

Unique roles of aminosilane in developing anti-fouling thin film composite (TFC) membranes for pressure retarded osmosis (PRO)

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Table 1. Spinning conditions for the fabrication of PEI hollow fiber substrate.

Dope composition (PEI/LiCl/NMP) (wt.%)	14/4/82
Dope flow rate (g/min)	3.26
Bore fluid (NMP/H ₂ O) (vol.%)	80/20
Bore fluid flow rate (ml/min)	2.5
Air gap (cm)	5
Take-up speed	Free fall
External coagulant	Tap water
Spinning temperature (°C)	23
Spinneret dimension, OD/ID (mm)	1.65/ 0.72

Table 2. Characteristics of the PEI hollow fiber membrane substrate before and after APTMS-grafting.

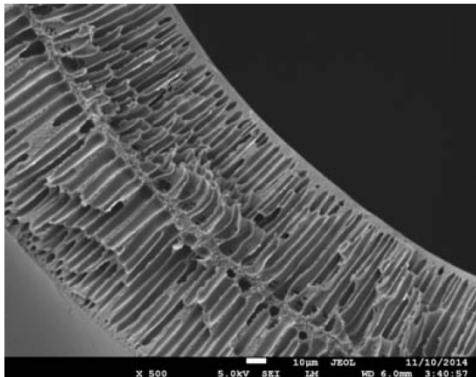
Membrane	PEI	APTMS-grafted PEI
Dimension (OD/ID) (mm)	$1.08 \pm 0.01 / 0.76 \pm 0.01$	$1.08 \pm 0.01 / 0.76 \pm 0.01$
MWCO (lumen side) (kDa)	161 ± 35	90 ± 19
Mean pore size D^* (nm)	10.01 ± 1.31	8.25 ± 1.29
Porosity ε (%)	81 ± 1	80 ± 1
PWP (L/m ² h bar)	386 ± 18	331 ± 15
Dynamic contact angle (outer surface) (°)	72 ± 4	28 ± 2
Tensile modulus (MPa)	112 ± 1	125 ± 1
Stress at break (MPa)	5.36 ± 0.07	5.36 ± 0.16
Strain at break (%)	55.8 ± 2.1	42.9 ± 0.8

Table 3. Characteristic comparison of polyamide selective layers.

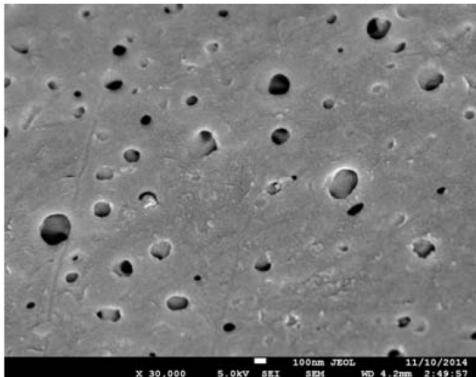
Selective layer	Contact angle (°)	Water permeability <i>A</i> (LMH/bar)	Salt permeability <i>B</i> (LMH)	Salt rejection <i>R_s</i> (%)	Structural parameter <i>S</i> (mm)
PA (MPD/TMC)	50 ± 3	1.02 ± 0.05	0.092 ± 0.013	86.6 ± 1.1	0.56 ± 0.03
APTMS-grafted PA (MPD/TMC)	25 ± 2	2.23 ± 0.10	0.262 ± 0.036	83.2 ± 1.3	0.56 ± 0.03
PA (APTMS/TMC)	24 ± 2	2.06 ± 0.09	0.298 ± 0.039	80.1 ± 1.4	0.56 ± 0.03

Cross section

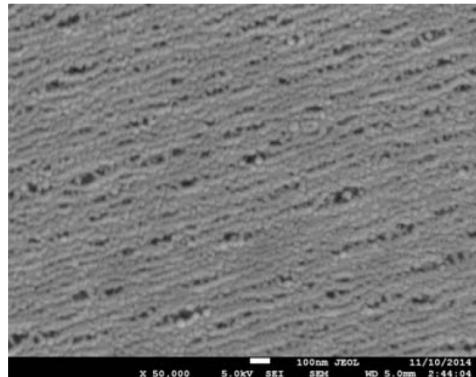
PEI



Outer surface



Inner surface



APTMS-grafted PEI

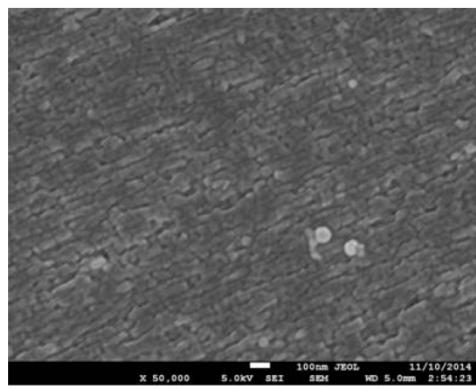
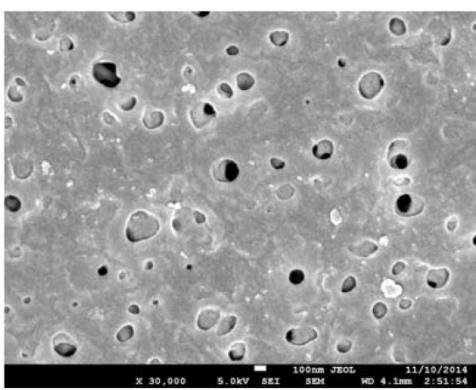
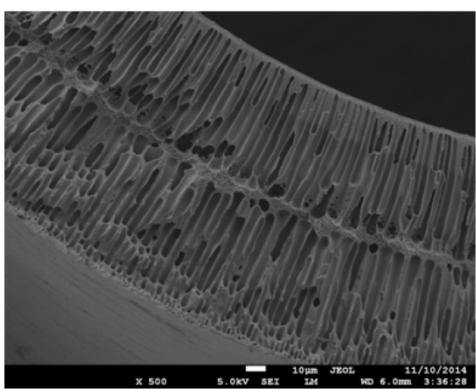


