the ENERGY lab

PROJECT FACTS

Carbon Sequestration

Pre-Combustion Carbon Capture by a Nanoporous, Superhydrophobic Membrane Contactor Process

Background

An important component of the Department of Energy (DOE) Carbon Sequestration Program is the development of carbon capture technologies for power systems. Pre-combustion carbon dioxide (CO_2) capture refers to the removal of the carbon content of a fuel before it is burned, thereby converting a fossil resource to a carbon-free energy carrier. Pre-combustion CO_2 capture is considered to be less expensive than post-combustion capture because CO_2 is at high concentrations and pressure in the exhaust stream. In alignment with DOE Carbon Sequestration Program goals, the National Energy Technology Laboratory (NETL) has teamed with Gas Technology Institute (GTI) to develop a pre-combustion CO_2 separation technology based on a solvent scrubbing process using a novel gas/liquid membrane contactor concept.

Project Description

The membrane contactor is a mass transfer device that operates with a liquid on one side of the membrane and gas on the other. The driving force for the membrane is the thermodynamic potential of CO_2 absorption into the liquid. The membrane comprises hollow fibers in a structured high surface area configuration. The superhydrophobic membrane strongly repels water, preventing the wetting of the membrane surface. The superhydrophobic nature of the membrane is the result of a nanoscale surface architecture and is sometimes referred to as simulating the lotus effect. The porous leaves of the lotus plant exhibit hydrophobic surface properties due to their nanoscale surface architecture. The non-wetted membrane surface increases the mass transfer rate of small molecules such as CO_2 into the liquid and

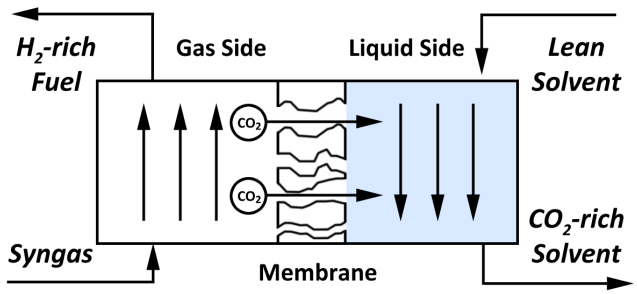

Figure 1. The membrane contactor allows the carbon dioxide to pass through to the liquid solvent so the hydrogen-rich syngas can be used to produce power with much lower carbon emissions.

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PROJECT DURATION

Start Date
9/30/2009

End Date
9/30/2011

COST

Total Project Value
$1,273,846

DOE/Non-DOE Share
$999,606 / $274,240

thus improves the absorption process efficiency. During the separation process, the liquid surface layer bridges the nanopores of the membrane when pressure is nearly equal on both sides. This design results in preferential transfer of the CO_2 through the surface liquid layer into the bulk liquid stream to be captured and stored. The resultant CO_2-depleted, hydrogen (H_2)-rich syngas stream is recovered and used for downstream processes.

Goals and Objectives

The primary goal of the project is to develop a practical and cost-effective technology for CO_2 separation and capture from the pre-combustion syngas in coal gasification plants.

The specific objective of the project is to (1) develop a membrane contactor module containing a superhydrophobic hollow fiber membrane (see Figure 2) with optimal pore size and surface chemistry, and (2) design the CO_2 separation process and conduct an economic evaluation.

Figure 2. PEEK membrane surfaces are hydrophobic and exhibit the same effect as does the lotus plant; that is, the lotus leaf surface is porous and enables transport of CO_2 and O_2 in wet environments.

The main efforts during the first year of this project were to develop a hollow fiber membrane with improved mass transfer suitable for the membrane contactor application with physical solvents, determine the feasibility of membrane contactor technology for syngas CO_2 separation (absorption and desorption), create the initial process design and conduct an economic analysis of the design which would demonstrate the feasibility of the technology. The main objective of the second year of the project has focused on increasing the process scale. This includes designing the membrane fabrication process, testing the stability and sensitivity of the membrane for the target application on a large scale, and performing an economic analysis based on the design and test results.

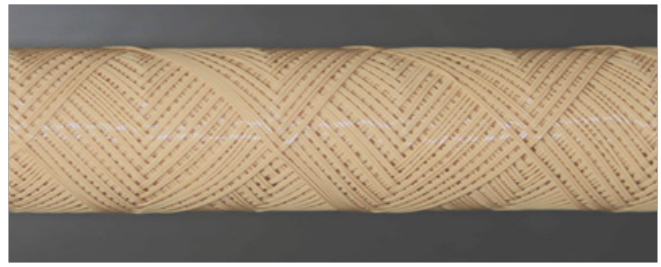

Figure 3. PEEK hollow fiber modules constructed by a computer controlled helical winding process.

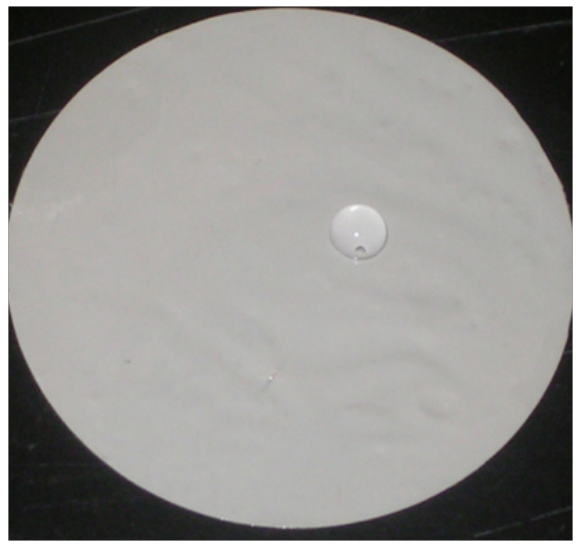

Figure 4. The A bead of isopropyl alcohol on the superhydrophobic porous PEEK membrane surface.

Accomplishments

The project has produced the following accomplishments to date:

- Demonstrated the proof of concept and tested the novel membrane contactor for CO_2 capture from high-pressure syngas. The superhydrophobic hollow fiber membrane was found to be chemically inert and temperature stable.
- Developed optimized superhydrophobic lab-scale membranes and fabricated membrane modules.
- Developed initial process and economic models.

Benefits

The research and development product, a superhydrophobic hollow fiber membrane contactor, can be used in an energy efficient process for CO_2 recovery from high-pressure syngas that minimizes hydrogen loss. The process has the potential to lower capital and operating costs and to reduce the system footprint compared to the conventional solvent scrubber process.