Supporting Information

Synthesis of highly soluble zirconium organic cages by iodine

substitution toward CO₂/N₂ separation membrane

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Experimental Section

1. Chemicals:

Bis(cyclopentadienyl)zirconium dichloride (Cp₂ZrCl₂, Energy Chemical, 98%), 2aminoterephthalic acid (Energy Chemical, 98%), diethylformamide (DEF, Energy Chemical, 99%), iodomethane (CH₃I, Energy Chemical, 99.5%), bromoethane (EtBr, Energy Chemical, 99%), N,N-tetramethylammonium iodide (N(CH₃)₄I, Energy Chemical, 99%), hydroxylamine (NH₂OH, Energy Chemical, 50 wt% in water), anhydrous potassium carbonate $(K_2CO_3,$ Sigma-Aldrich, 99%), 5.5'.6.6'tetrahydroxy-3,3,3'3'-tetramethyl-1,1'-spirobisindane (TTSBI, Alfa-Aesar, 98%), 2,3,5,6-tetrafluoroterephthalonitrile (TFTPN, Sigma-Aldrich, 99%), anhydrous tetrahydrofuran (THF, Energy Chemical, <50 ppm water) and anhydrous N,Ndimethylformamide (DMF, Energy Chemical, <50 ppm water) were used as received. The solvents of methanol (CH₃OH) and chloroform (CHCl₃) in analytical grade were received from Beijing Chemical Works.

2. ZrT-NH₂ Synthesis:

ZrT-NH₂ was synthesized according to the literature.^{S1} Typically, Cp_2ZrCl_2 (17.5 mg, 0.06 mmol), 2-aminoterephthalic acid (5.4 mg, 0.03 mmol), DEF (1 mL) and H₂O (150 µL) were added into a 5 mL vial. The mixture became clear yellow solution after sonication for 3 minutes. The solution was then heated in a preheated oven at 60 °C for 8 h followed by naturally cooling to room temperature for 4 h. Yellow cubic crystals were yielded and washed with fresh DEF.

3. ZrT-NH₂-I Synthesis:

ZrT-NH₂ (100 mg, 0.044 mmol) was dispersed in 1 mL of DMF in a 5 mL vial, followed by the addition of CH₃I (20 μ L, 0.32 mmol). After reaction at room temperature for 2 h, the solution was subjected to rotary evaporation and the solvent was removed to yield brown product of ZrT-NH₂-I in powder form. This product was washed with CHCl₃ for 3 times in order to remove unreacted CH₃I.

The solubility of ZrT-NH₂-I was measured via two methods of direct dissolution and liquid lyophilization of supersaturated solution. (a) ZrT-NH₂-I with definite mass was added slowly into 1 mL of the solvent (CH₃OH, DMF) and this compound was completely dissolved (clear transparent solution). The mass per unit solvent volume was defined as the solubility. (b) ZrT-NH₂-I was continuously added into 1 mL of the solvent (CH₃OH, DMF) until the solution became supersaturated (appearance of suspension, Tyndall phenomenon). The supersaturated solution was centrifuged at 20000 rpm for 30 minutes to collect the supernatant. This supernatant was further lyophilized to get the ZrT-NH₂-I mass, and the solubility was back calculated using ZrT-NH₂-I mass and solvent volume. The solubility values measured by these two methods are quite consistent.

ZrT-NH₂ (100 mg, 0.044 mmol) was dispersed in 1 mL of DMF in a 5 mL vial, followed by the addition of EtBr (24 μ L, 0.32 mmol). After reaction at room temperature for 1 d, the solution was subjected to rotary evaporation and the solvent was removed to yield yellow product of ZrT-NH₂-Br. This product was washed with CHCl₃ for 3 times in order to remove unreacted EtBr.

5. ZrT-NH₂-PhCH₂I Synthesis:

ZrT-NH₂ (100 mg, 0.044 mmol) was dispersed in 1 mL of DMF in a 5 mL vial, followed by the addition of PhCH₂I (40 μ L, 0.32 mmol). After reaction at room temperature for 1 d, the solution was subjected to rotary evaporation and the solvent was removed to yield yellow product of ZrT-NH₂-PhCH₂I. This product was washed with CHCl₃ for 3 times in order to remove unreacted PhCH₂I.

