the ENERGY lab

R&D FACTS

Carbon Capture

Pre-combustion Solvents for Carbon Capture

Background

Carbon capture and storage from fossil-based power generation is a critical component of realistic strategies for arresting the rise in atmospheric CO_2 concentrations, but capturing substantial amounts of CO_2 using current technology would result in a prohibitive rise in the cost of producing energy. In high-pressure CO_2-containing streams, such as those found in coal gasification processes, one well-established approach to removing CO_2 and other acid gases is the use of physical solvents. The high partial pressure of CO_2 in the pre-combustion fuel gases found in these processes allows physical solvents to efficiently remove CO_2 from lighter gases, including hydrogen. The standard, commercially available physical solvents for CO_2 capture are Selexol® (Union Carbide, Houston, Texas, United States) and Rectisol® (Lurgi AG, Frankfurt am Main, Germany.) Both of these solvents are hydrophilic, which means that water vapor must be removed prior to CO_2 absorption by lowering the temperature of the syngas to less than 40 °C. Lowering the temperature, removing the water vapor, and then raising the temperature to ~200 °C for combustion is inefficient from both a cost and net electricity perspective. Hydrophobic solvents could be operated at higher temperatures and minimize the energy and cost penalties associated with cooling the syngas to below 40 °C.

Approach

The National Energy Technologies Laboratory (NETL) is pursuing a multifaceted approach, which leverages cutting-edge research facilities, world-class scientists and engineers, and strategic collaborations to foster the discovery, development, and demonstration of efficient and economical approaches to carbon capture. Using this approach, which takes advantage of many scientific and engineering disciplines to create synergies and accelerate technology development and commercialization, NETL has created two new materials that may have superior performance to the existing commercial capture solvents. By chemically combining the active ingredient in Selexol®, polyethylene glycol diethyl ether (PEGDME), with hydrophobic silicone oil and polydimethyl siloxane (PDMS), NETL researchers have invented a new material with the best properties of each parent compound (Figure 1). The second technology is an ionic liquid that overcomes the usual problems of that class of materials, including high viscosity (Figure 2). Previous research has focused on fully characterizing the solvents' CO_2 capture performance between 40 °C and 200 °C in the presence of water vapor and exploring their kinetics, mass transfer, regeneration energy, and stability. Each of these properties is a parameter that may be tuned through the addition of additives or minor changes to the solvents' molecular structure to optimize CO_2 separation energetics and ultimately CO_2 capture

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cost. NETL is also conducting system and economic studies to determine the precise impact of the new materials on cost of pre-combustion capture from integrated gasification combined cycle (IGCC) power plants. NETL-developed solvents are currently being tested in a slip stream of synthesis gas at the National Carbon Capture Center (NCCC) in Wilsonville, Alabama.

Accomplishments

The PDMS-PEGDME hybrid solvent has shown similar or greater CO_2 capacity and CO_2-hydrogen solubility selectivity compared to its parent compounds in capture performance testing. Other important parameters such as viscosity, stability, and heat capacity are also similar to the commercial materials. The primary advantage of the new solvent is its lack of affinity for water. Figure 3 shows the relative hydrophobicity of PEGDME, PDMS, and the hybrid. An additional advantage of the new solvent is that its performance actually seems to improve in the presence of other acid gases such as hydrogen sulfide. The ionic liquid solvent has also shown exceptional performance in capacity and selectivity. These findings will be confirmed in the presence of real fuel gas at the NCCC in the coming months. If these tests are successful, the solvents will be slated for testing at successively larger scales. A provisional patent application has been submitted for the hybrid solvent and a full application submitted for the ionic liquid. Industrial partners are currently being sought for transfer, scale-up, and commercialization.

Expected Outcomes

The solvents are expected to prove to be economically viable replacements for Selexol® and Rectisol® in pre-combustion capture of CO_2 from fuel gas streams from IGCC power plants.

Benefits

This research will move toward the programmatic goal of capturing 90 percent of the CO_2 produced by an IGCC power plant at a cost of less than \$40/tonne CO_2.

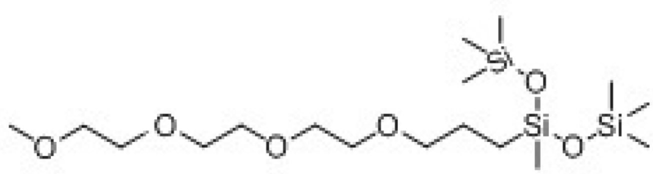

Figure 1: Molecular structure of the hybrid PDMS-PEGDME solvent

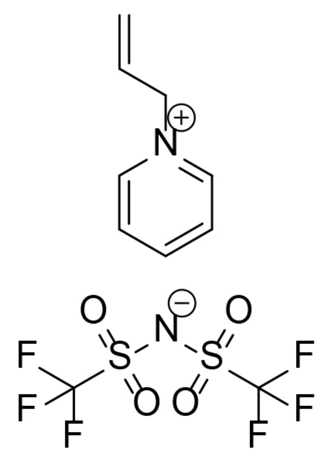

Figure 2: Molecular structure of the pyridinium allyl Tf_2N ionic liquid solvent

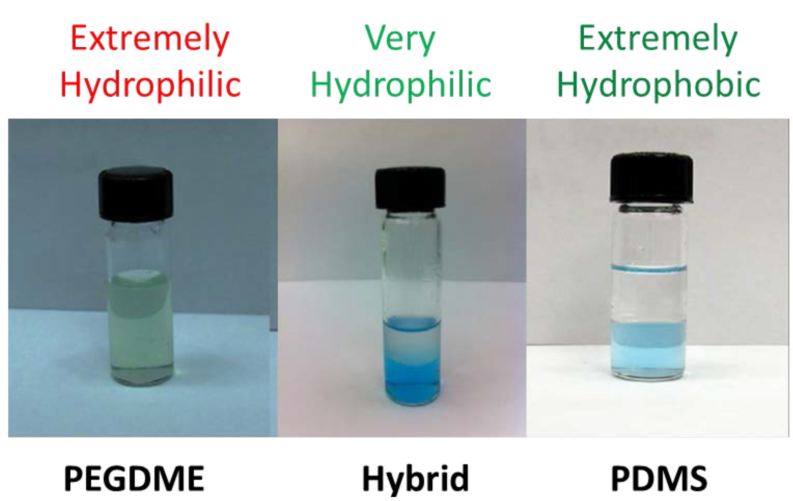

Figure 3: Solubility of water in pre-combustion solvents