Fig. 1. Morphological comparison of the PEI hollow fiber membrane substrate before and after APTMS-grafting.

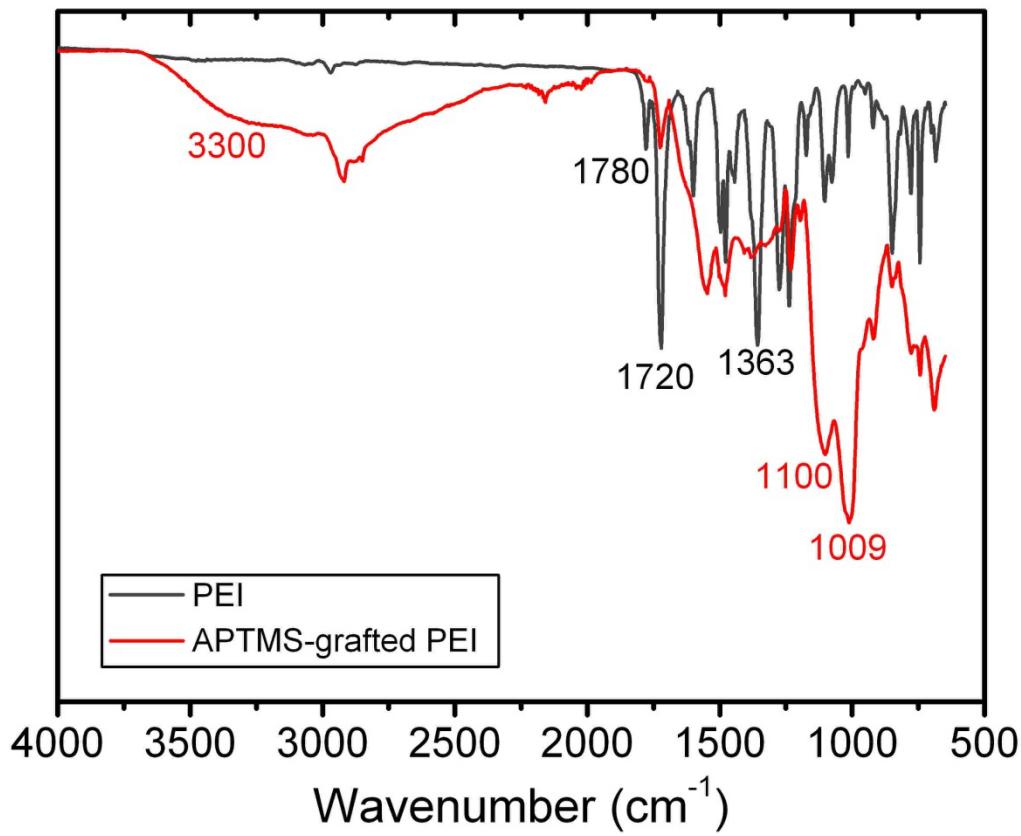


Fig. 2. ATR-FTIR comparison of the PEI hollow fiber membrane substrate before and after APTMS-grafting.

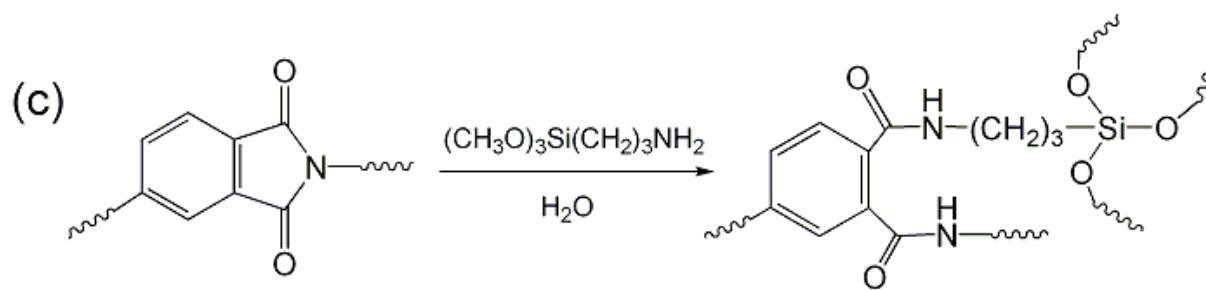
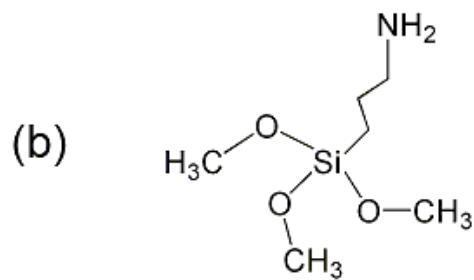
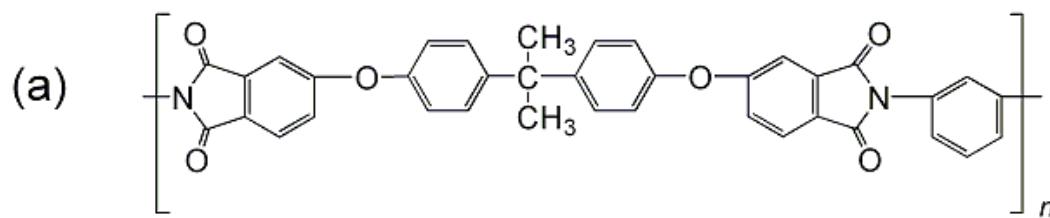


