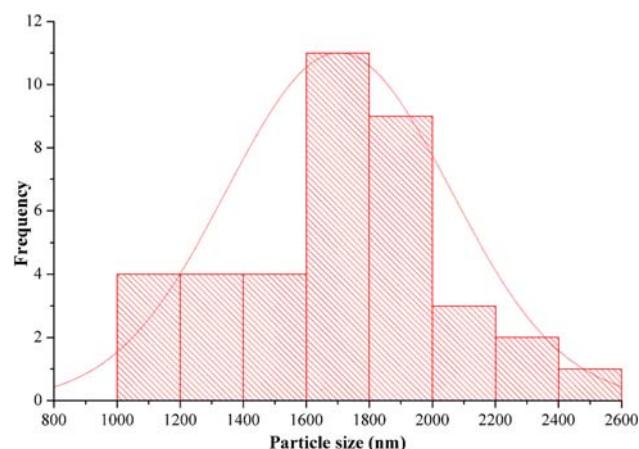


5 Supplementary material

Appendix 1: Particle size distribution of MIL-100(Al)

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Figure S1: Particle size distribution of MIL-100(Al).

20 Appendix 2: Particle distribution of MIL-100(Al) on membrane analyzed by EDX

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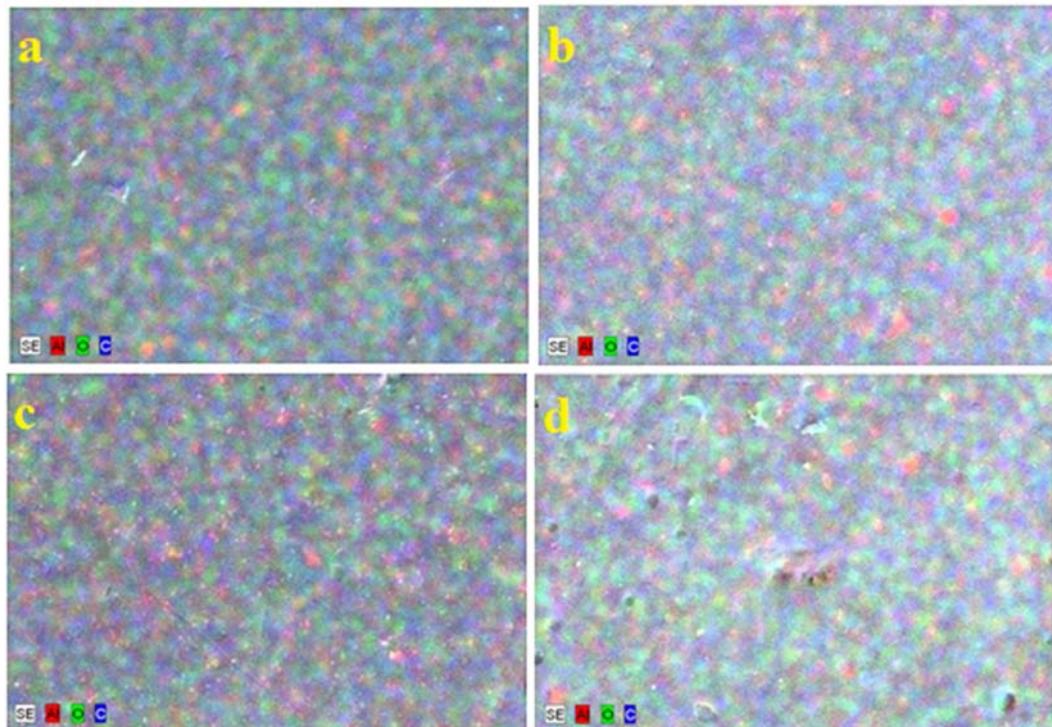


Figure S2: Particle distribution of MIL-100(Al) on membrane analyzed by EDX, (a) PES/MIL-100(Al) 5%, (b) PES/MIL-100(Al) 10%, (c) PES/MIL-100(Al) 20%, (d) PES/MIL-100(Al) 30%.

Appendix 3: Thermogram of MIL-100(Al)

5 Formula of MIL-100(Al) = $\text{Al}_3\text{O}(\text{OH})(\text{H}_2\text{O})_2[\text{BTC}]_2 \cdot x\text{H}_2\text{O} \cdot y\text{DMF}$
1st mass loss ca. 11.09%

$$11.09\% = \left(\frac{18x}{18x + 564.21} \right) \times 100\%$$

$$199.62x + 6257.0889 = 1,800x$$

$$6257.0889 = 1600.38x$$

10 $x = 4$ (uncoordinated water), if added with 2 coordinated water which stated in the main formula then the total water molecules ca. 6.

