Supported Ionic Liquid Membranes for Carbon Dioxide Separation

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Precombustion CO$_2$ Capture in IGCC
Potential of Ionic Liquids

- Negligible Vapor Pressure
- Thermally Stable above 200°C
- High CO₂ Solubility Relative to H₂, N₂, and CH₄
Several Fabrication Options

- Porous Substrate
- Dense Substrate
Selection of Support Material Significant

PES Support-Supor®
- Suggested by Noble et al. as a useful support*
- \( T_g \sim 210^\circ C \)
- Visible change when heated to 100\(^\circ C\) in the presence of [hmim][Tf\(_2\)N]
- Membrane failure occurs at less than 50\(^\circ C\)

PSF Support-HT Tuffryn®
- Unmodified \( T_g \sim 150^\circ C \)
- Membrane stable to 125\(^\circ C\)

Constant Pressure Flux Measurements

[Diagram showing a flowchart of a system with labeled components: Feed, Furnace, Carrier Gas, GC, and Sweep and Carrier Gas (argon).]
Support Failure Limits Performance

Permeability (Bar) vs. Temperature (°C)

- CO₂: $Y = 6206e^{-0.6435x}$, $R^2 = 0.9569$
- He: $Y = 72571e^{-2.0902x}$, $R^2 = 0.9994$

Selectivity vs. $1000/T (K^{-1})$

- $Y = 0.1154e^{1.3483x}$, $R^2 = 0.9954$
Other Mechanisms Inconsistent

Original Mechanism

New Mechanism
DSC Confirms Large T_g Reduction for PES

Heat Flow (W/g) vs. Temperature (°C)

- **PES without Ionic Liquid**
- **PES with Ionic Liquid**

DSC confirms large T_g reduction for PES.
PSF Less Affected

Heat Flow W/g

Temperature °C

PSF without Ionic Liquid

PSF with Ionic Liquid
Permeabilities Similar to Literature


Diffusivities Comparable to Literature

Separation from H$_2$ Favorable

![Graph showing permeability of CO$_2$, H$_2$, and He at different temperatures.](image)
Temperature Dependence Similarity

Selectivity vs. \( \frac{1000}{T} \) (K\(^{-1}\))

- **CO\(_2\)/He**
- **CO\(_2\)/H\(_2\)**

Key temperatures:
- 100°C
- 75°C
- 50°C
- 35°C
H$_2$O in Feed and Non-Ideality Insignificant

<table>
<thead>
<tr>
<th></th>
<th>Pure Gas</th>
<th>Dry Gas Mixture</th>
<th>Wet Gas Mixture</th>
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<tbody>
<tr>
<td>Temperature (°C)</td>
<td>37</td>
<td>100</td>
<td>37</td>
</tr>
<tr>
<td>CO$_2$ Permeability (Barrer)</td>
<td>817</td>
<td>1170</td>
<td>840</td>
</tr>
<tr>
<td>H$_2$ Permeability (Barrer)</td>
<td>136</td>
<td>359</td>
<td>121</td>
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<tr>
<td>Selectivity (CO$_2$/H$_2$)</td>
<td>6.4</td>
<td>3.3</td>
<td>7.0</td>
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</tbody>
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SILM’s versus Polymers


Polymer Literature Data

CO₂/H₂ Selectivity vs. Permeability (Barrer)
Summary

- Support selection in SILM is nontrivial.
- Support performance is predictable by DSC analysis.
- Current performance limited by support failure and IL blowout.
- Ideal and non-ideal selectivities similar.
- Performance not significantly impacted by a small amount of water in the feed.
- Unoptimized SILM’s are competitive with the best polymer membranes.
Acknowledgements

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