Fig. 3. (c) Chemical reaction between (a) PEI (Ultem® 1000) and (b) APTMS.

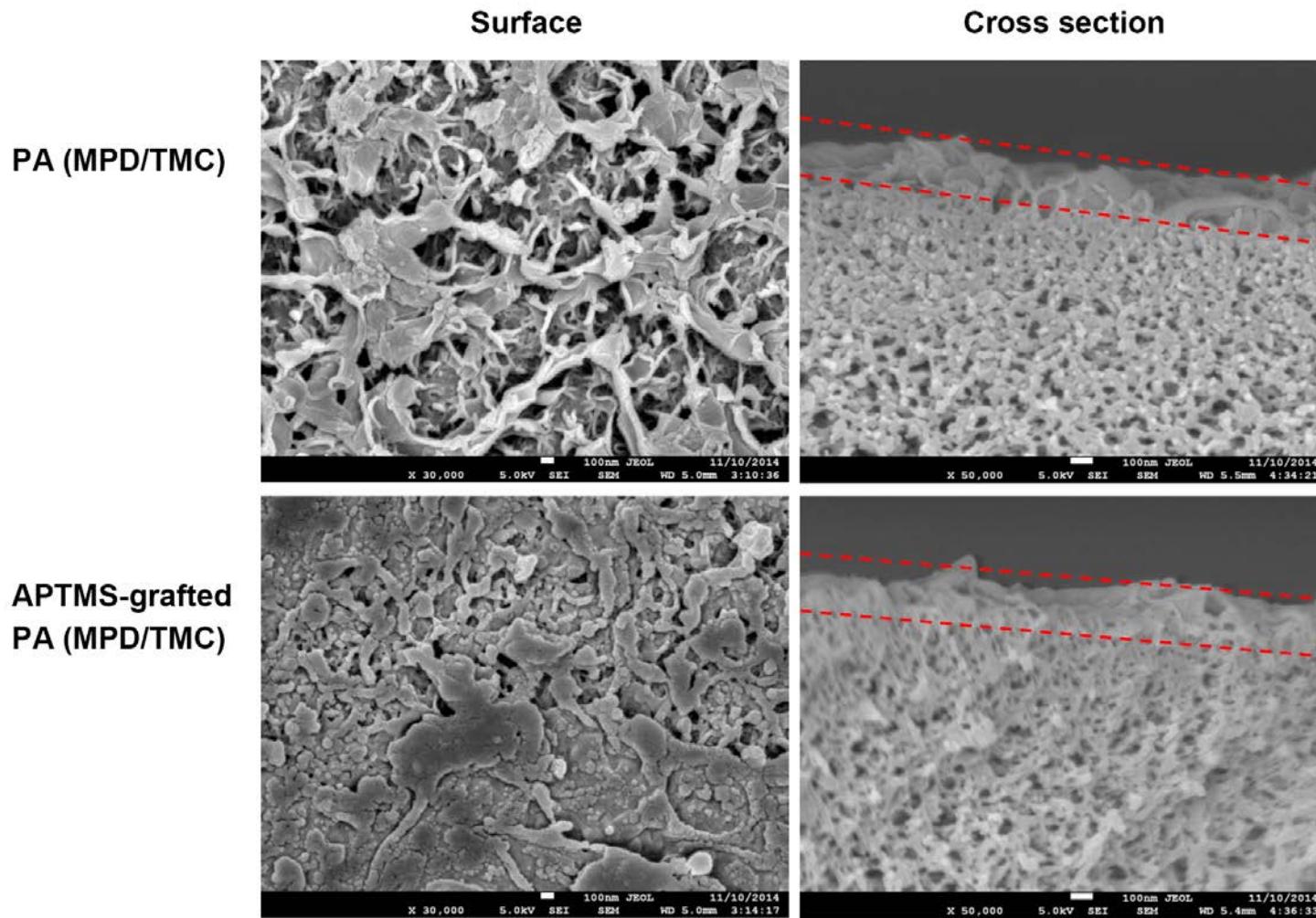


Fig. 4. Morphological comparison of the polyamide selective layer before and after APTMS-grafting.