6. ZrT-NH₂-N(CH₃)₄I Synthesis:

ZrT-NH₂ (100 mg, 0.044 mmol) was dispersed in 1 mL of DMF in a 5 mL vial, followed by the addition of N(CH₃)₄I (64 mg, 0.32 mmol). After reaction at room temperature for 1 d, the solution was subjected to rotary evaporation and the solvent was removed to yield faint yellow product of ZrT-NH₂-N(CH₃)₄I. This product was washed with CHCl₃ and H₂O for 3 times each, respectively.

7. PIM-1 Synthesis:

PIM-1 was obtained following a previously reported method.^{S2} Under a nitrogen atmosphere, TFTPN (1.204 g), TTSBI (2.05 g) and anhydrous DMF (40 mL) were added into a 100 mL three-necked flask. After TFTPN and TTSBI were completely dissolved, anhydrous milled K_2CO_3 (1.664 g) was added in the flask. Then, the reaction was started by heating up to 65 °C for 72 h at the same temperature under stirring. The yellow precipitate was filtrated out and washed fully with deionized water to remove any K_2CO_3 . The polymer product was first dissolved in CHCl₃ and then reprecipitated in MeOH for 3 times. The final PIM-1 was obtained after drying at room temperature for 24 h.

8. PIM-PAO Synthesis:

PIM-PAO was obtained following a previously reported method.^{S2} PIM-1 (0.5 g) was first dissolved in THF (30 mL) and then heated to reflux under nitrogen atmosphere. Then, NH₂OH (5.0 mL) was added dropwise, and the solution was further refluxed for 20 h. The resultant polymer was precipitated by an addition of ethanol, filtered and then washed thoroughly with ethanol and water, and finally dried at 110 °C for 10 h. The molecular weight (Mw) of PIM-PAO is 192923.

9. Fabrication of ZrT-NH₂-I@PIM-PAO Membranes:

The pristine membrane of PIM-PAO and mixed-matrix membranes of ZrT-NH₂-I@PIM-PAO were fabricated by the solution-casting method. To fabricate a pure polymer membrane, 3 wt% PIM-PAO in DMF was filtered through a 0.45 μ m PTFE filter onto a silicon pellet. After slow evaporation of the solvent at 60 °C, a dense

membrane was obtained. The membrane was then placed in a high-vacuum oil-free oven at 150 °C for 10 h to remove the residual solvent. To fabricate the mixed-matrix membrane, a clear DMF solution of 3 wt% ZrT-NH₂-I and PIM-PAO was first configured and then stirred for 1 h before sonication for 30 minutes. The casting procedure for the membrane of ZrT-NH₂-I@PIM-PAO was the same as that of PIM-PAO. The loadings of ZrT-NH₂-I in the membranes were varied in the range of 0-10 wt%.

10. Characterizations:

Nuclear magnetic resonance spectroscopy (NMR): NMR spectra were recorded on a Brüker Advance 500 (¹H: 500 MHz), and TMS was used as intrinsic internal standard. ZrT-NH₂-I was dissolved in CD₃OD and its NMR spectrum was directly measured. For measuring the NMR spectrum of hydrolyzed ZrT-NH₂-I, ZrT-NH₂-I was first decomposed with 1.0 M NaOH solution and centrifuged to remove solid residuals, and then extracted by n-hexane to obtain the ligand solution. This solution was further acidified with 1.0 M HCl solution and extracted by ethyl acetate, and the ligand was obtained after solvent removal. This pretreatment was done in order to eliminate the impurity effect on the organic ligand. An internal standard of 1,3,5-trimethoxybenzene was added into DMSO-d6 for NMR measurement.

Powder X-ray diffraction (PXRD): PXRD was performed using a Rigaku SmartLab X-ray diffractometer (Cu-K α radiation, λ =1.5418 Å, 40 kV, 30 mA) in the range of 5-40° with a scanning rate of 10° min⁻¹.

High-resolution mass spectrometry (HRMS): HRMS data were recorded on Brüker Apex IV RTMS using ESI method.

Gas sorption: N₂ adsorption-desorption isotherms were collected at 77 K on a Quantachrome Autosorb-IQ2 analyzer. Prior to gas sorption measurements, the sample was washed with 10 mL CHCl₃ for 3 times each day, and the procedure was repeated for 2 days. The sample was then activated under a dynamic vacuum (\leq 1 Pa) at 80 °C for 12 hours in order to remove all solvent residues. High-pressure gas adsorptions were measured on XEMIS (Hiden Isochema) for the same sample.

