SRI International

Multiple Applications of Polybenzimidazole (PBI) Hollow-Fiber Membranes

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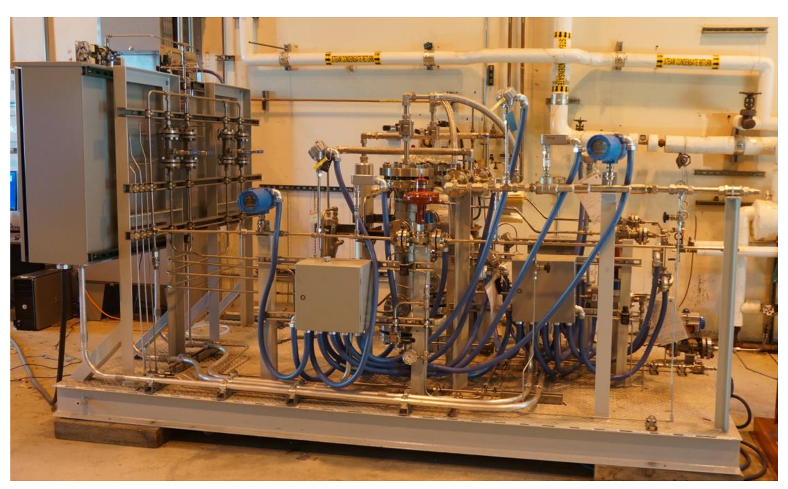
Summary: Polybenzimidazole (PBI) hollow-fiber membranes (HFMs) developed at SRI exhibit excellent thermal/chemical stability and can be chemically and physically optimized for various commercial gas or liquid separation applications. PBI is a commercially available polymer, and the membrane modules assembled at SRI have been successfully demonstrated for both CO_2 capture from syngas and water desalination. New applications include flue gas desulfurization (FGD) wastewater treatment and CO_2 removal from flue gas streams. **Contact:** Indira S. Jayaweera, Senior Staff Scientist/Program Manager, indira.jayaweera@sri.com, +1-650-859-4042

Gas Separation

CO_2-rejecting membrane for H_2 recovery from syngas (current DOE project, DE-FE0012965)



SRI's 50-kW_{th} skid operated for more than 600 hours at the NCCC in April 2017.

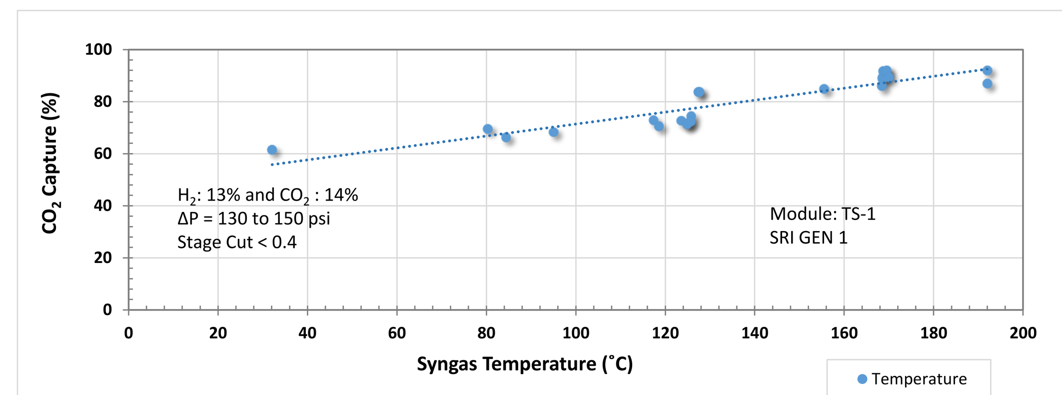
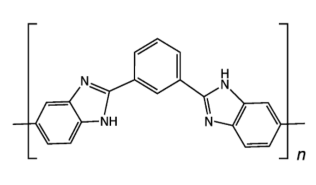


Figure 1. Observed CO_2 capture for GEN-1 membrane element with changing temperature when operating with syngas. Data for a stage cut at 40% are shown.



m-Polybenzimidazole (m-PBI)

Temperature effect: The membrane performance is greatly enhanced as the temperature increases; more than 90% CO_2 capture is possible with air-blown syngas at temperatures >180˚C.

