the ENERGY lab

PROJECT FACTS

Carbon Capture

SO_2-Resistant Immobilized Amine Sorbents for CO_2 Capture

Background

Fundamental and applied research on carbon capture and storage (CCS) technologies is necessary to allow the current fleet of coal-fired power plants to comply with existing and emerging environmental regulations. These technologies offer great potential for mitigating carbon dioxide (CO_2) emissions into the atmosphere without adversely influencing energy use or hindering economic growth.

Deploying these technologies in commercial-scale applications requires a significantly expanded workforce trained in various CCS technical and non-technical disciplines that are currently under-represented in the United States. Education and training activities are needed to develop a future generation of geologists, scientists, and engineers who possess the skills required for implementing and deploying CCS technologies.

The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL), through funding provided by the American Recovery and Reinvestment Act (ARRA) of 2009, manages 43 projects that received more than $12.7 million in funding. The focus of these projects has been to conduct carbon capture and geologic storage training and support fundamental research projects for graduate and undergraduate students throughout the United States.

Project Description

DOE has partnered with the University of Akron (Akron) to conduct research and training in the development of an effective solid amine sorbent for large-scale post-combustion CO_2 capture from power plant flue gas. Carbon capture costs can be reduced by an effective sorbent with high CO_2 adsorption capacity, long-term regeneration capacity, and a low regeneration energy requirement. The sorbent's capability to avoid irreversible reactions with sulfur dioxide (SO_2) is an important characteristic for post-combustion CO_2 capture, as SO_2 in the flue gas stream could compete with CO_2 for the amine adsorption sites.

Akron has identified amine-grafted mesoporous silicate materials that exhibit high CO_2 capture capacities. The CO_2 and SO_2 capture concept is built on the integration of acid-base chemistry with a novel approach for manipulating basic site distributions. In preliminary studies, Akron has shown that aromatic amines, which possess lower basicity than aliphatic amines and therefore negligible CO_2 capture capacity, are capable of adsorbing and desorbing SO_2 in the same temperature range as aliphatic amines do for CO_2. This project will focus on fine-tuning the basicity, dispersion, and distribution of immobilized amines on a series of porous solids which have large pores, high surface area, and/or high thermal conductivity. The sorbent materials consist of low-cost porous carbon and silica support structures with immobilized aliphatic amines distributed inside the material's pores and immobilized aromatic amines placed on the external surface and pore mouth of the material (Figure 1). Macropores of about 10 micrometers will be formed during creation of the material by using high molecular weight polyethylene

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PROJECT DURATION

Start Date	End Date
12/01/2009	08/31/2013

COST

Total Project Value
$386,052

DOE/Non-DOE Share
$300,000/$86,052

Government funding for this project is provided in whole or in part through the American Recovery and Reinvestment Act.

PROJECT NUMBER

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glycol (PEG) as a template. The aromatic amines on the pore mouths and particle surface of the dual-amine structure are expected to prevent sorbent deactivation by selectively capturing SO_2, thus allowing the aliphatic amines within the pores to capture CO_2 instead of irreversibly adsorbing residual SO_2 from the flue gas desulfurization-treated flue gas. In industry, low molecular weight PEG has been shown to have advantageous characteristics such as a strong affinity to CO_2, high thermal stability, high availability of ether and hydroxyl groups to form hydrogen bonds, water solubility, low toxicity, and low cost, which make PEG an attractive additive to improve the efficiency of the immobilized amine solid sorbent.

Goals/Objectives

The primary project objective is to develop an efficient low-cost CO_2 capture solid sorbent that is highly resistant to deactivation by SO_2 and thermal degradation. The project tasks will include fabrication of dual-amine solid sorbent particles with a controlled pore size, evaluation and fine-tuning of CO_2 and SO_2 capture capacity, stability of amine sorbents under simulated flue gas conditions, and characterization of the sorbent particle structures. The project is focused on achieving an adsorption capacity of greater than 1.5 millimoles of CO_2 per gram of sorbent, and less than 10 percent sorbent degradation per 100 cycles.