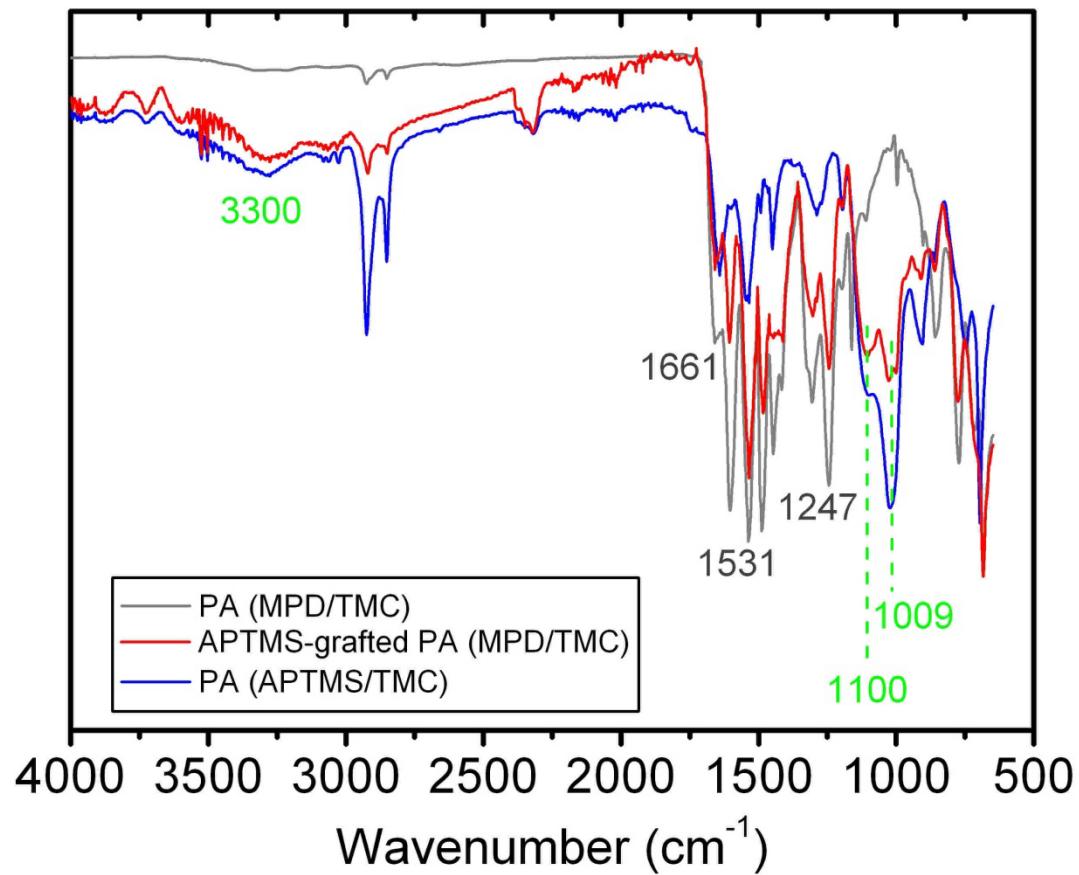


Fig. 5. ATR-FTIR comparison of polyamide selective layers.