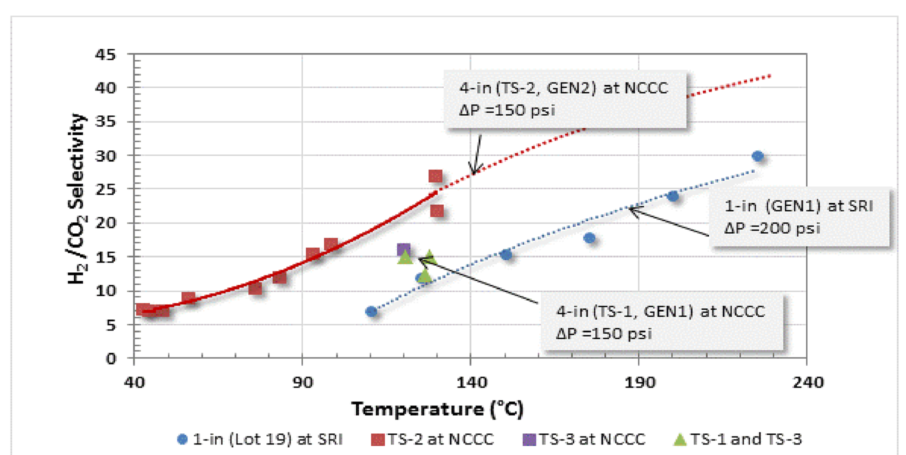
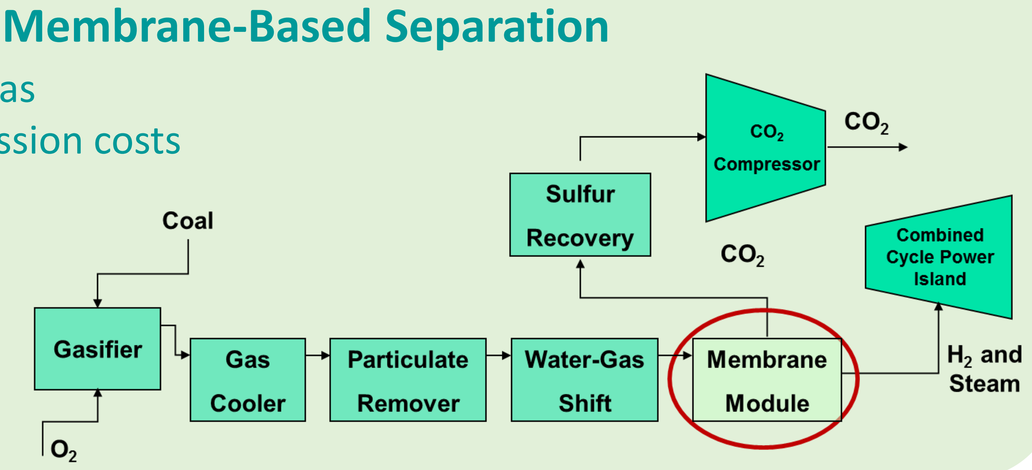


Figure 2. Comparison of measured H_2/CO_2 selectivity for GEN-1 (150 GPU) and GEN-2 (100 GPU) modules.