Fourier transform infrared (FT-IR): all FT-IR spectra were measured on an IRPrestige-21 FTIR spectrometer.

Thermogravimetric analysis (TGA): TGA was carried out on a METTLER-TOLEDO TGA/DSC 3+ analyzer at a heating rate of 10 °C min⁻¹ in air atmosphere.

Scanning electron microscopy (SEM) and energy-dispersive X-ray (EDX) spectroscopy: SEM images and EDX mappings were obtained on a field emission scanning electron microscope (FE-SEM, SU-8010, Hitachi).

Inductively coupled plasma optical emission spectroscopy (ICP-OES): ICP-OES was measured on a spectrometer of Agilent ICPOES730.

Elemental analysis: the contents of C/H/N were measured for the desolvated samples of $ZrT-NH_2$ and $ZrT-NH_2-I$ on Eurovector EA3000.

Zeta potential and dynamic light scattering (DLS): Zeta potentials and DLS of ZrT- NH_2 -I and ZrT- NH_2 were measured on an instrument of Malvern Zetasizer-Nano.

Transmission electron microscopy (TEM): TEM images were taken on JEM-2100F transmission electron microscope.

X-ray photoelectron spectroscopy (XPS): XPS spectra were collected on an Esca-Lab MK II photoelectronic spectrometer with Al K α (1200 eV).

Gel permeation chromatography (GPC): the molecular weight of PIM-PAO was measured by GPC with DMF as the carrier solvent.

Raman spectroscopy: Raman spectra were recorded using Raman spectrometer (LabRAM Odyssey) with a laser ($\lambda_{ex} = 785 \text{ nm}$) as an excitation source. The spectra were recorded in the region of 50 – 1000 cm⁻¹, the acquisition time was 60 s, and the accumulation was 2. Raman spectra were used to analyze the iodine status in ZrT-NH₂ and ZrT-NH₂-I. Before the measurement, the samples were subjected to the following treatment: first, iodine I₂ was dissolved in the solvent of cyclohexane to form 0.01 mol L⁻¹ solution. Then, 100 mg ZrT-NH₂ or ZrT-NH₂-I were added into a sealed vial containing 5 mL solution of 0.01 mol L⁻¹ iodine/cyclohexane at room temperature statically without any disturbance. Dark brown products were obtained after ~12 h.

11.Gas Permeation:

Gas permeation experiments were executed on PIM-PAO and ZrT-NH₂-I@PIM-PAO membranes according to the Wicke-Kallenbach mode. The membranes were first fixed in a home-made membrane chamber and then tightly sealed with Teflon O-rings. A gas flow system was directly connected to the membrane chamber. Single CO₂ and N₂ gases (25 mL min⁻¹) or binary gas mixtures (CO₂ and N₂ of 25 mL min⁻¹) with volume ratio of 1:1 were fed into the membrane module on the feed side, and the permeate gases were collected from the permeate side using argon as a sweep gas (15 mL min⁻¹). The feed and permeate gases were detected by on-line gas chromatography (GC-7890B, Agilent). For all measurements, gas permeation data were analyzed after a steady state was reached. In addition, each membrane was repeated for five times at each condition to guarantee the result reproducibility. The separation characteristics were defined by permeability (Barrer) and selectivity according to Equation (1) and (2):

$$P = D \times S = \frac{F \times l}{\Delta p \times A} (1)$$

where $P \pmod{m^{-1} \text{ s}^{-1} \text{ Pa}^{-1}}$, 1.0 Barrer = $3.35 \times 10^{-16} \text{ mol m}^{-1} \text{ s}^{-1} \text{ Pa}^{-1}$), $D \pmod{2} \text{ s}^{-1}$) and $S \pmod{m^{-3} \text{ Pa}^{-1}}$ are permeability, diffusivity and solubility of CO₂ or N₂. $F \pmod{3^{-1}}$ and Δp (Pa) are molar flux and pressure drop of CO₂ or N₂, respectively; $l \pmod{3}$ and $A \pmod{2}$ are membrane thickness and area.