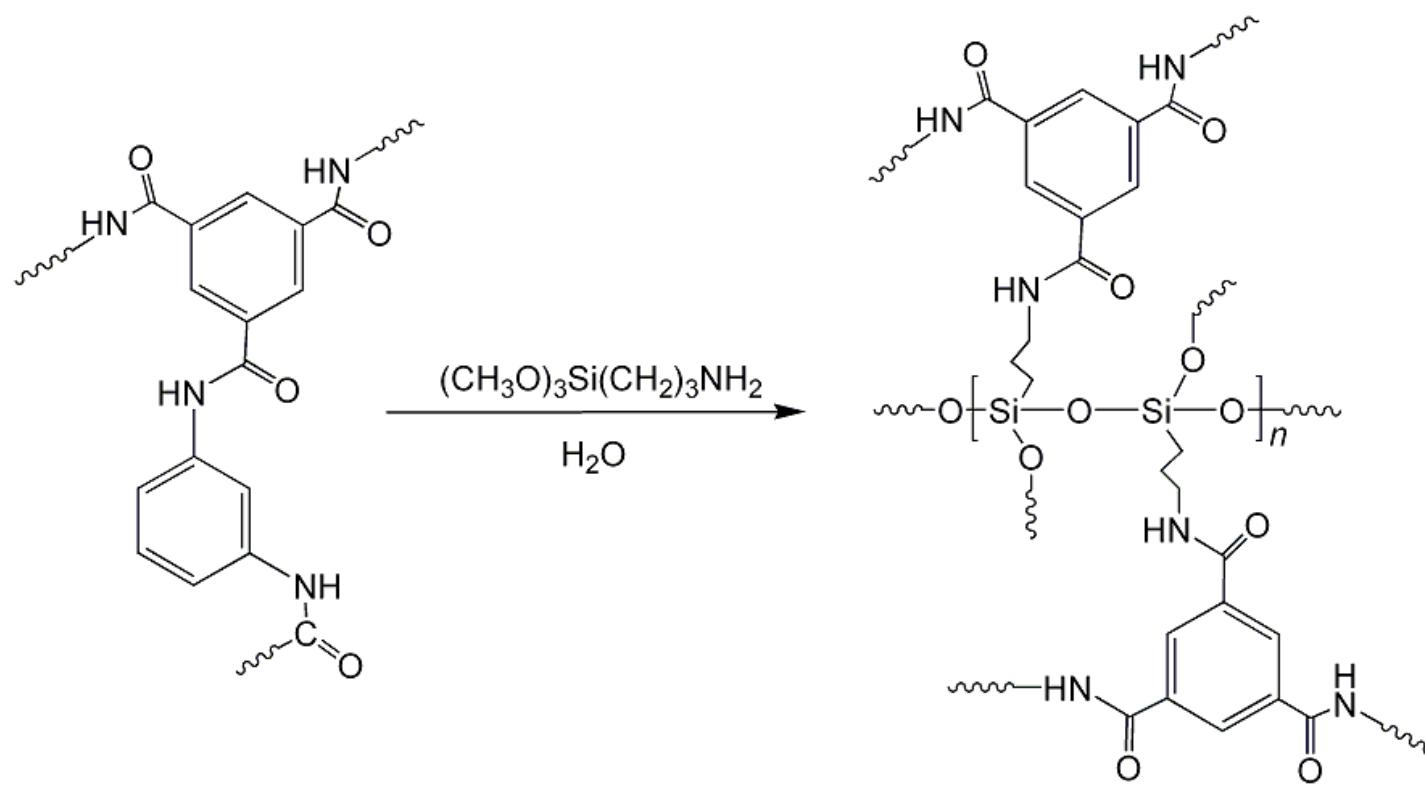


Fig. 6. Chemical reaction between polyamide (MPD/TMC) and APTMS.

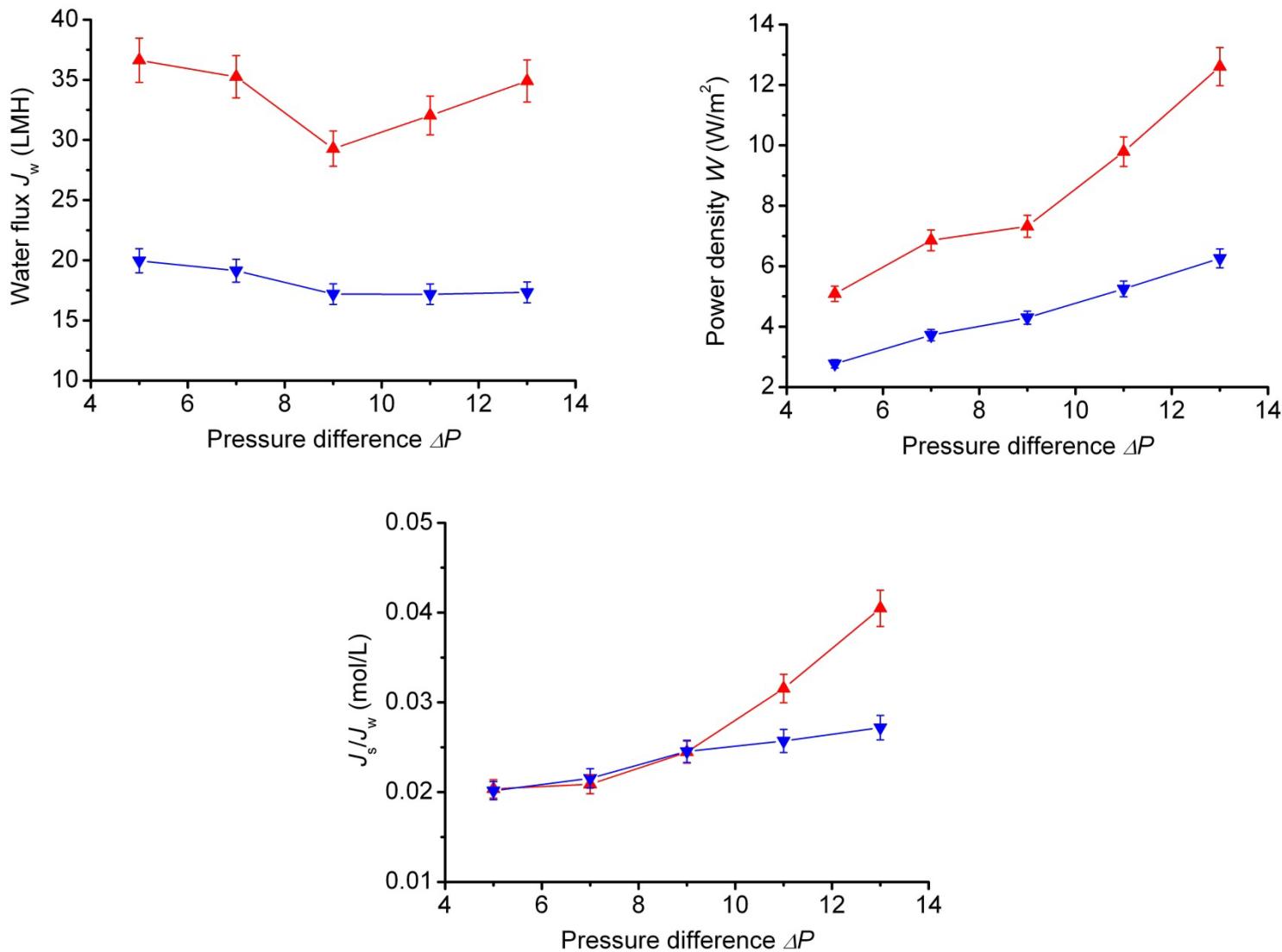


Fig. 7. PRO performance comparison in terms of water flux, power density and specific salt flux of the TFC PEI hollow fiber membrane before (blue) and after (red) APTMS-grafting.

