the ENERGY lab

PROJECT FACTS

Existing Plants, Emissions & Capture

Development of Novel Carbon Sorbents for CO_2 Capture

Background

The mission of the U.S. Department of Energy's (DOE) Existing Plants, Emissions & Capture (EPEC) Research and Development (R&D) Program is to develop innovative environmental control technologies to enable full use of the nation's vast coal reserves, while at the same time allowing the current fleet of coal-fired power plants to comply with existing and emerging environmental regulations. The EPEC R&D Program portfolio of post- and oxy-combustion carbon dioxide (CO_2) emissions control technologies and CO_2 compression is focused on advancing technological options for the existing fleet of coal-fired power plants in the event of carbon constraints.

Pulverized coal (PC)-fired power plants are large, stationary sources of CO_2 emissions. The flue gas from a conventional PC-fired power plant, downstream of a flue gas desulfurization (FGD) system, is typically at atmospheric pressure and temperature ranging between 50° C to 60° C and is water saturated and acidic. An existing 500 megawatt (MWe) coal-fired power plant emits 2 to 3 million tons of CO_2 per year. Carbon capture and sequestration holds the potential for deep reductions in greenhouse gas (GHG) emissions, although capturing and sequestering such a large volume of CO_2 is a major challenge. Any viable industrial process to reduce CO_2 emissions must rely on a regenerative concept, or else the quantities of the reagent and product become unmanageable and prohibitively expensive.

Description

In collaboration with Advanced Technology Materials Inc. (ATMI), SRI International (SRI) will develop an innovative, low-cost, and low energy-consuming CO_2 capture technology based on adsorption on a high capacity and low-cost carbon sorbent. SRI will identify and determine the chemical, physical, and mechanical properties of the sorbent that are relevant to the effective capture of CO_2 from PC-fired flue gas streams. SRI will achieve this by chemically functionalizing the high surface area sorbent in order to increase the selectivity and loading for CO_2 capture and reduce thermal requirements for CO_2 desorption. A bench-scale, fixed-bed reactor system will be designed and constructed for performing adsorption and regeneration studies. In addition, a simulated flue gas stream containing both major gases and minor contaminants will be used to determine the CO_2 capture rates. Based on the results of the adsorber and regenerator parametric tests, a selected set of conditions will be used to perform cyclic tests with the reactors operating in adsorption and regeneration modes. Finally, a technical and economic evaluation will be conducted on the feasibility of the novel carbon sorbents for cost-effective CO_2 capture from PC-fired power plants. The information obtained from this project will be used to design a 0.25 MW or larger capacity pilot unit that will treat a slipstream from an operating PC-fired power plant in a future phase.

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PARTNERS

Advanced Technology Materials Inc.

PERIOD OF PERFORMANCE

10/1/2008 to 9/30/2011

COST

Total Project Value

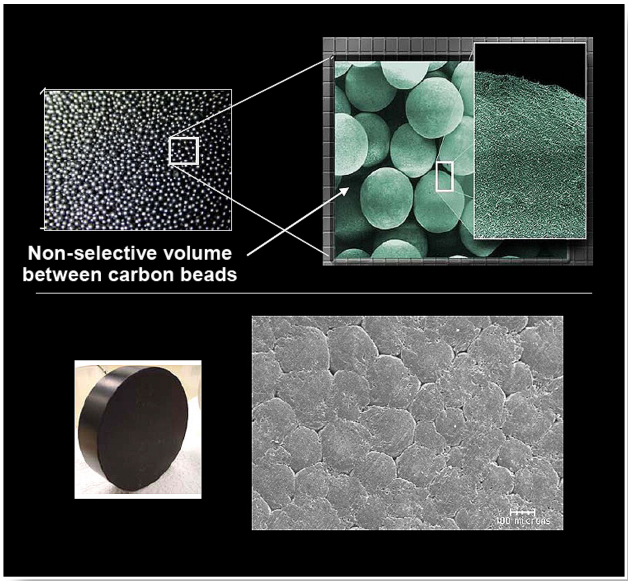
$2,249,957

DOE/Non-DOE Share

$1,799,957 / $450,000

AWARD NUMBER

DE-NT0005578



ATMI's Adsorbent Carbon Materials

Primary Project Goal

The project goal is to develop a novel, high-capacity carbon sorbent with moderate thermal requirements for regeneration in order to capture CO_2 from PC-fired power plants.

Objectives

This project seeks to: (1) validate the performance of this concept on a bench-scale system, (2) perform parametric experiments to determine the optimum operating conditions, and (3) evaluate the technical and economic viability of the technology.

Benefits

A key attribute of CO_2 sorbents is that less water is present compared to solvent-based systems, thereby reducing the sensible heating and stripping energy requirements. The success of this post-combustion CO_2 technology offers the following benefits: (1) the sorbent is low-cost and stable in the operating range of 20 °C to 100 °C; (2) high capacity of CO_2 loading (0.1 to 0.2 kilogram of CO_2 per kilogram of sorbent); (3) low heat of adsorption reaction (26 to 29 kilojoule/mole CO_2); and (4) low heat requirements for regeneration—the carbon sorbent can be regenerated to release CO_2 at atmospheric pressure and a temperature range of 80 °C to 100 °C.

Planned Activities

Phase I:

- Determine the relevant physical, mechanical, and thermal properties of the sorbent that are relevant for effective CO_2 capture from PC-fired power plant flue gas streams.
- Chemically functionalize the high surface area carbon adsorbent with substituted amine groups to increase the selectivity and loading for CO_2 capture and reduce thermal requirements for CO_2 desorption.
- Determine the CO_2 capture rate of the current and improved sorbents in a small bench-scale reactor using a simulated flue gas containing air and CO_2.
- Preliminarily evaluate the suitability of the novel carbon sorbents for CO_2 capture from PC-fired power plants.

Phase II:

- Determine the CO_2 adsorption capacity and the regenerability of the sorbent as a function of the process parameters by using a bench-scale, fixed bed reactor system.
- Select a set of conditions for optimum adsorption and regeneration conditions and operate the adsorber-regenerator system under cyclic conditions based on the results of the adsorber and regenerator parametric tests.
- Develop an Aspen Plus® simulation to generate the equipment sizing and heat and material flows in the CO_2 capture system.

Phase III:

- Perform a 1,000-cycle test under the most suitable process conditions for CO_2 capture using simulated flue gas containing major gases and minor contaminants; the release of CO_2 from the loaded sorbent will be investigated as a function of temperature in a CO_2 carrier gas.
- Evaluate the technical and economic merits of CO_2 capture from PC-fired power plants using the novel carbon sorbents.

Accomplishments

- The initial carbon sorbent was tested to determine the adsorption properties (surface area, heat of adsorption and desorption, compressive strength, attrition resistance, size and shape of the sorbent particles). The sorbent demonstrated the capability to remove more than 90 percent of the CO_2 in fixed-bed adsorption and desorption tests.
- Additional sorbents with modified structural properties (pore size distribution) were fabricated and tested.
- Screening tests were performed to evaluate the CO_2 adsorption and desorption behavior of the sorbents using simulated flue gas, and to determine changes in the sorbent as it ages. The preliminary evaluation showed that the regeneration temperature and low heat of regeneration provide a significant advantage over the current amine-based CO_2 capture process.
- A bench-scale moving bed reactor was designed and constructed. Parametric tests were initiated with the initial results showing greater than 90 percent CO_2 capture with more than 99 percent purity.