Membranes based on Polymerized Metal-Organic Frameworks for CO_2 Capture (SC0018956)

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Objectives of DOE STTR Project

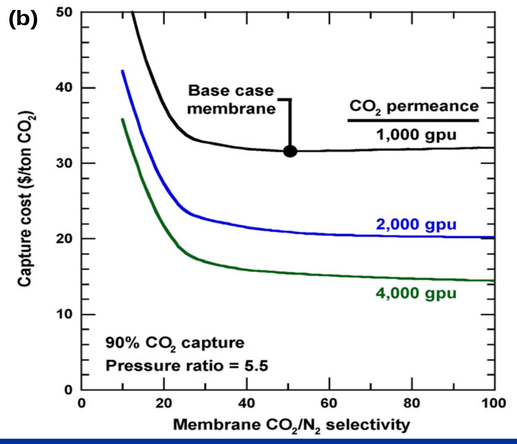
Objective 1: Develop pMOFs exhibiting CO_2 permeability of 2,000 Barrer or above and CO_2/N_2 selectivity of 40 or greater at 60 °C;

Objective 2: Develop thin film composite (TFC) membranes based on pMOFs exhibiting CO_2 permeance of 4,500 GPU or above and CO_2/N_2 selectivity of 40 or greater at 60 °C;

Objective 3: Demonstrate stability of the developed TFC membranes in the presence of water vapor and SO_x and NO_x;

Objective 4: Develop suitable process incorporating developed membranes with potential to achieve <$30/ton CO_2 captured.

Defining Membrane Properties for CO_2/N_2 Separation



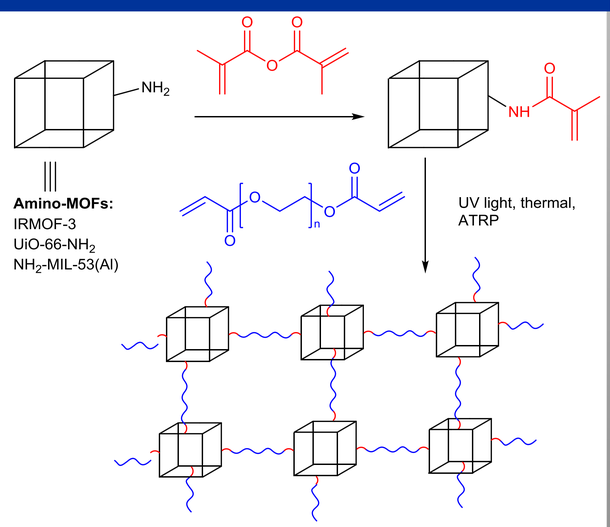
Target: CO_2 permeance of 4500 GPU and CO_2/N_2 selectivity of 40 or greater at 60 °C

Merkel, et al., Pilot testing of a membrane system for post-combustion CO_2 capture (DE-FE0005795), Membrane Technology and Research, Inc., final report to DOE NETL, 2015.

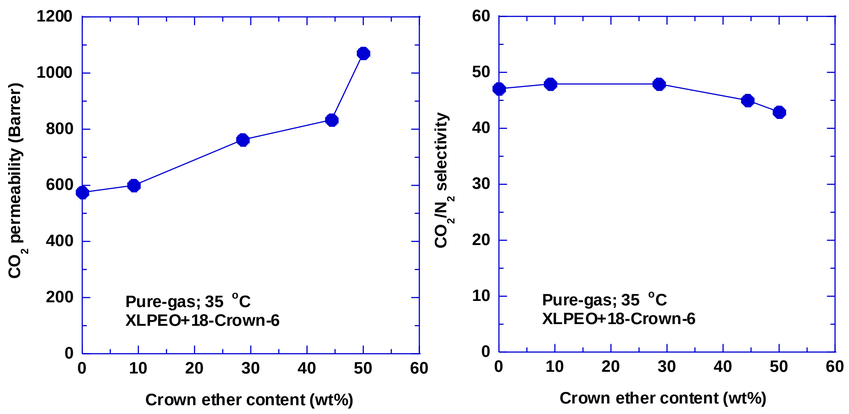
Our Approach: polymerizable MOFs (pMOFs)

Three steps:

1. Synthesize UiO-66-NH_2 nanoparticles with size less than 50 nm;
2. Functionalize UiO-66-NH_2 with methacrylate groups;
3. Copolymerize with polyethylene oxide (PEO)-based macromonomers