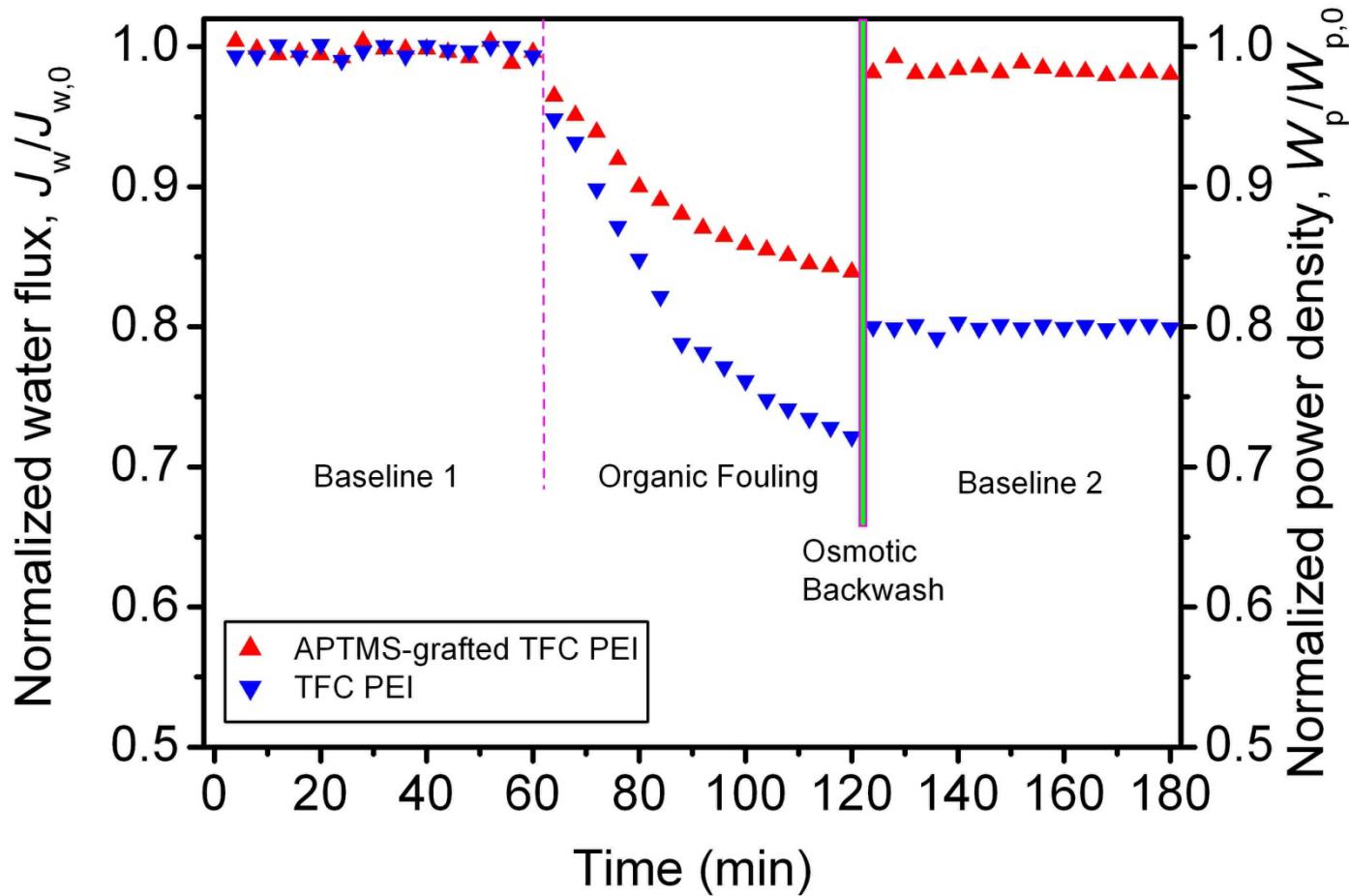


Fig. 8. Anti-fouling comparison of the TFC PEI hollow fiber membrane before and after APTMS-grafting.