Advantages of PBI Membrane-Based Separation

- No need to cool syngas
- Reduces CO_2 compression costs
- Emission free
- Low maintenance
- Modular



Novel Concept: CO_2-rejecting membranes (CRM) for concentrating dilute CO_2 flue gas streams

Doped PBI hollow-fiber membrane with pKa < 4 to reject CO_2 and transport N_2

*SRI's current high-temperature PBI membranes are already CO_2-rejecting (pKa 5.4)

Same architecture as PBI Composite for desalination can be used in CO_2-rejecting membranes

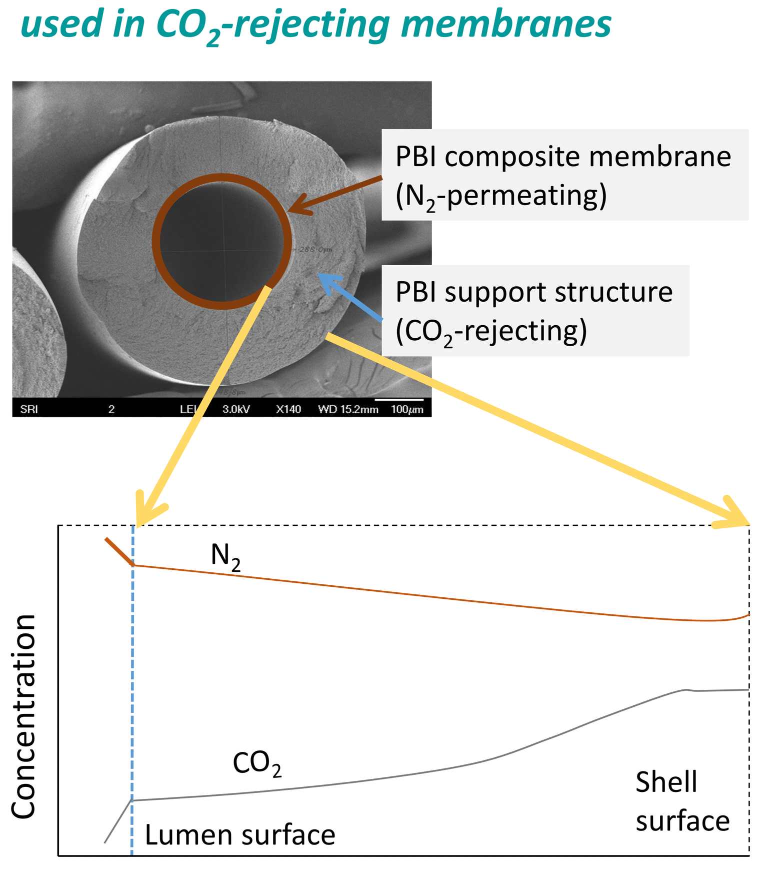
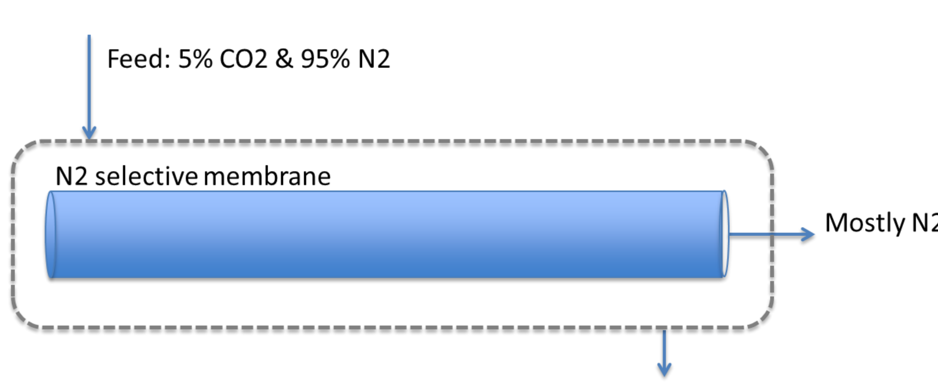


Figure 3. Concentration profiles across the HFM wall thickness.



