Polymeric-Metallic Composite Membranes for High Temperature Applications

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AIChE National Meeting
Reno, Nevada
November 9, 2001
Collaborators

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- **Pall Corporation**
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- **University of Colorado**
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- **Idaho National Engineering and Environmental Laboratory**
  Eric Peterson, Chris Orme, Alan Wertsching
Project Objective

- Develop a polymeric based membrane that can withstand greater temperatures and pressures than current materials
Project Approach

- Begin with polybenzimidazole (PBI) from Celanese
  - Thermally stable (Tg of 450°C)
  - Chemically resistant
  - Processable, derivatizable, blendable
- Use porous metal supports to provide support for polymer
Challenges

- Differences in thermal expansion
  - PBI \(60 \times 10^{-6}\)
  - Porous metal support \(6.36 \times 10^{-6}\)
- Forming thin films
- Sealing
- High temperature experimentation
Thin Film Formation

- Koros’ Group
  - >200,000 MW of a rigid polymer
  - on alumina membranes (0.02µm pores)
  - Thin films to <1 µm thick

- This Work
  - PBI is 20,000 MW
  - Support is stainless steel porous metal membrane (0.2µm pores)

Membrane Formation

- Prepared a solution of 10 wt.% PBI in dimethylacetamide by heating to 150 °C and stirring until PBI goes into solution
- 40 µl of solution are placed on the membrane (0.78 cm in diameter)
- Dried briefly at room temperature, heated to 50 °C for an hour
- Heat cycled between 50 °C and 300 °C five times (90 minute cycle)
Composite Membrane
Composite Membrane
Composite Membrane
Gas Permeation Test Rig
Permeability, barrers

\[ P = \frac{10^{10} \ast \nu \ast L}{A \ast \Delta p} \]
Permeability vs. Inverse Temperature

Permeability, barrer

1000/T, K^{-1}

H2
CO2
CH4
N2

350 °C
17 °C
H$_2$/N$_2$ Permeation Data

He/N2 Permeation using Polyimides

![Graph showing permeability ratio $P_{He}/P_{N2}$ vs. permeability in barrer for different polyimide samples. The graph includes data points and a trend line for Robeson He/N2.]
H₂/CH₄ Permeation Data

CO₂/CH₄ Permeation Data

H$_2$/CO$_2$ Permeation Data

Linear Variable Differential Transformer (LVDT) Device

- LVDT
- PT-1
- PT-2
- Feed gas
- Permeate collection bottle
- Retentate to vent
- Solenoid valve
- Constant temperature oven
- To vent
- PC
- To vent
LVDT Data - Compaction

![Graph showing compaction and upstream pressure over time.](image-url)
LVDT Data - Permeability

![Graph showing permeability data with time (hours) on the x-axis and upstream pressure (psi) on the y-axis. The graph displays a trend of permeability over time with markers indicating specific values of permeability (P/l) in $10^{-6}$ cm$^3$/cm$^2$ s cmHg].
Progress To Date and Future Work

To Date
- Fabricated thick intact composite PBI/porous metal membranes
- Built test rigs and automated data collection
- Tested membranes to temperatures of 350 °C with H₂, and N₂
- Demonstrated working principle of LVDT

Future Work
- Test permselectivity to temperatures of 350 °C with CO₂ and CH₄
- Determine effects of pressure on permselectivity
- Perform mixed gas tests
- Test modified polymers and polymer blends
- Increase temperature range of LVDT
Acknowledgements

- Funded by DOE Fossil Energy, administered by the National Energy and Technology Lab, Morgantown