Reversible Ionic Liquids as Double-action Solvents for Efficient CO_2 Capture

Background

Post-combustion carbon dioxide (CO_2) capture presents technical challenges because the flue gas is at atmospheric pressure and the CO_2 concentration is 10 to 15 volume percent, resulting in a low CO_2 partial pressure and a large volume of gas that needs to be treated. In spite of this difficulty, post-combustion CO_2 capture offers the greatest near-term potential for reducing greenhouse gas emissions because the technology can be retrofitted to existing units and tuned for various capture levels. The relatively low chemical potential for separating CO_2 from existing power plant flue gas streams supports the use of chemical processes like amine-based scrubbing, which is capable of achieving high levels of CO_2 capture from flue gas due to fast kinetics and strong chemical reactions. However, off-the-shelf amine solvents are corrosive and susceptible to degradation by trace flue gas constituents and necessitate significant amounts of energy for solvent regeneration.

The development of new solvent formulations that offer step-change improvements in both cost and energy efficiency will be required to ensure that CO_2 capture for existing pulverized coal (PC)-fired power plants can be achieved at costs and impacts that are economically acceptable. This project will aggressively develop a novel class of solvents known as ionic liquids (ILs), which have a strong potential for recovering CO_2 from PC-fired power plants in a much more cost-effective manner than existing solvent technology.

Description

The Georgia Tech Research Corporation will employ cutting-edge chemistry and established implementation methods to produce a solvent that results in a less-expensive, more energy-efficient CO_2 scrubbing system for PC-fired power plants. First, two classes of reversible ILs will be synthesized and characterized—one based on silyl amines and one based on guanidines. Structure-property relationships will be used to optimize the structure to yield the desired thermodynamic and physical properties, ranging from low heat of absorption, high CO_2 capacity, and low viscosity. Laboratory-scale test results will be used to conduct a detailed techno-economic analysis, which will examine the feasibility of large-scale, post-combustion CO_2 capture.

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PARTNERS

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PERIOD OF PERFORMANCE

10/1/2008 to 9/30/2011

COST

Total Project Value
$2,033,549

DOE/Non-DOE Share
$1,620,478 / $413,071

Primary Project Goal

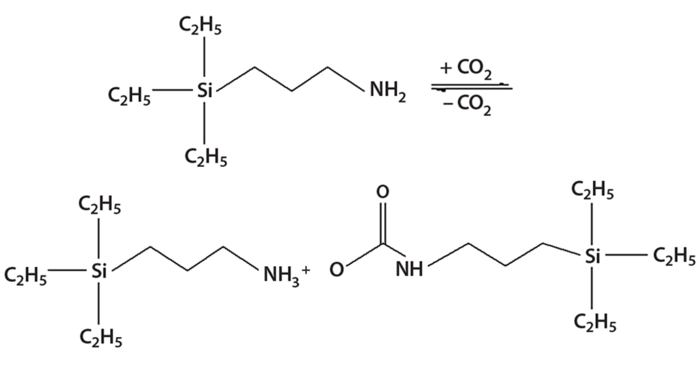
The project goal is to develop a novel class of solvents for post-combustion recovery of CO_2 from PC-fired power plants that will achieve a substantial increase in CO_2 carrying capacity and low energy penalty, resulting in a significant cost reduction compared to current solvent scrubbing methods.

Objectives

The project team will: (1) create, test, and apply optimum reversible ILs for CO_2 capture; (2) perform the process design and cost analysis for solvent implementation; and (3) develop a process for commodity-scale production of these solvents.

Benefits

The success of this post-combustion CO_2 technology offers the following benefits: (1) a higher CO_2 capacity allows for the development of a system with a smaller footprint, making the technology more attractive for retrofit to existing PC-fired power plants; (2) the potential for lower solvent regeneration energy makes the system less invasive to the existing power cycle and improves CO_2 removal efficiency; (3) IL chemistry can be tailored to withstand other flue gas pollutants like sulfur oxides and nitrogen oxides; (4) IL solvents are stable and non-volatile, meaning they are environmentally safe; and (5) ILs are stable at high temperature and, as a result, systems may be designed to regenerate the CO_2 stream at a higher temperature and pressure.



CO_2 Capture via a Single-Component, Reversible Ionic Liquid (based on a silylated amine mechanism)

Planned Activities

The project will:

- Complete synthesis and characterization of single-component, silyl amine-based ILs and silyl guanidine-based ILs.
  - Develop and optimize methods of large-scale bulk synthesis and production of CO_2 capture solvents.
  - Design the molecular architecture to tune the rapid and efficient capture and release of CO_2 within narrow temperature ranges.
  - Run nuclear magnetic resonance (NMR) spectra and evaluate the extent of the reaction by comparing disappearance of starting material with the formation of product.
  - Compare elemental analyses, which will yield the carbon, nitrogen, oxygen, silicon, and hydrogen content of the material synthesized, to the theoretical numbers from the assumed structure.
  - Use conductivity measurements to prove IL formation.
  - Test synthesized compounds to determine the temperature at which the IL reverts back to the neutral precursor and also the amount of heat required for this reversal.
  - Measure the viscosity of the synthesized ILs in a commercial viscometer.
- Complete laboratory measurements of the rates of formation of single-component, silyl amine-based and silyl guanidine-based reversible ILs.
  - Develop and apply methods to measure accurate equilibrium thermodynamic properties; specifically, heat of absorption and equilibrium constants for absorption and desorption reactions.
- Optimize the CO_2 capture solvent structure for IL-based CO_2 scrubbing systems.
  - Mathematically balance the thermodynamic properties to minimize the energy requirement.
- Complete a process design and economic analysis for IL-based CO_2 scrubbing systems.
  - Employ ASPEN software to optimize the economics of the CO_2 absorption/desorption process.
  - Calculate the energy requirements and material costs for a range of new solvents, evaluate the economics of scaleup of the optimized designs, and design a bulk synthesis process for the solvent(s) whose overall economics are found to be most favorable.