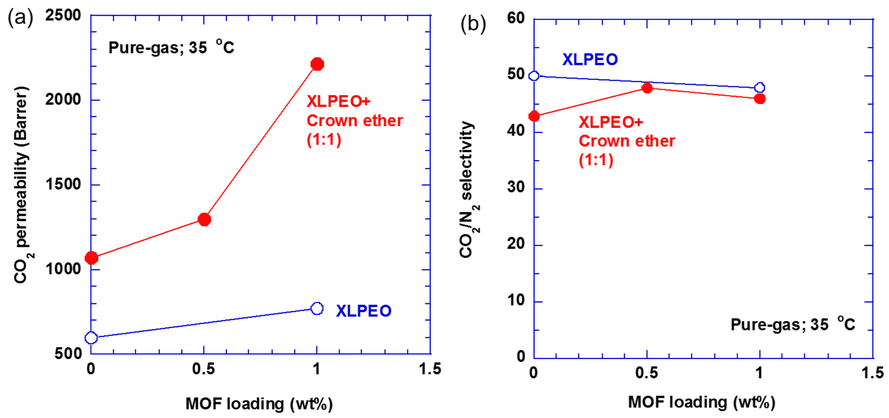


Gas Separation Performance of PEO-based Materials



Adding 18-Crown-6 in crosslinked PEO (XLPEO) increases CO_2 permeability

Gas Separation Performance of PMOFs

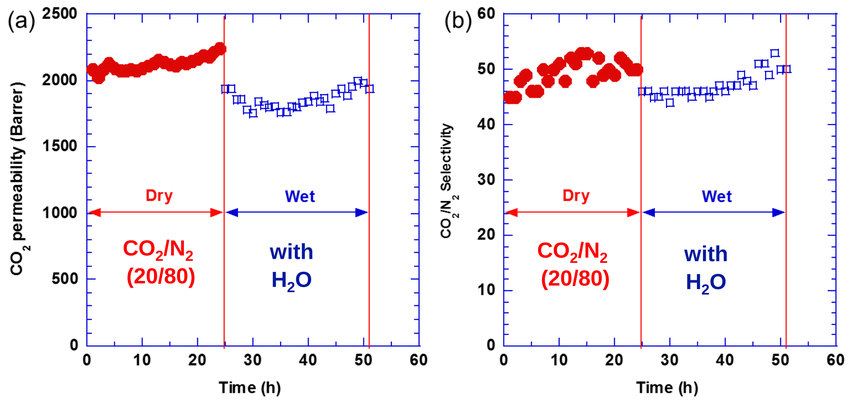


Adding MOFs improves the performance of XLPEO

Mixed gas tests:
Composition: 49.5% XLPEO + 49.5% 18-Crown-6 + 1 wt% MOF;
Film thickness: ~100 μm
100 – 150 psig; 20% CO_2/80% N_2

T (°C)	Pure- or Mixed-gas	P (CO_2) (Barrer)	P (N_2) (Barrer)	CO_2/N_2 Selectivity
35	Pure	2200	48	46
35	Mixed	2200	44	49
50	Mixed	2900	100	29
60	Mixed	3000	100	30

Excellent stability against water, SO_x, and NO_x



75 ppm SO_x and 75 ppm NO_x in N_2

SOx/Nox exposure	P (CO_2) (Barrer)	CO_2/N_2 selectivity
No exposure	2200	46
After 100-h exposure	2400	46

Process Development and Economic Analysis

- **550MW SCPC plant**
- **Process:**
  - 2-Stg Cascade + Cryo
  - MTR air refluxed 3-Stg + Cryo
  - Capture efficiency: 91.5%
- **Membrane properties:**
  - CO2 perm: 3500-4500 GPU
  - CO2/N2 selectivity: 35-40
- **50 mil Power; $50/m²**

	Mem 1 - Low End		Mem 2 - High End	
	W/o Cryo	W/- Cryo	W/o Cryo	W/- Cryo
Overall Capture eff	91.5%	91.5%	91.5%	91.5%
Prod CO2 Conc.	85.5%	100.0%	87.0%	100.0%
Power Used (MW)	59.5	109.0	58.5	108.0
CO2 Capture Cost ($/ton)	21.2	29.5	20.1	28.5

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