Benefits of CO_2-rejecting and N_2-permeating membranes:

1) Standalone technology for concentrating dilute CO_2 streams
2) May be used in series with conventional CO_2-permeating membrane systems
3) Tolerant of O_2, H_2O vapor, and SO_2 in the flue gas
4) May be used for concentrating SO_2
5) Operates at higher temperature than conventional membranes

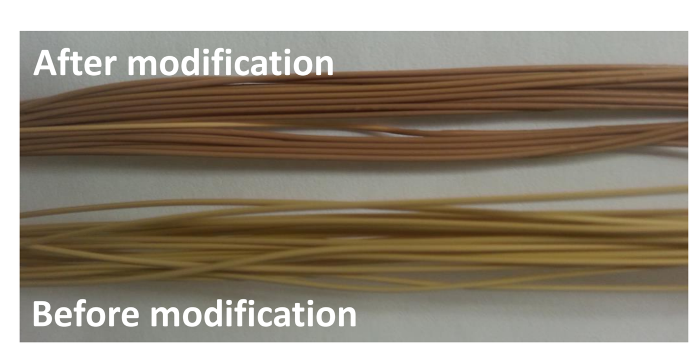


Figure 4. Color change of PBI fibers after modification to lower pKa.

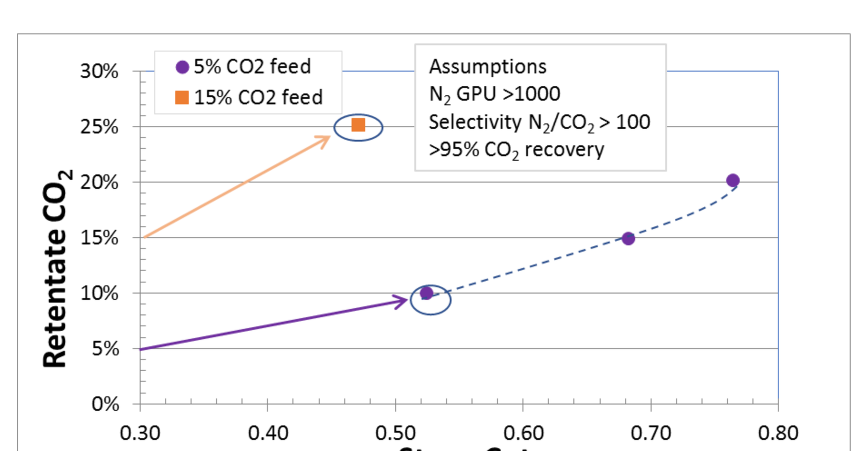


Figure 5. Enerfex modeling shows the concentration of CO_2 can be doubled using a CRM with N_2/CO_2 selectivity >100 and 65 psi pressure differential.

Liquid Separation

Seawater and brackish water desalination

Why hollow-fiber membranes? Packing density 5-10x higher than spiral-wound membranes → high water flux per module.

Approach: Start with high-flux membranes (smaller air gap during spinning leads to a thinner dense layer and a greater porosity of the support structure). Apply a coating to increase the salt rejection. A polyamide coating is applied to the exterior or lumen of fibers through *bonded interfacial polymerization*. Coating the lumen is preferable to avoid scale formation on the coating.

