism of nanostrand structure.

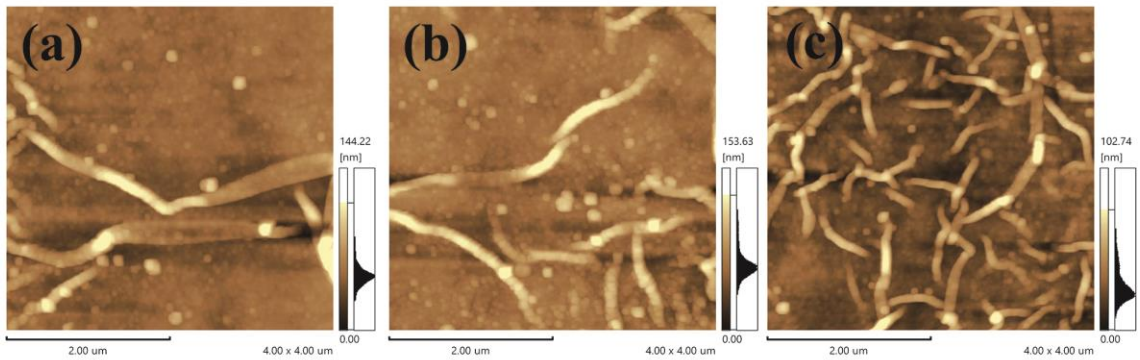

Fig. S17 AFM topography images of PIP-TMC membranes fabricated on PSF-3: (a) PIP-0.01wt% (b) PIP-0.1wt% (c) PIP-5.0 wt% (TMC-0.1 wt %, IP time-30 s).

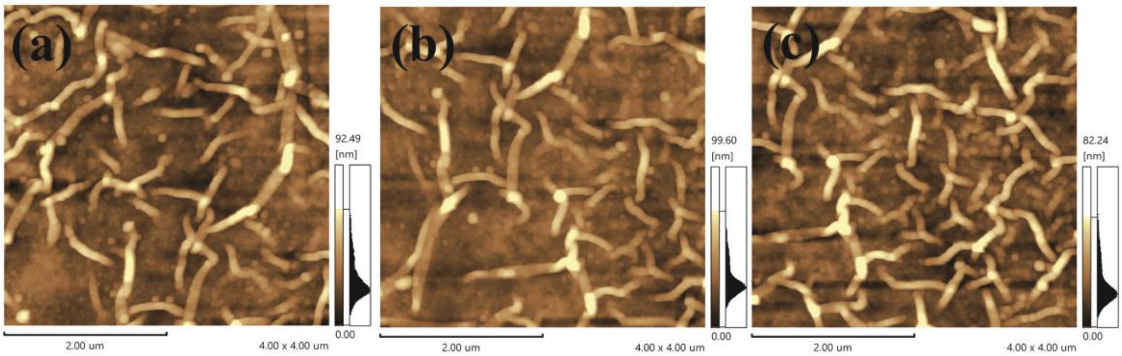

Fig. S18 AFM topography images of PIP-TMC membranes fabricated on PSF-3: (a) TMC-0.01wt% (b) TMC-0.5 wt% (c) TMC-1.0 wt% (PIP-1.0 wt%, IP time-30 s).