D and *S* were experimentally and theoretically obtained. *S* in the membrane was quantified from gas uptake at high pressure. The unit of mmol g^{-1} for the uptake was converted to mmol cm⁻³ using ZrT-NH₂-I (0.958 g cm⁻³) and PIM-PAO densities (0.92 g cm⁻³). *P* in the membrane was measured from gas permeation test. *D* was back calculated according to Equation (1). The selectivity was calculated according to Equation (2):

$$\alpha_{co_2/N_2} = \frac{P_{co_2}}{P_{N_2}} = \frac{D_{CO_2}}{D_{N_2}} \times \frac{S_{CO_2}}{S_{N_2}}$$
(2)

where $\alpha_{CO2/N2}$ is the selectivity for CO₂ over N₂.

Supporting Figures and Tables



Fig. S1 Simulated and experimental powder X-ray diffraction (XRD) patterns of ZrT-NH₂ and ZrT-NH₂-I. After activation, ZrT-NH₂ lost crystallinity. ZrT-NH₂-I was amorphous.



Fig. S2 Measured (top) and simulated (bottom) high-resolution mass spectra of ZrT- NH_2 solution in methanol. Values of m/z are 804.4, 1072.5 and 1608.7, respectively.



Fig. S3 Measured (top) and simulated (bottom) high-resolution mass spectra of ZrT-NH₂-Br solution in methanol. Values of m/z are 804.4, 1072.5 and 1608.7, respectively.



Fig. S4 Measured (top) and simulated (bottom) high-resolution mass spectra of ZrT- NH_2 -I solution in methanol. Values of m/z are 804.4, 1072.5 and 1608.7, respectively.



Fig. S5 FTIR spectra of ZrT-NH₂ and ZrT-NH₂-I.



Fig. S6 ¹H NMR spectra of organic ligands after ZrT-NH₂-I hydrolysis (0.02 mmol ZrT-NH₂-I, 0.02 mmol 1,3,5-trimethoxybenzene as an internal standard).



Fig. S7 ¹H NMR spectra of different organic and inorganic model molecules after reaction with $CH_{3}I$ for 2 h in DMF. The spectra in green and blue represent the molecules before and after reaction, respectively.



Fig. S8 XPS survey scans of ZrT-NH₂, ZrT-NH₂-Br and ZrT-NH₂-I. The elements of Cl, Br and I in ZrT-NH₂, ZrT-NH₂-Br and ZrT-NH₂-I are circled, respectively.



Fig. S9 XPS spectra of Zr 3d (a), Cl 2p (b), I 3d (c) and Br 3d (d) for ZrT-NH₂, ZrT-NH₂-I and ZrT-NH₂-Br.



Fig. S10 SEM image of ZrT-NH₂ and elemental mappings of Zr, Cl and I.



Fig. S11 SEM image of ZrT-NH₂-I and elemental mappings of Zr, Cl and I.



Fig. S12 TG curves of as-synthesized different Zr-MOC materials.



Fig. S13 ¹H NMR spectra of PIM-1 (black) and PIM-PAO (red).



Fig. S14 FT-IR spectra of PIM-1 (black) and PIM-PAO (red).



Fig. S15 Molecular weight (*Mw*) distribution plot of PIM-PAO.



Fig. S16 N_2 adsorption-desorption isotherms of PIM-1 and PIM-PAO at 77 K.

PIM-PAO		ZrT-NH ₂ -I@ PIM-PAO(3%)	ZrT-NH ₂ -I@ PIM-PAO(5%)	ZrT-NH₂-I@ PIM-PAO(8%)	ZrT-NH₂-I@ PIM-PAO(10%)	
11.11.11.12.12.13.1.1	i las Kola					
	20 um	20 um	20 um	20 um	20 um	
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	1 um	1 um	Tum	1 um	1 um	
SU8303 3 GkV 9 5mm x30 Gk 62(U)	t.coum su	dooo 3 dwy 3 dem v3c Dk 85(UL)	3.8000 3.04V 9 tmm x00 04 86(U)	Contraction from the first of t	BL6000 S 04/4 Sem via 54 65(UL)	
51-9000 3 04V 7 Smm v3 00k SE(U)	10 µm	10 µm	10 µm	10 µm	10 µm	

Fig. S17 SEM images of cross-sectional view and top view with different magnifications for the membranes of PIM-PAO and ZrT-NH₂-I@PIM-PAO (3%, 5%, 8%, 10% ZrT-NH₂-I).