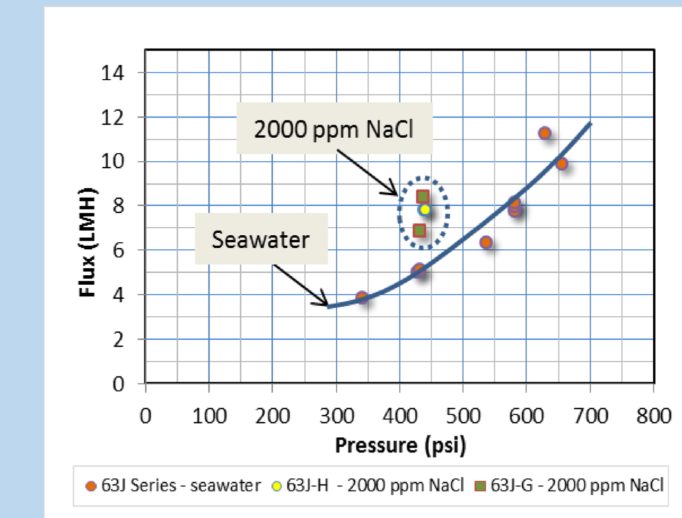
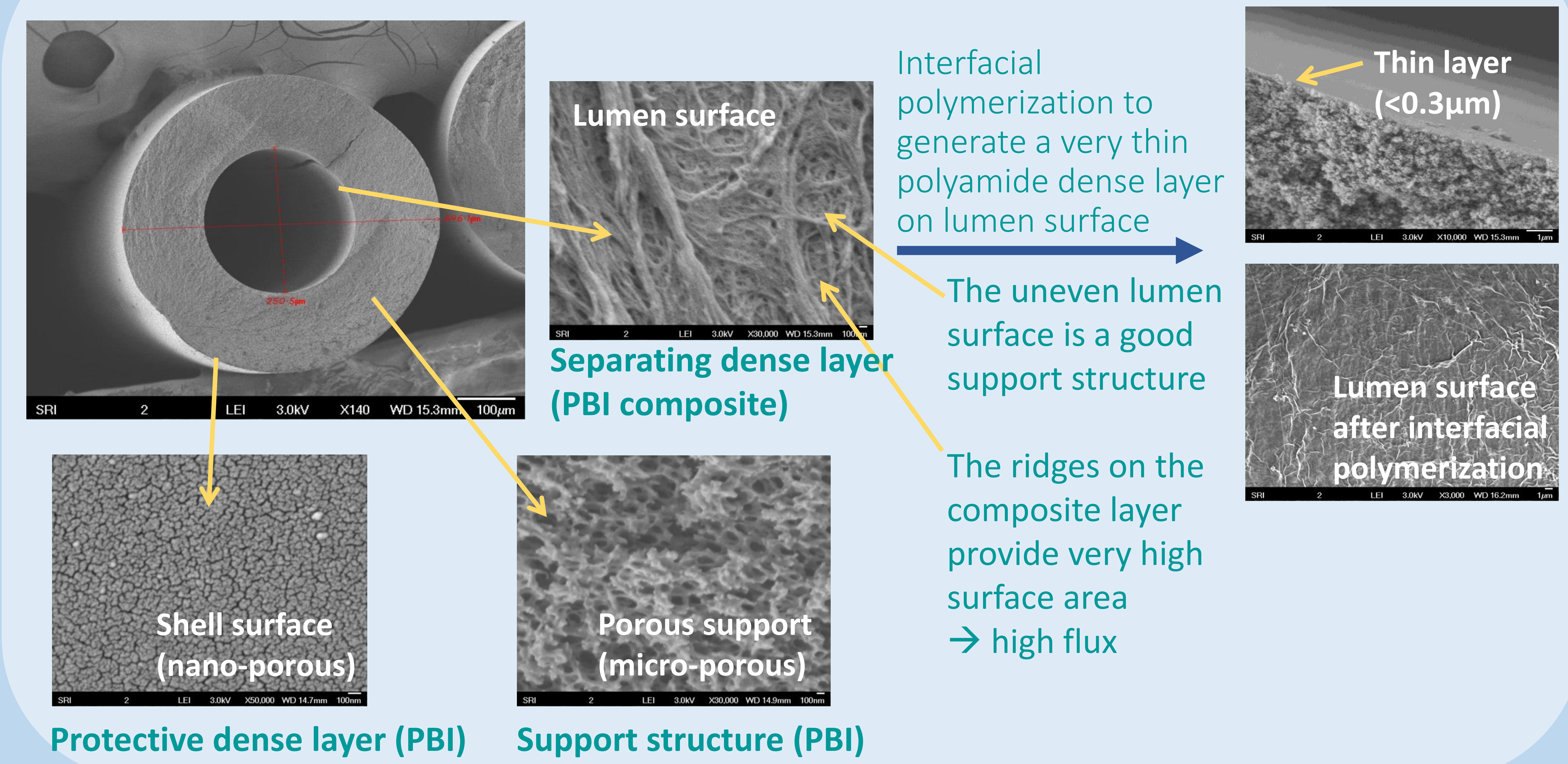


Figure 6. Observed flux as a function of the applied pressure; >98% salt rejection.