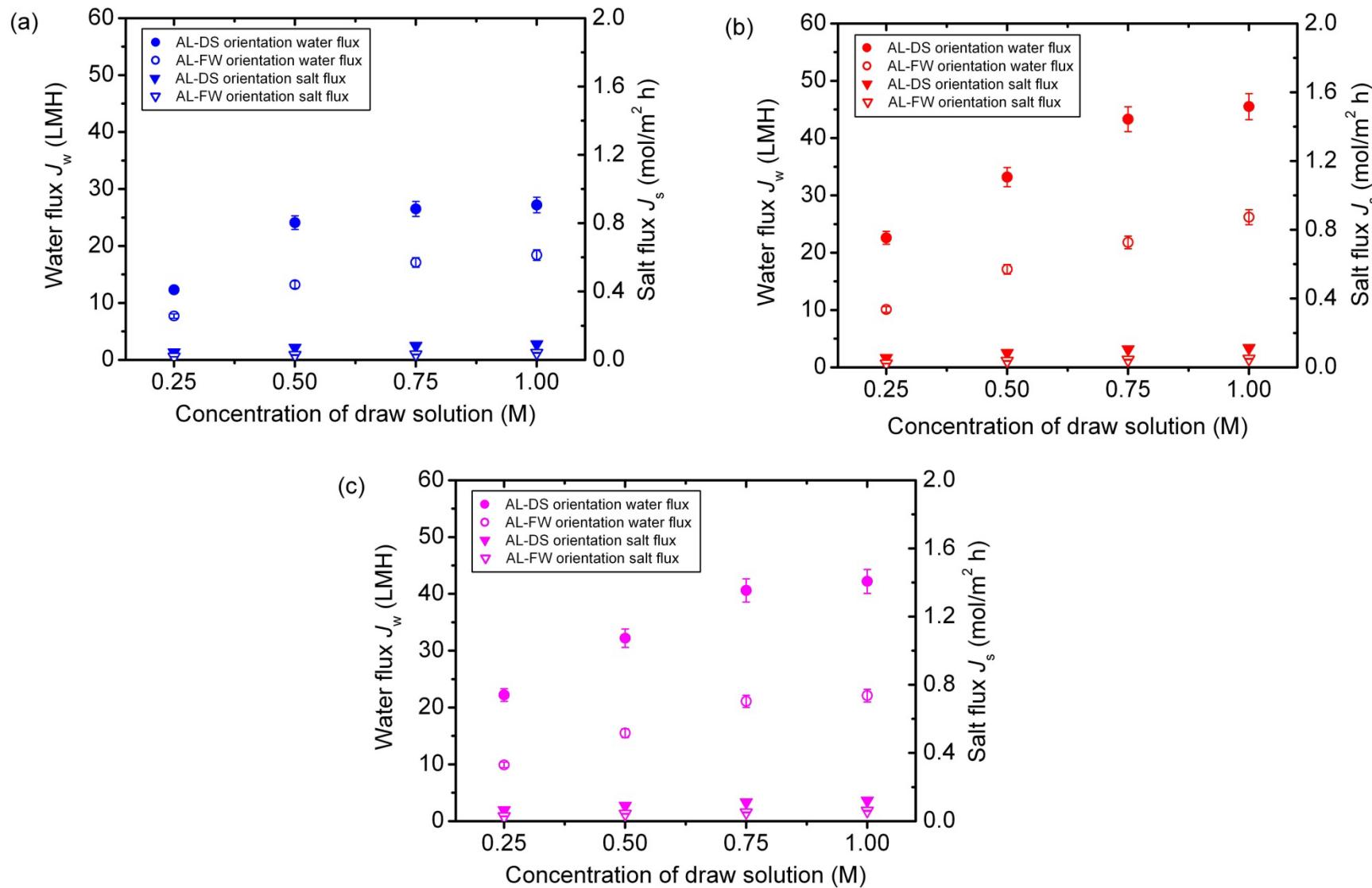


Fig. A1. FO testing results for different polyamide selective layers: (a) PA (MPD/TMC), (b) APTMS-grafted PA (MPD/TMC) and (c) PA (APTMS/TMC).