Accomplishments

- As of September 2012, two students had accumulated 5,720 training related hours under the program.
- The experimental system was constructed and tested. Step and pulse calibrations were performed to develop a consistent method for SO_2 calibration and to determine the SO_2 sensitivity of the mass spectrometer under conditions similar to flue gas.
- Sulfur dioxide capture was studied via an in situ technique involving both infrared and mass spectrometry. This technique provided insight into many aspects of SO_2 capture such as adsorption mechanism, formation of adsorbed species, and changes in sorbent surface.
- Numerous immobilized amine sorbents were prepared by impregnating both aliphatic and aromatic amines into porous activated carbon and high surface area silica.
- The effect of desorption temperature on SO_2 desorption from the sorbents was studied.
- The SO_2 capture capacity of the aromatic amine/PEG thin liquid films was evaluated. Coating the sorbent with various amounts of low molecular weight PEG dispersed the aromatic amines on the sorbent, reducing agglomeration of the immobilized amine on the sorbent and increasing the stability of the SO_2 capture capacity.
- The effect of SO_2 concentration on the CO_2 capture capacity of the solid amine sorbent was studied.
- The nature of CO_2 adsorbed species on immobilized amine sorbents and on liquid amines was investigated using a hydrogen chloride (HCl) probing technique. PEG was added to one sorbent and one liquid amine to study the effect of hydroxide (OH) groups on the adsorption of CO_2. The capture capacity of the sorbents was tested in batch mode using an in situ FTIR technique.
- Twenty-five CO_2 capture cycles have been performed on immobilized amine sorbents with a simulated flue gas—a 15 percent CO_2/air mixture—in the presence of 40 parts per million SO_2 with and without the presence of water vapor.

Benefits

This project will provide greater insight into the development of high-efficiency and low-cost CO_2 post-combustion capture technologies, contributing key innovative concepts including the use of PEG as a template to control the pore size of sorbent particles, and the use of a covalent bond linker to bind the sorbent structure. The low cost of raw materials for the synthesis of these dual-amine sorbents could lead to a breakthrough in technology for the effective capture of CO_2 from flue gas of coal-fired power plants and is expected to contribute toward the DOE goal of capturing 90 percent of CO_2 emissions with a cost of electricity increase of less than 35 percent. The added benefit of this ARRA-funded opportunity is that college students participating in this effort are learning how to use basic chemistry and chemical engineering principles to address critical issues in sorbent preparation, performance evaluation, and characterization. These skills are required to implement CCS technologies on a commercial scale.

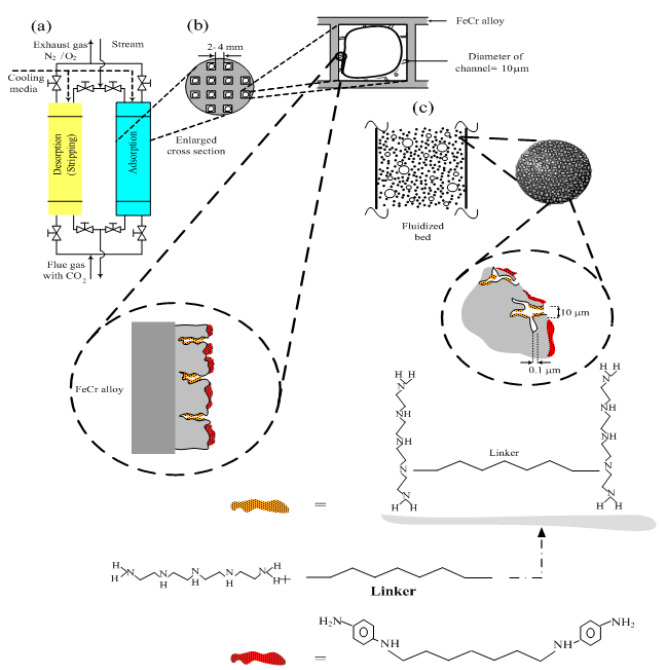

Figure 1: Illustration of the immobilized amine sorbent application in a typical solid sorbent CO_2 capture system (a) with CO_2 adsorption and adsorbent regeneration modules. The illustrations depicting two different types of adsorption modules—monolithic (b) and fluidized bed (c)—detail the locations of the immobilized dual-amines on the high surface area materials.