Electronic Supplementary Information

One-Step Synthesis of ZIF-8/90-based Type I Porous Liquid

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**Mass content of ZIF-8/90 in ZIF-8/90-PL**

The weight percent of polyetheramine in ZIF-8/90-PL as determined by TGA instrument. To ensure the accuracy of the experiment, the sample was heated from 25 °C to 130 °C in a nitrogen atmosphere at a rate of 10 °C/min for 60 minutes to eliminate gas or water vapor molecules absorbed or adsorbed by the sample during the experiment. Then it was heated to 800 °C in an air atmosphere at the same rate for 30 minutes. The weight percent of polyetheramine in ZIF-8/90-PL was calculated according to Eq. (S1):

\[
\text{Content} = 1 - \frac{m_0}{m_1} / \left( \frac{m_2}{m_3} \right) \quad (S1)
\]

Where \(m_0\) and \(m_1\) are the residual mass of ZIF-8/90-PL after thermal treatment and the initial mass of ZIF-8/90-PL before thermal treatment, respectively; \(m_2\) and \(m_3\) are the residual mass of ZIF-8/90 after thermal treatment and the initial mass of ZIF-8/90 before thermal treatment.

**Gas Absorption Test**

Volumetric CO\(_2\) absorption data were collected using a Micromeritics 3 Flex instrument at 298 K and pressure of 1 bar. The absorption chamber was loaded with ca. 0.5 g of liquid sample residing the sample bucket. The atmospheric gas absorption of CH\(_4\) and N\(_2\) uptakes were also collected in a Micromeritics 3 Flex instrument at 298 K.

Gravimetric CO\(_2\) absorption data were collected using a Mettler Toledo TGA/DSC 3+ instrument. A specified weight of absorbents was placed into the sample pan and activated under a pure N\(_2\) flow at a rate of 50 mL/min at 100 °C for 30 min. Then, the CO\(_2\) capture experiment was tested under pure CO\(_2\) at room temperature with a rate of 50 mL/min.

**CO\(_2\) Absorption heat**

The CO\(_2\) adsorption heat was also evaluated according to the integral area of the DSC curves (data from Mettler Toledo TGA/DSC 3+), as follows:

\[
\text{Adsorption heat} = \frac{\text{Heat}}{\text{CO}_2 \text{ adsorption capacity}} \quad (S2)
\]

**The IAST calculation**

The ideal adsorption solution theory (IAST) was utilized to predict the binary mixture composed of CO\(_2\) (15%) and N\(_2\) (85%) from the experimental pure-gas isotherms. Herein the single-component isotherms were fit to the Langmuir equation. The selectivity \(S_{A/B}\) in a binary
mixture of component A and B is defined as \((x_A/y_A)/(x_B/y_B)\), where \(x_i\) and \(y_i\) are the mole fractions of component \(i\) \((i=A,B)\) in the sorbed and bulk phases respectively.

**Gas Separation Test of Membranes**

The gas separation performance of composite membranes via a constant pressure/variable volume method.\(^1\) The gas permeance experiments were carried out in triplicate. Test results were calculated by the following equation:

\[
P = \frac{1}{\Delta P \cdot A} \cdot \frac{273.15 \cdot P_{atm} \cdot d_V}{T \cdot 76 \cdot \frac{dV}{dt}}
\]

(S3)

Where \(P\) is the gas permeance \((1 \text{ GPU} = 10^{-6} \text{ cm}^3 \text{ (STP)} \text{ cm}^{-2} \text{ s}^{-1} \text{ cm Hg})\), \(\Delta P\) is the transmembrane pressure \((\text{atm})\), \(A\) is the effective area of membrane, \(P_{atm}\) represents the atmospheric pressure \((\text{atm})\), \(T\) is the testing temperature \((\text{K})\), and \(dV/dt\) represents the volumetric displacement rate in the bubble flow meter.

The mixed gas permeation test was measured at 1 atm and 298 K. A mixture of CO\(_2\)/N\(_2\) (or CH\(_4\)) \((50 \text{ vol%}: 50 \text{ vol%})\) was employed as the feed gas, while He (helium) was chosen as the sweep gas. A gas chromatography \((\text{GC}, 7820A, \text{Agilent Technologies})\), equipped with thermal conductivity detector \((\text{TCD})\) and a packed column of HAYESEP-DB, was used to analyse gas compositions.

The selectivity of binary gas mixtures can be calculated as follows:

\[
\alpha_{A/B} = \frac{y_A/y_B}{x_A/x_B}
\]

(S3)

Where \(x\) and \(y\) are the volumetric fraction of the one component in the feed and permeate side, respectively.
Fig. S1 (a) SEM image of ZIF-8/90; (b) Calculated PXRD patterns of ZIF-8/90, experimental PXRD patterns of ZIF-8, ZIF-90 and ZIF-8/90; (c) N$_2$ sorption isotherms at 77 K of ZIF-8/90; (d) Thermal gravimetric measurements of ZIF-8, ZIF-90 and ZIF-8/90 under N$_2$ atmosphere at a heating rate of 10 °C/min and (e) Alkali resistance test of ZIF-8/90, ZIF-8/90 was stable at the pH of 12.
Fig. S2 $^1$H-NMR spectra for ZIF-8/90.

Fig. S3 TEM image of ZIF-8/90-PL.