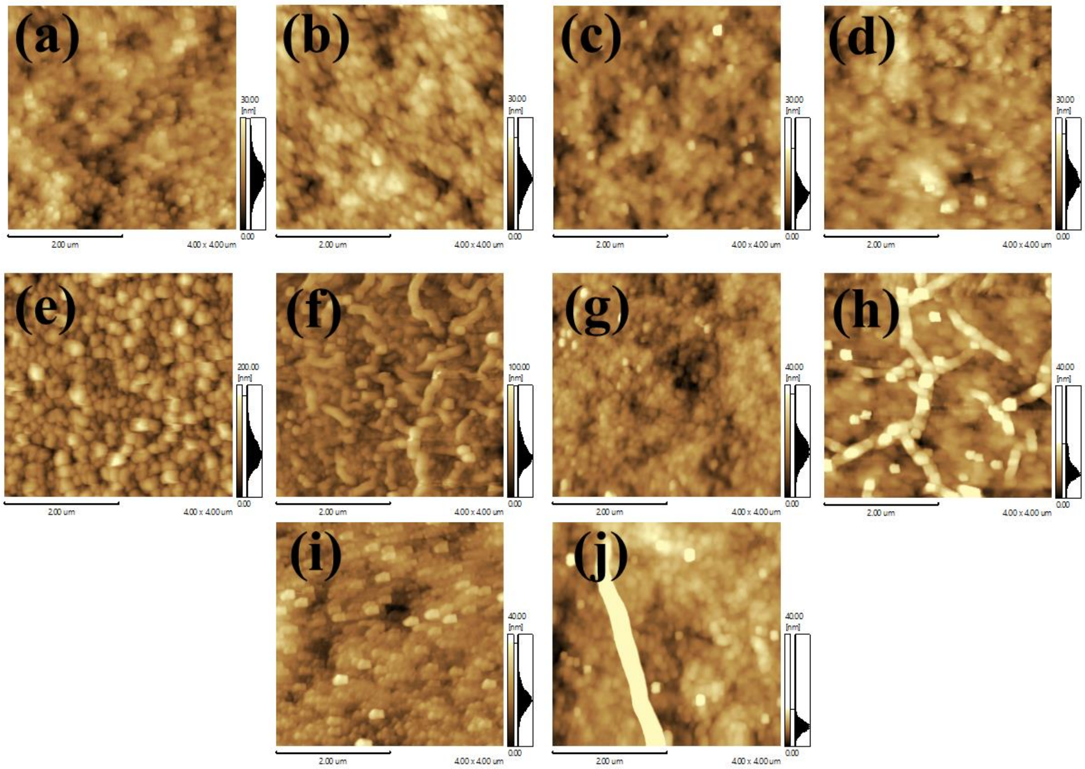

Fig. S19 AFM topography images of (a) TFC-PEI 600/TMC-PSF-0 (b) TFC-PEI 600/TMC-PSF-3 (c) TFC-TAEA/TMC-PSF-0 (d) TFC-TAEA/TMC-PSF-3 (e) TFC-MPD/TMC-PSF-0 (f) TFC-MPD/TMC-PSF-3 (g) TFC-1, 4-CHD/TMC-PSF-0 (h) TFC-1, 4-CHD/TMC-PSF-3 (i) TFC-EA/TMC-PSF-0 and (j) TFC-EA/TMC-PSF-3 (Amine monomer-1.0 wt%, TMC-0.1 wt %, IP time-30 s).

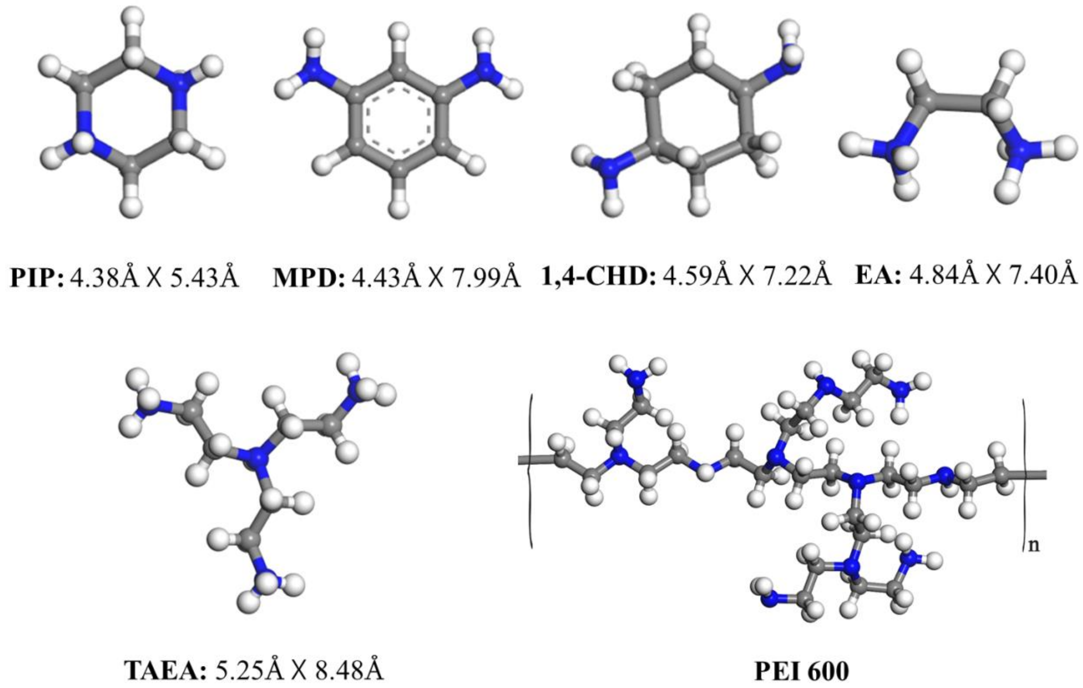

Fig. S20 The chemical structures and dimensions of various amine monomers (As a polymer, the dimension of PEI 600 is not figured out).

