the ENERGY lab

PROJECT FACTS

Carbon Sequestration

Pre-combustion Carbon Dioxide Capture by a New Dual-Phase Ceramic Carbonate Membrane Reactor

Description

A membrane separation device that consists of a porous metal phase and a molten carbonate phase can conduct carbonate ions (CO_3^{2-}) at a very high rate. The metal-carbonate membranes only conduct electrons, and oxygen (O_2) should be mixed with carbon dioxide (CO_2) in the feed to convert CO_2 to $CO_3^{=}$ ions. However, the presence of O_2 can oxidize the metallic support and reduce its electronic conductivity and, thus, CO_2 permeability. The problem is solved by a dual phase ceramic-carbonate membrane configuration consisting of a porous ionic conducting ceramic phase and a molten carbonate phase, which conducts O_2 and CO_3^{2-}, respectively, and separates the CO_2 from the shifted synthesis gas (syngas).

Conceptually, the dual-phase membrane will be made of a continuous, thin, mesoporous oxygen ionic conducting ceramic layer filled with a molten carbonate supported on stainless steel with a sub-micron, pore-sized intermediate layer of the same oxygen ionic conducting material. The membranes will have high CO_2 perm-selectivity, commercially relevant permeance, and chemical resistance against poisoning for application in a water-gas-shift (WGS) reaction.

Primary Project Goal

The objectives of the project are experimental studies of the synthesis of a high-temperature, chemically and thermally stable and CO_2 perm-selective dual-phase membrane and its use as a membrane reactor for WGS reaction to produce H_2 and CO_2 rich streams. The project will include experimental and modeling studies on the performance of the WGS reaction in the dual-phase inorganic membrane reactors. An intended result is to identify experimental conditions for WGS reaction in the dual-phase membrane reactor that will optimally produce the H_2 and CO_2 streams with a desired 93 percent and 95 percent purity. The project will also perform system studies on the potential of the proposed membrane in integrated gasification combined cycle (IGCC) plants.

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PERIOD OF PERFORMANCE

10/1/2009 to 9/30/2013

COST

Total Project Value
$820,404

DOE/Non-DOE Share
$656,316 / $164,088

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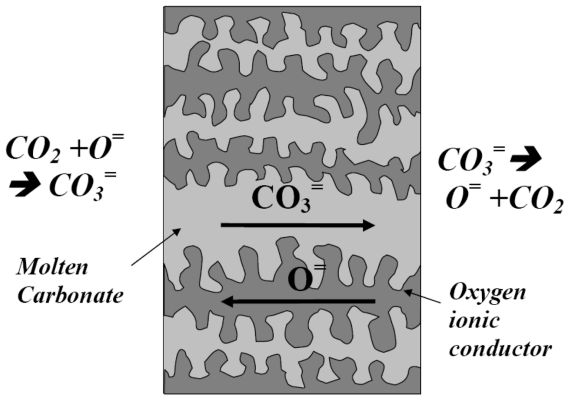
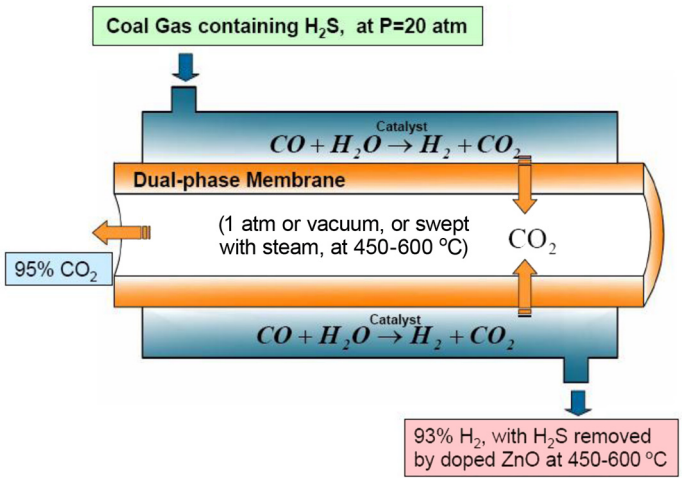
U.S. DEPARTMENT OF ENERGY

The scope of this project is divided into two phases. Phase I work will include identifying optimum conditions for the synthesis of adequate membrane supports and the dual-phase membranes, fabrication of the dual-phase membranes in tubular geometries, and study of permeation and chemical and mechanical stability of the tubular membranes relevant to their uses as membrane reactors for WGS reaction.

Phase II work will be directed towards studying the dual-phase membrane reactor performance for WGS reaction and for H_2 production and CO_2 capture. The work will include synthesis and kinetic studies of a high-temperature WGS catalyst and experimental and modeling studies of WGS reaction using dual-phase membrane reactors. The experimental data will be compared with modeling results to identify optimum conditions for WGS reaction. The project will perform an economic analysis for the dual-phase membrane as a WGS reactor for H_2 production and carbon capture integrated with a combined cycle gasification plant.



Concept of ceramic-carbonate dual phase membranes for CO_2 separation. Neutral CO_2 permeates from feed to permeate sides without the need to mix O_2 with CO_2.



Schematic illustration of CO_2 dual-phase membrane reactor for WGS.

Accomplishments

This is a new project. The first significant milestone of synthesizing candidate three-layer membranes on disk supports with desired pore structures is anticipated to be completed in FY2010.

Benefits

Fossil fuels, used extensively for generating electricity, produce CO_2. Pre-combustion CO_2 capture removes the carbon content in a fuel before it is burned, thereby converting a fossil fuel into a carbon-free energy source. Pre-combustion capture is mainly applicable to gasification plants, where fuel is converted into gaseous components by applying heat under pressure in the presence of steam and a controlled amount of O_2. Coal gasification reactions produce syngas, a mixture of H_2 and carbon monoxide (CO). The syngas is processed in a WGS reactor, which converts CO into CO_2 while producing additional H_2, thus increasing the H_2 and CO_2 concentrations. Because CO_2 is present at much higher concentrations in shifted syngas (after WGS) than in post-combustion flue gas, and it is at a higher pressure, CO_2 management is less expensive for pre-combustion capture. Once the carbon is removed from the fuel, the H_2 can be used in the combustion turbine of a combined cycle plant to generate electricity. Successful pre-combustion CO_2 capture technology offers the potential to increase the use of low-cost domestic coal as the preferred electricity production feedstock.

The proposed research and development, when successfully executed, will demonstrate at an appropriate scale that the dual-phase membrane-based separation device will cost effectively separate CO_2 from typical WGS mixture feeds at practical rates and produce H_2 of acceptable purity. The H_2 can then be introduced into the combustion turbines of IGCC plants. The project has the potential to contribute to achieving the DOE Carbon Sequestration Program Goal, which is to develop fossil fuel conversion systems that offer 90 percent capture with 99 percent storage permanence of CO_2 at less than 10 percent increase in the cost of energy services by 2015.