Fig. S18 Cross-sectional SEM image of ZrT-NH₂-I@PIM-PAO (8% ZrT-NH₂-I) and EDX mappings of C, N, Zr and I elements in the membrane.



Fig. S19 Cross-sectional SEM images for the membrane of $ZrT-NH_2@PIM-PAO$ (5 wt% $ZrT-NH_2$) at low (a) and high (b-d) magnifications. The precipitates of $ZrT-NH_2$ are circled in (b).



Fig. S20 Solution (top) and membrane (bottom) photos of PIM-PAO, ZrT-NH₂-I@PIM-PAO and ZrT-NH₂@PIM-PAO. The cracks were observed in the high-loading membrane of ZrT-NH₂@PIM-PAO (8% ZrT-NH₂). An optical photograph of a ZrT-NH₂-I@PIM-PAO membrane (8% ZrT-NH₂-I) with a diameter of 50 mm.



Fig. S21 CO₂ adsorption isotherms of PIM-PAO membrane, ZrT-NH₂-I powder and ZrT-NH₂-I@PIM-PAO membrane (8% ZrT-NH₂-I) at 195 K.



Fig. S22 Separation performances of CO_2/N_2 gas mixture (v/v: 1/1) for the membranes with different fillers (8% fillers in PIM-PAO).



Fig. S23 Performance comparison of CO_2/N_2 separation for ZrT-NH₂-I@PIM-PAO (8% ZrT-NH₂-I) and relevant MMMs (data in red star is from this work, black line is 2008 Robeson upper bound, orange symbols for other MOCs based MMMs, green symbols for other MMMs of metal organic frameworks (MOFs), blue symbols for other MMMs of covalent organic frameworks (COFs) and their analogues, half-filled symbols for single gas, filled symbols for mixture gas.).

Samula	Test Theoretical		Actual content	Exchange	Reaction
Sample	element	content (mg L ⁻¹)	(mg L ⁻¹)	rate (%)	time
ZrT-NH ₂ -I	Ι	13.63	13.055	96%	2 h
ZrT-NH ₂ -Br	Br	9.04	9.3352	>99%	2 h
ZrT-NH ₂ -	Ι	13.63	5.4463	40%	1 d
N(CH ₃) ₄ I					
ZrT-NH ₂ -PhCH ₂ I	Ι	13.63	3.0620	22%	1 d

Table S1 ICP results of I or Br contents in different MOCs after iodine substitution.

Table S2 The elemental contents of C, H and N, and ICP results of Zr in ZrT-NH₂ and ZrT-NH₂-I.

Sample	С	Н	Ν	Zr	C/N	C/H	Zr/C
	(wt%)	(wt%)	(wt%)	(wt%)	(molar ratio)	(molar ratio)	(molar ratio)
ZrT-NH ₂	37.67±0.78	3.13±0.39	2.47 ± 0.36	32.13±1.3	17.8±0.89	$1.0{\pm}0.09$	0.11 ± 0.005
	(38.59)	(3.04)	(2.5)	(32.59)	(18)	(1.06)	(0.11)
ZrT-NH ₂ -	34.9±0.42	2.7±0.24	$2.24{\pm}0.87$	29.25±2.1	18.1±1.21	$1.07 {\pm} 0.06$	$0.11 {\pm} 0.007$
Ι	(34.8)	(2.74)	(2.26)	(29.39)	(18)	(1.06)	(0.11)

The values in brackets are theoretically from the chemical formulas.

Table S3 Solubility of $ZrT-NH_2$, $ZrT-NH_2-I$, $ZrT-NH_2-Br$, $ZrT-NH_2-N(CH_3)_4I$ and $ZrT-NH_2$ -PhCH₂I in MeOH or DMF at room temperature.

Sample	MeOH (mg mL ⁻¹)	DMF (mg mL ⁻¹)	Dissolve in DMF*
ZrT-NH ₂	3.3(3.5)	0.1(0.1)	
ZrT-NH ₂ -I	33(34)	200(202)	
ZrT-NH ₂ -Br	10(10.8)	40.6(41)	
ZrT-NH ₂ -N(CH ₃) ₄ I	9(9.4)	18.1(18)	

*The concentration of MOC in DMF is 10 mg mL⁻¹. The solubility was reported by the lyophilization of the supersaturated solution, and the value in brackets was reported by the direct dissolution.