15 Where MW $\text{Al}_3\text{O}(\text{OH})(\text{H}_2\text{O})_2[\text{BTC}]_2 = 564.21 \text{ g mol}^{-1}$ about the DMF molecules containing in the compound $\text{Al}_3\text{O}(\text{OH})(\text{H}_2\text{O})_2[\text{BTC}]_2 \cdot x\text{H}_2\text{O} \cdot y\text{DMF}$.

20 2nd mass loss in total ca. 32.21% (from the beginning).

$$32.21\% = \left(\frac{18.02x + 73.09y}{527.92 + 18.02x + 73.09y} \right) \times 100\%$$

$$17004.63 + 580.42x + 2354.23y = 1,802x + 7,309y$$

$$17004.63 = 1221.58x + 4954.77y$$

25 If $x = 6$ then

$$9675.15 = 4.954, 77y$$

$$y = 2$$

30 The third mass reduction amount 49.99%

$$49.99\% = \frac{204z}{782.22 \text{ g/mol}} \times 100\%$$

35 (It is possible to loss of 2 ligand BTC molecules ($\text{Mr} = 204 \text{ g mol}^{-1}$))

$$t = 13.6 \text{ s}$$

Trial condition (1):	STP condition (2):
Pressure = 150.012 cm Hg	Pressure = 75.006
Temperature = 26°C =	Temperature = 0°C =
299.15 K	273.15 K

Conversion gas volume to volume at STP condition
Ideal gas equation:

$$\frac{P_1 V_1}{n_1 R T_1} = \frac{P_2 V_2}{n_2 R T_2}$$

Because $n_1 = n_2$; R constant; so the equation is

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$V_2 = \frac{P_1 V_1 T_2}{P_2 T_1}$$

$$V_2 = \frac{150.012 \text{ cm Hg} \times 10 \text{ mL} \times 273.15 \text{ K}}{75.006 \text{ cm Hg} \times 299.15 \text{ K}}$$

$$= 18.262 \text{ mL [STP]}$$

$$Q = \frac{V}{t} = \frac{18.262}{13.6} = 1.342 \text{ cm}^3/\text{s [STP]}$$

25 N_2 gas permeability

$$P = \frac{Ql}{AP} \times 10^{10}$$

$$= \frac{1.342 \text{ cm}^3/\text{s} \times 1.01 \times 10^{-4} \text{ cm}}{15.9107 \text{ cm}^2 \times 150.012 \text{ cm Hg}} \times 10^{10}$$

$$= 568.44 \text{ Barrer}$$

Appendix 5: Calculation of gas selectivity on MMMs PES/MIL-100(Al)

$$\alpha_{i/j} = \frac{P_i}{P_j}$$

$$\alpha_{\text{CO}_2/\text{N}_2} = \frac{P_{\text{CO}_2}}{P_{\text{N}_2}}$$

$$= \frac{574.53 \text{ Barrer}}{568.44 \text{ Barrer}}$$

$$= 1.01$$

Appendix 4: Calculation of gas permeability on variation of MIL-100(Al) addition on polyethersulfone

40 Example of calculation N_2 gas permeability on PES membrane

45 Constant parameter: $A = 3.14 \times (2.25 \text{ cm})^2 = 15.9107 \text{ cm}^2$

If: $l = 0.000101 \text{ cm}$

$V = 10 \text{ mL} = 10 \text{ cm}^3$

Table S1: PES *neat* membrane

Gas	V (cm³)	Q (cm³/s)	T (K)	P (cm Hg)	l (cm)	Permeability (barrer)	Average permeability (barrer)
N ₂	18.26	1.33	299.15	150.01	0.000101	560.60	564.52 ± 5.54
	18.26	1.34	299.15	150.01	0.000101	568.44	5
O ₂	18.26	0.49	299.15	150.01	0.000101	209.07	213.89 ± 6.81
	18.26	0.52	299.15	150.01	0.000101	218.71	
CO ₂	18.26	1.34	299.15	150.01	0.000101	565.52	570.03 ± 6.37
	18.26	1.36	299.15	150.01	0.000101	574.53	10