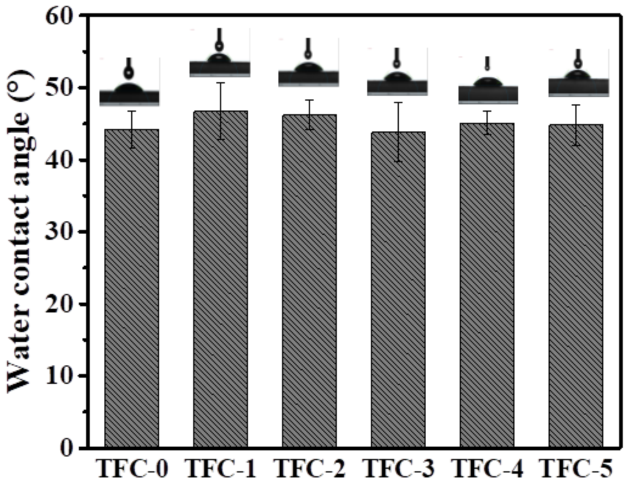

Fig. S21 Water contact angle for various NF membranes

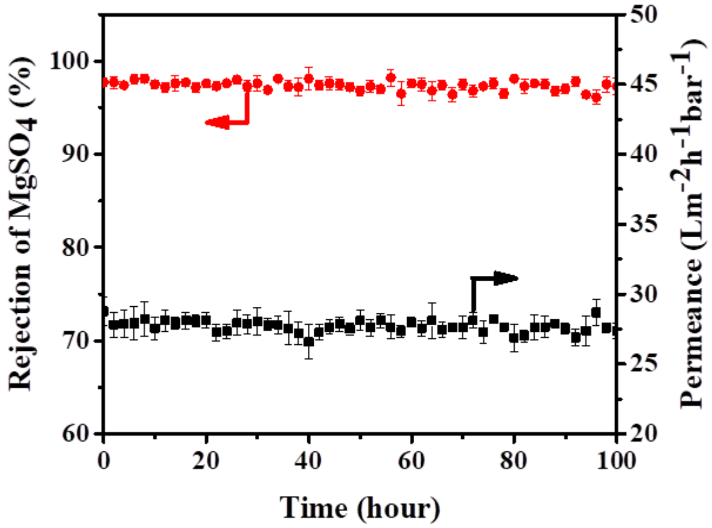

Fig. S22 The long-time stability of TFC-3 NF membrane.

Table S1 Surface roughness of PSF-0, PSF-1, PSF-2, PSF-3, PSF-4 and PSF-5 membranes

Membranes	Ra (nm)	Rq (nm)
PSF-0	5.05	6.34
PSF-1	3.82	4.77
PSF-2	4.44	5.51
PSF-3	4.80	5.95
PSF-4	4.17	5.24
PSF-5	5.00	6.18

Ra: average roughness; Rq: root means square roughness

Table S2 The quantitative elemental analysis for PSF-0, PSF-1, PSF-3 and PSF-5 membranes

Membranes	C (%)	N (%)	O (%)	S (%)
PSF-0	82.44	0.47	13.18	3.91
PSF-1	81.50	1.39	14.15	2.96
PSF-3	78.95	2.57	16.09	2.39
PSF-5	76.04	6.98	14.62	2.36

Table S3 Surface roughness and actual surface area of TFC-0-TFC-5 membranes

Membranes	AFM scans (um^2)	Ra (nm)	Rq (nm)	Surface area (um^2)
TFC-0	4╳4	7.88	9.55	16.224
TFC-1	4╳4	8.17	11.04	16.756
TFC-2	4╳4	10.83	14.59	17.152
TFC-3	4╳4	15.67	18.94	18.556
TFC-4	4╳4	10.96	13.81	17.012
TFC-5	4╳4	9.29	12.09	16.819

Ra: average roughness; Rq: root means square roughness; Surface area： the actual membrane surface area was calculated by Matlab according to AFM image data

Table S4 Performance comparison among various NF membranes

Membranes	$R(MgCl_2)$ (%)	$R(Na_2SO_4)$ (%)	$[R(MgCl_2)+R(Na_2SO_4)]/2$ (%)	Permeance /($Lm^{-2}h^{-1}bar^{-1}$)	Ref.
PIP-TMC/CNC/PES MF	15.5	97.7	56.6	34.0	1
PIP-TMC/SWCNTS/PES MF	61.8	95.9	78.8	32.0	2
PIP-TMC/SWCNTS+Nanoparticle/PES MF	40.0	95.0	67.5	53.5	3
PIP-TMC/PVC UF	98.6	94.3	96.5	15.2	4
PIP-TMC/MWCNTS/PES MF	78.0	95.0	86.5	17.6	5
PIP-TMC/TA-DETA/PSF UF	70.0	98.0	84.0	10.5	6
PEI-TMC/UCN	89.7	39.1	64.4	21.9	7
PIP-TMC/PDA/PES UF	12.3	93.5	52.9	11.4	8
PEI/PDA-MWCNTS+TMC/PSF UF	91.5	45.2	68.4	15.3	9
PDA/PVA-TMC/PSF UF	6.5	92.3	49.4	13.4	10
MWNT-rGO/PVDF UF	9.6	81.0	63.4	11.3	11
MPD-5-DCPO-IPDC/BTEC/PSF UF	92.1	99.0	95.6	17.9	12
BPF/PIP-TMC/PES UF	49.4	96.6	73.0	11.9	13

PIP/PVA-TMC/PSF UF	91.2	99.6	95.4	24.9	14
Dow-Filmtec NF 270	60.0	98.0	79.0	13.2	15
Dow-Filmtec NF 90	96.0	98.6	97.3	6.7	16
PIP-TMC/Noria-PEI /PSF UF	97.7	96.8	97.3	27.6	This work

UF: ultrafiltration membrane; MF: microfiltration membrane

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