Development and Testing of Polybenzimidazole (PBI) Hollow-Fiber Membrane Technology for Pre-Combustion CO_2 Capture (FE0031633)

Palitha Jayaweera, Elisabeth Perea, Srinivas Bhamidi, Xiao Wang, Regina Elmore, Indira Jayaweera*

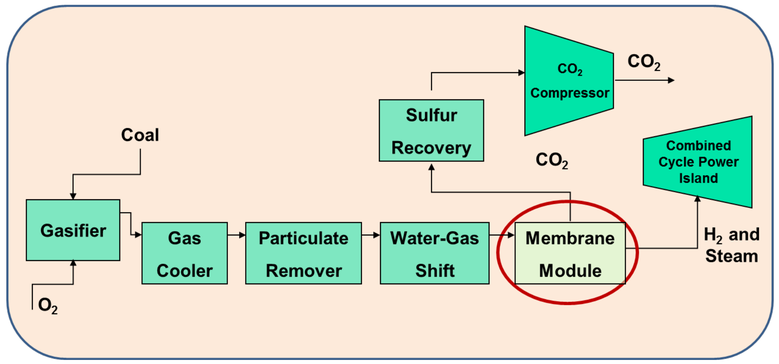
Summary: SRI has developed Polybenzimidazole (PBI) hollow-fiber membranes (HFMs) that can be chemically and physically optimized for various commercial gas separation applications. PBI is a commercially available polymer with excellent thermal/chemical stability and, PBI HFMs and the membrane modules assembled at SRI have been successfully demonstrated for CO_2 capture from syngas streams containing CO_2, H_2, CO, steam, and other trace-level gases. In the pre-combustion application, the membrane system will be situated downstream of the water gas shift reactors of the IGCC plant. The syngas stream will be operated above its dew point, and the membrane module will be used to separate H_2 and steam from the rest of the syngas stream. The permeate content, H_2, steam, and a few percent of acid gases along with the sweep gas N_2 will be sent to the turbine unit. The retentate that include CO_2 will be compressed to pipeline pressure for delivery/transportation after removal of trace gases in a high-pressure processing unit.

In this new project, we plan to perform parametric and steady-state testing of PBI-HFM gas separation skid to obtain system performance data covering full range of operating pressures and temperatures with actual coal-derived syngas stream from an oxygen-blown gasifier. Furthermore, we will perform component and system modeling and simulation, and techno-economic analysis of the commercial concept of PBI-HFM capture system integrated into a 550-MW (net) power plant.

Project Team: SRI International, University of Kentucky, PBI Performance Products, Enerfex Inc, Energy Commercialization.

Contact: Indira S. Jayaweera, Senior Staff Scientist/Program Manager, indira.jayaweera@sri.com, +1-650-859-4042

Concept of integration of a Hollow Fiber Membrane system in an IGCC plant



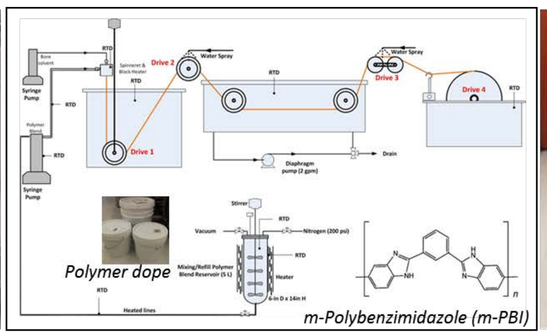
Characteristics of PBI Membranes

- PBI has an attractive combination of throughput and degree of separation
- Thermally stable up to ~ 300°C and sulfur tolerant
- Tested for 1000 hr at 225°C by SRI

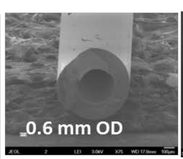
Advantages of Membrane-Based Separation

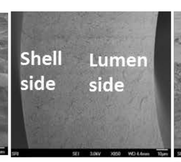
- No need to cool syngas
- Reduced CO_2 compression costs
- Emission free, i.e., no solvents
- Decreased capital costs
- Low maintenance
- Modular

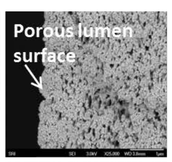
PBI Hollow Fiber Spinning

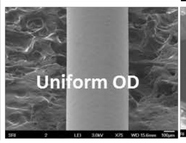


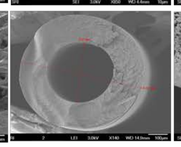
PBI Hollow Fibers and Microstructure

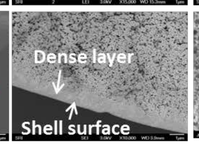












PBI Hollow Fiber Module Fabrication

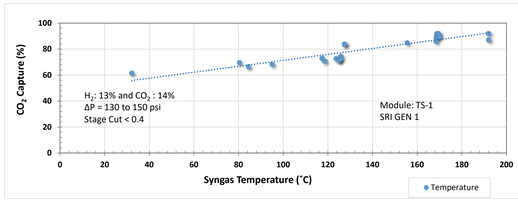
PBI HFM Performance Evaluation

SRI's Laboratory test station for small module performance testing with simulated syngas.

SRI's 50-kW_{th} skid for 4-in module testing

SRI 's skid was operated for more than 600 hours at the NCCC in April 2017 under DOE contract, DE-FE0012965. Testing performed using syngas from an air-blown gasifier, with and without added H_2 and CO_2.

Test Results with Syngas from Air-Blown Gasifier.



***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 1.).

***Pressure effect*:** Hydrogen permeance through the membrane increases rapidly with increase in pressure leading to increase in selectivity (Figure 2).

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.

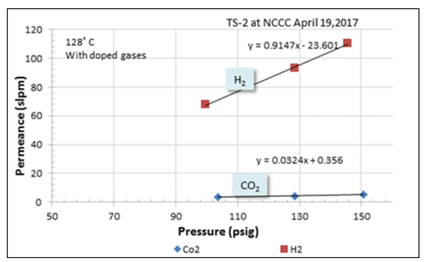


Figure 2. Measured H_2 and CO_2 permeances for GEN-2 modules with varying pressure at 128°C modules.

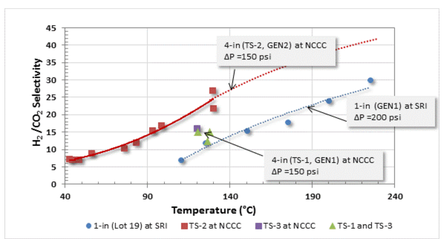


Figure 3. Comparison of measured H_2/CO_2 selectivity for GEN-1 (150 GPU) and GEN-2 (100 GPU) modules.

New Project - Testing with Syngas from Oxygen-Blown Gasifier.

In the new project, we will spin high performance GEN-2 fibers and fabricate 4-in modules . We plan to upgrade the 50 kW_{th} skid with additional gas flow meters and newly designed vessels to use four 4-in modules. We will perform parametric and steady-state testing of PBI-HFM gas separation skid to obtain system performance data covering full range of operating pressures and temperatures with actual coal-derived syngas stream from an oxygen-blown gasifier at University of Kentucky- Center for Applied Energy Research. We will use the data to validate the system models, and prepare technology maturation plan and techno-economic analysis of the commercial concept of PBI-HFM capture system integrated into a 550-MW (net) power plant.

Acknowledgements

National Energy Technology Laboratory (NETL) of the U.S. Department of Energy (Contract No. DE-FE0012965) and the partners – PBI Performance Products; Enerfex, Inc.; Generon, IGS; University of Kentucky-CAER, and Energy Commercialization LLC.

Disclaimer

This poster may include an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.