Fig. S4 TG curves of ZIF-8/90, M2070 and ZIF-8/90-PL under air flow at a heating rate of 10 °C/min.
**Fig. S5** CO₂ sorption data of ZIF-8/90-PL with 2-formylimidazolate percentage of 40%, 50% and 60% at 298 K.

**Fig. S6** The N₂ and CH₄ uptakes of ZIF-8/90-PL and M2070, performed at 298 K and 1 bar.

**Fig. S7** The reuse of ZIF-8/90-PL for the absorption of CO₂ at 298K.
**Fig. S8** Images of the thin film composite membranes. (a) M2070 coated on the \(\alpha\)-Al\(_2\)O\(_3\) hollow fiber and (b) ZIF-8/90-PL coated on the \(\alpha\)-Al\(_2\)O\(_3\) hollow fiber.

**Fig. S9** IAST-predicted selectivity of the mixture of CO\(_2\) and CH\(_4\) for ZIF-8/90-PL and M2070.

**Fig. S10** IAST-predicted selectivity of the mixture of CO\(_2\) and N\(_2\) for ZIF-8/90-PL and M2070.
Table S1. Comparison of CO\(_2\) absorption capacities of various PLs with the currently prepared ZIF-8/90-PL (298 K).

<table>
<thead>
<tr>
<th>Porous liquid</th>
<th>Porogen</th>
<th>CO(_2) uptake (mmol g(^{-1}))</th>
<th>Type</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZIF-8@BPEI-PDMS(1000)-5%</td>
<td>ZIF-8</td>
<td>0.0581 (1 bar)</td>
<td>I</td>
<td>2</td>
</tr>
<tr>
<td>ZIF-8-g-BPEI-PDMS(1000)-5%</td>
<td>ZIF-8</td>
<td>0.0475 (1 bar)</td>
<td>I</td>
<td>2</td>
</tr>
<tr>
<td>UiO-66-liquid</td>
<td>UiO-66-OH</td>
<td>0.86 (30 bar)</td>
<td>I</td>
<td>3</td>
</tr>
<tr>
<td>UiO-66@OS@PEGS</td>
<td>UiO-66</td>
<td>0.636 (10 bar)</td>
<td>I</td>
<td>4</td>
</tr>
<tr>
<td>UiO-66-liquid-M1000</td>
<td>UiO-66</td>
<td>1.95 (10 bar)</td>
<td>I</td>
<td>5</td>
</tr>
<tr>
<td>UiO-66-liquid-M2070</td>
<td>UiO-66</td>
<td>2.68 (10 bar)</td>
<td>I</td>
<td>5</td>
</tr>
<tr>
<td>Deim-Uio-PL</td>
<td>UiO-66</td>
<td>5.93 (9 bar)</td>
<td>I</td>
<td>6</td>
</tr>
<tr>
<td>ZIF-8/90-PL</td>
<td>ZIF-8/90</td>
<td>0.269 (1 bar)</td>
<td>I</td>
<td>This work</td>
</tr>
<tr>
<td>15-C-5-PL</td>
<td>KACC cage</td>
<td>0.375 (10 bar)</td>
<td>II</td>
<td>7</td>
</tr>
<tr>
<td>18-C-6-PL</td>
<td>Scrambled CC3-R</td>
<td>0.429 (5 bar)</td>
<td>II</td>
<td>8</td>
</tr>
<tr>
<td>CC3-R/Hexachloropropene (HCP)</td>
<td>PMOP</td>
<td>0.14 (1 bar)</td>
<td>II</td>
<td>9</td>
</tr>
<tr>
<td>ZIF-8/[DBU-PEG] [NTf(_2)]-PL</td>
<td>ZIF-8</td>
<td>0.39 (10 bar)</td>
<td>III</td>
<td>10</td>
</tr>
<tr>
<td>ZIF-8/[P(_{6,6,6,14})] [NTf(_2)]-PL</td>
<td>ZIF-8</td>
<td>0.467 (5 bar)</td>
<td>III</td>
<td>11</td>
</tr>
<tr>
<td>ZIF-8/[Bpy][NTf(_2)]-PL</td>
<td>ZIF-8</td>
<td>0.057 (1 bar)</td>
<td>III</td>
<td>12</td>
</tr>
<tr>
<td>ZIF-8/[P(_{4,4,4,4})] [Lev]-PL</td>
<td>ZIF-8</td>
<td>1.14 (1 bar)</td>
<td>III</td>
<td>13</td>
</tr>
<tr>
<td>D2000@UIO-66/[M2070][IPA]</td>
<td>UiO-66</td>
<td>1.66 (10 bar)</td>
<td>III</td>
<td>14</td>
</tr>
<tr>
<td>UiO-66(185)@xPDMS/PDMS</td>
<td>UiO-66@PDMS</td>
<td>1.38 (1bar)</td>
<td>III</td>
<td>15</td>
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<tr>
<td>UiO-66-SO(<em>2)H(</em>{10}%) -CE</td>
<td>UiO-66-SO(_2)H</td>
<td>2.90 (bar)</td>
<td>III</td>
<td>16</td>
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<tr>
<td>Zn(AzDC)(4,4'BPE)(_3) [BMIM][NTf(<em>2)](</em>{0.5})</td>
<td>Zn(AzDC)(4,4'BPE)</td>
<td>0.178 (1bar)</td>
<td>III</td>
<td>17</td>
</tr>
</tbody>
</table>
References