Table S2: MMMs PES/MIL-100(Al) 5%

Gas	V (cm³)	Q (cm³/s)	T (K)	P (cm Hg)	l (cm)	Permeability (barrer)	Average permeability (barrer)
N ₂	4.49	1.35	304.15	75.01	0.000105	1194.52	1149.91 ± 63.09
	4.49	1.25	304.15	75.01	0.000105	1105.30	
O ₂	4.49	0.85	304.15	75.01	0.000105	750.81	862.13 ± 157.42
	4.49	1.10	304.15	75.01	0.000105	973.44	20
CO ₂	4.49	2.02	304.15	75.01	0.000105	1783.18	1799.51 ± 23.09
	4.49	2.06	304.15	75.01	0.000105	1815.84	

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Table S3: MMMs PES/MIL-100(Al) 10%

Gas	V (cm³)	Q (cm³/s)	T (K)	P (cm Hg)	l (cm)	Permeability (barrer)	Average permeability (barrer)
N ₂	4.48	0.67	305.15	75.01	0.000131	733.63	824.62 ± 128.68
	4.48	0.83	305.15	75.01	0.000131	915.60	
O ₂	4.48	0.42	305.15	75.01	0.000131	466.99	448.06 ± 26.78
	4.48	0.39	305.15	75.01	0.000131	429.12	
CO ₂	4.48	1.65	305.15	75.01	0.000131	1819.72	1749.68 ± 99.05
	4.48	1.52	305.15	75.01	0.000131	1679.65	35

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Table S4: MMMs PES/MIL-100(Al) 20%

Gas	V (cm³)	Q (cm³/s)	T (K)	P (cm Hg)	l (cm)	Permeability (barrer)	Average permeability (barrer)
N ₂	4.52	0.65	302.15	75.01	0.000237	1292.70	1194.20 ± 139.31
	4.52	0.55	302.15	75.01	0.000237	1095.69	45
O ₂	4.52	0.25	302.15	75.01	0.000237	488.68	492.21 ± 4.99
	4.52	0.25	302.15	75.01	0.000237	495.74	
CO ₂	4.52	1.22	302.15	75.01	0.000237	2428.88	2210.77 ± 308.46
	4.52	1.00	302.15	75.01	0.000237	1992.65	50

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Table S5: MMMs PES/MIL-100(Al) 30%

Gas	V (cm ³)	Q (cm ³ /s)	T (K)	P (cmHg)	l (cm)	Permeability (barrer)	Average permeability (barrer)
N ₂	4.48	3.00	305.15	75.01	0.000361	9062.27	8536.14 ± 744.06
	4.48	2.65	305.15	75.01	0.000361	8010.01	
O ₂	4.48	1.89	305.15	75.01	0.000361	5724.35	5743.87 ± 27.61
	4.48	1.91	305.15	75.01	0.000361	5763.39	
CO ₂	4.48	2.87	305.15	75.01	0.000361	8667.25	9741.99 ± 1519.91
	4.48	3.58	305.15	75.01	0.000361	10816.72	

Table S6: Example of calculation CO₂/N₂ gas selectivity on PES membrane

Membrane	Permeability (barrer)			Selectivity					
	N ₂	O ₂	CO ₂	O ₂ /N ₂	CO ₂ /N ₂	CO ₂ /O ₂	CO ₂ /O ₂		
PES <i>neat</i>	560.60	209.07	565.52	0.37	0.38 ± 0.01	1.01	1.01 ± 0.00	2.70	2.67 ± 0.04
	568.44	218.71	574.53	0.38		1.01		2.63	
PES/MIL-100(Al) 5%	1194.52	750.81	1783.18	0.63	0.75 ± 0.18	1.49	1.57 ± 0.11	2.38	2.12 ± 0.36
	1105.30	973.44	1815.84	0.88		1.64		1.87	
PES/MIL-100(Al) 10%	733.63	466.99	1819.72	0.64	0.55 ± 0.12	2.48	2.16 ± 0.46	3.90	3.91 ± 0.01
	915.60	429.12	1679.65	0.47		1.83		3.91	
PES/MIL-100(Al) 20%	1292.70	488.68	2428.88	0.38	0.42 ± 0.05	1.88	1.85 ± 0.04	4.97	4.49 ± 0.67
	1095.69	495.74	1992.65	0.45		1.82		4.02	
PES/MIL-100(Al) 30%	9062.27	5724.35	8667.25	0.63	0.68 ± 0.06	0.96	1.15 ± 0.28	1.51	1.70 ± 0.26
	8010.01	5763.39	10816.72	0.72		1.35		1.88	

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