Table S4 CO₂ and N₂ solubility (*S*) and diffusivity (*D*), and the corresponding selectivity for the membranes of PIM-PAO and ZrT-NH₂-I@PIM-PAO (8% ZrT-NH₂-I) from single-gas adsorption and permeation results.

Membrane	Solubility (10 ⁻² cm ³ (STP) cm ⁻³ cmHg ⁻¹)		S_{CO2}/S_{N2}	Diffu (10 ⁻⁸ c	sivity m ² s ⁻¹)	D_{CO2}/D_{N2}	P_{CO2}/P_{N2}
	CO ₂	N_2		CO_2	N ₂		
PIM-PAO	24.6	1.63	15	137	121	1.1	17.1
ZrT-NH ₂ -I	20.6	1 59	10	51	20.2	1 9	22.7
@PIM-PAO	29.0	1.38	19	51	20.3	1.8	33.7

Note: at 2 bar and 298 K, CO_2 adsorption capacities of PIM-PAO and ZrT-NH₂-I@PIM-PAO were measured at 41.0 and 49.3 cm³ g⁻¹, respectively; and N₂ adsorption capacities were 2.7 and 2.6 cm³ g⁻¹, respectively.

Table S5 Separation performances of CO_2/N_2 gas mixture (v/v: 1/1) for ZrT-NH2-I@PIM-PAO membranes with different thicknesses (8 wt% ZrT-NH2-I).

Thickness (µm)	CO ₂ Permeability (Barrer)	CO ₂ /N ₂ Selectivity
18	1376.9(±8.2)	44.8(±0.4)
28	1320.7(±8.8)	$44(\pm 0.5)$
30	1327.2(±27.9)	43(±1)

Table S6 Performance comparison of CO_2/N_2 separation for ZrT-NH₂-I@PIM-PAO and relevant MMMs reported in the literature.

Membrane	Test condition	Permeability (Barrer)	Selectivity	Reference			
МОС							
ZrT-NH2-I@PIM-PAO(8%)	25 °C, 2 bar	1376.9	45	This work			
MOP-18/Matrimid5218(23%)*	35 °C, 2.6 bar	9.4	27.6	S3			
FeMOP/PVDF(10%)*	35 °C	4.5	23	S4			
MOP-3/PolyPDXLA(10%)*	35 °C, 7.9 bar	210	53	S5			
MOP-15/6FDA-DAM(10%)	25 °C, 1 bar	1700	19	S6			
EG3-MOP/PEG9DMA(5%)*	35 °C, 2.5 bar	130.8	30.1	S7			
EG3-MOPs/XLPEO(2.5%)	30 °C, 6 bar	144.7	26.5	S8			
MOF							
UiO-66-NH ₂ /PAO-PIM-1(7%)	35 °C, 1 bar	3825	30.0	S2			
UiO-66/PIM-1(10%)	25 °C, 4 bar	6981	16	S9			

ZIF-8/Pebax-2533(10%)*	25 °C, 2 bar	427	31.4	S10				
NH ₂ -Co/ZIF-8/PEO(5%)	30 °C, 1 bar	2916	47	S11				
NH2-ZIF-8/Pebax(6%)	25 °C, 1 bar	163.8	62	S12				
NH ₂ -MIL-53(Al)/CA(15%)	25 °C, 3 bar	34.8	15.8	S13				
BUCT-2/PEO(30%)*	35 °C, 5 bar	635.1	41.8	S14				
PHNZ-2/Pebax(10%)	25 °C, 1 bar	121.9	96.6	S15				
HKUST-1/6FDA-Durene(13.8%)	25 °C, 2 bar	1101.6	27.1	S16				
	COF and analogs							
POP/PGO(10-2)*	30 °C	232	80.7	S17				
CTF-1/PSF(8%)*	25 °C, 3 bar	9.2	23	S18				
COF-LZU1/XLPEG(1%)	25 °C, 0.5 bar	322.5	28.2	S19				
COF-5/Pebax-1657(0.4%)	30 °C, 1 bar	493	49.3	S20				
HOF-21/Pebax(3%)	40 °C, 2 bar	840	60	S21				
Pebax1074/PEG1500(10%)	35 °C, 5 bar	99.9	43.8	S22				

*Results from single-gas permeation. The numbers in brackets are the filler loadings, and the performances are compared on the basis of filler loadings as similar as possible.

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