Hollow-fiber membrane architecture for high salt rejection and high flux



PBI composite fiber for reverse osmosis (RO): >98% salt rejection and 8-10 L/m^2hr water flux at 400 psi (2000 ppm NaCl feed solution)

Novel Concept: FGD wastewater treatment and water recovery

Reduced scaling: suitable for treating wastewater from FGD blowdown

To maintain optimum operating conditions in a wet scrubber, a purge stream is discharged from the system (primarily for chloride control to allow efficient SO_2 removal and corrosion control). This aqueous purge stream (FGD blowdown) is ***acidic*** (pH ~ 4-6) supersaturated with gypsum(***$CaSO_4 2H_2O$***) and contains high total dissolved solids (TDS) and total suspended solids (TSS).

The TDS is composed of heavy metals, chlorides, sulfates, calcium, magnesium, and dissolved organic compounds.

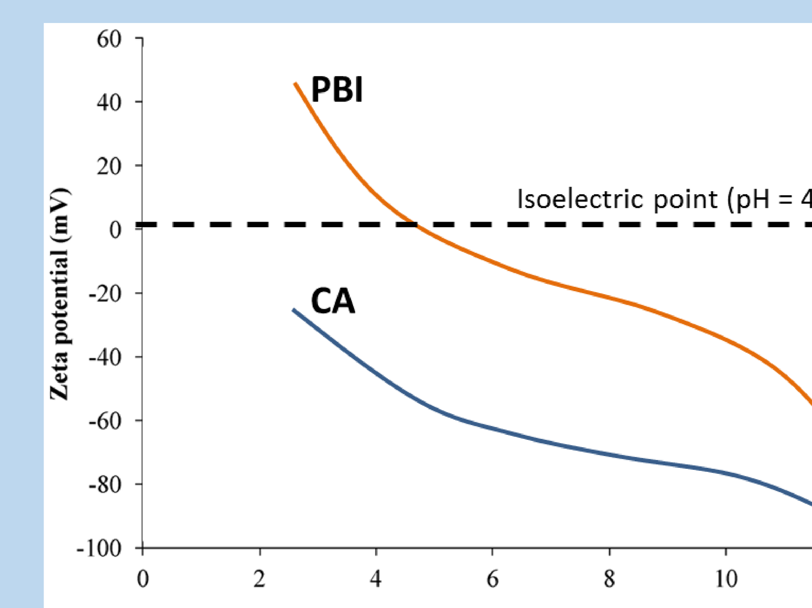
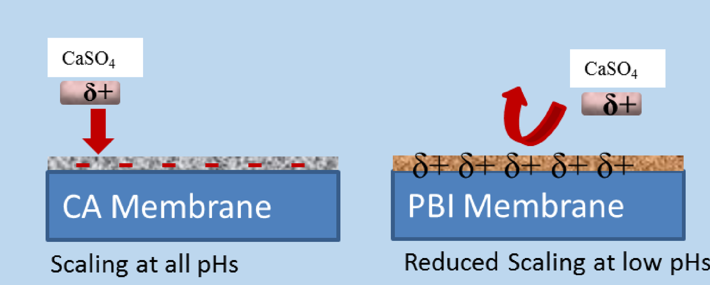


Figure 7. Zeta potential as a function of pH for PBI and CA membranes. Source for Zeta potential data: *Membranes* **2013**, *3*(4), 354-374.



SRI data for PBI HFM for sulfate removal:
>99% removal with 10 liter/m^2 hr water flux at 20 bar (2000 to 5000 sulfate).

Acknowledgements

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