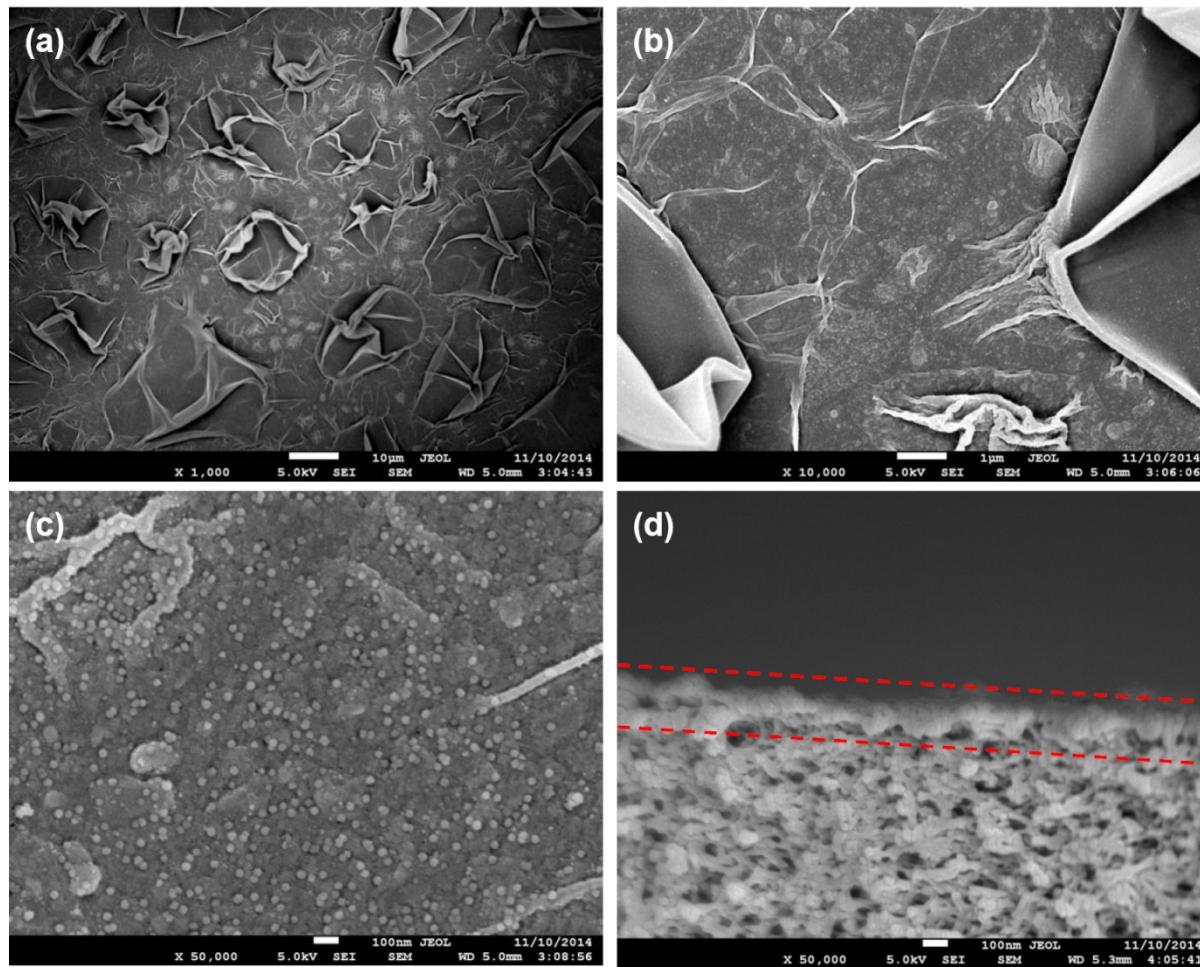


Fig. B1. Morphologies of the APTMS/TMC polyamide selective layer: (a) enlarged at 1,000 \times ; (b) enlarged at 10,000 \times ; (c) enlarged at 50,000 \times ; (d) the cross section view.

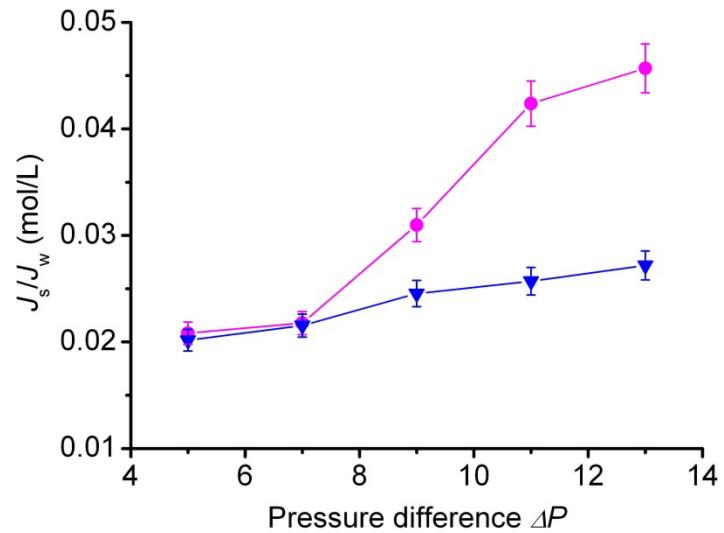
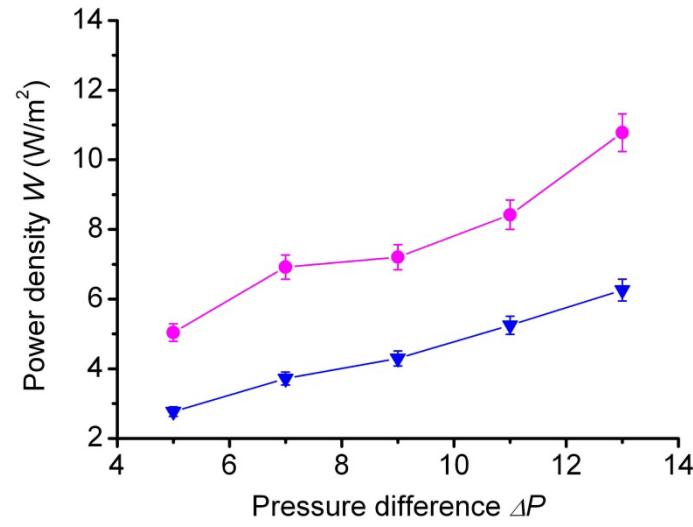
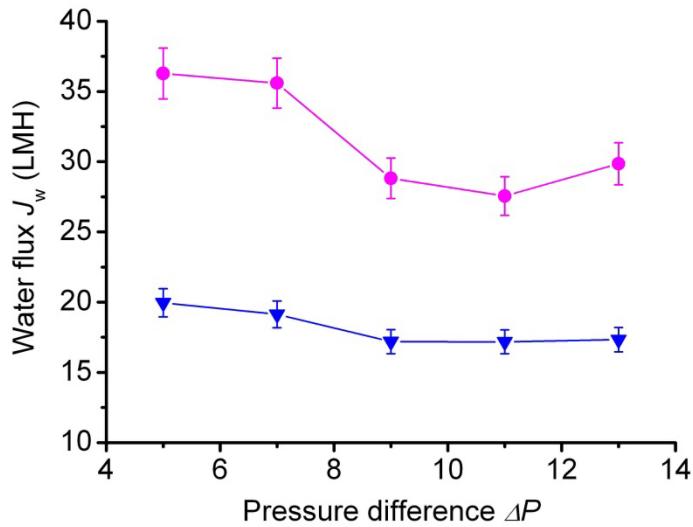


Fig. B2. PRO performance comparison between the APTMS/TMC TFC PEI hollow fiber membrane (pink) and the original MPD/TMC TFC PEI hollow fiber membrane (blue).