U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

INDUSTRIAL TECHNOLOGIES PROGRAM

Robust Polymer Composite Membranes for Hydrogen Separation

Enabling Carbon Capture and Hydrogen Purification at Process Relevant Conditions

This project will develop membranes aimed at improving the economics and performance of hydrogen separation from synthesis gas, enabling more-efficient and cleaner energy, chemicals, and fuels production from solid fuels such as coal, renewable biomass, and waste.

Introduction

In the gasification process, hydrocarbon feedstocks such as coal, biomass, and organic waste are reacted with a controlled amount of oxygen and steam. The output of gasification is called synthesis gas, or syngas, which, after further processing, is composed primarily of hydrogen and carbon dioxide (CO_2).

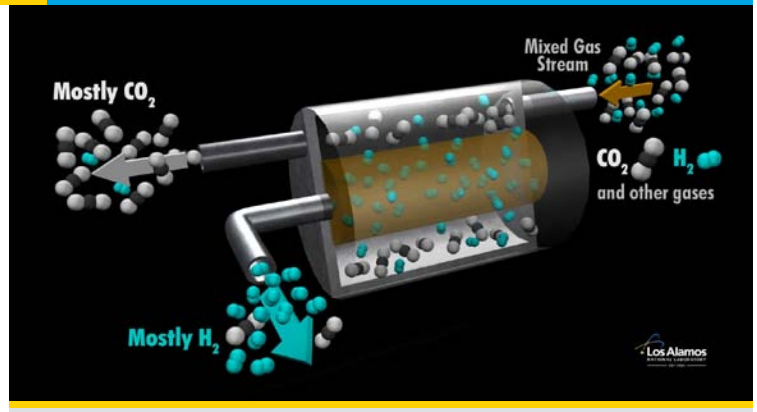
Gas separation, a critical post-gasification processing stage, allows hydrogen to be isolated from syngas and used as a clean fuel or feedstock. The leftover CO_2 can then be captured and sequestered rather than released into the atmosphere.

However, current gas separation technologies used to capture CO_2 are burdened with high capital equipment and operating costs. For example, capturing CO_2 from a power plant using today's technology will increase the cost of electricity between 45%–80 %.[1]

Compared with conventional technologies, the use of emerging polymer membranes in separation processes can lower energy consumption, reduce maintenance requirements, and increase selectivity, a measure of the membrane's effectiveness in filtering hydrogen from the input mixed gas stream.

Successful use of polymer membranes in syngas operations requires a material that retains thermal, chemical, and mechanical stability at the high temperature and pressure experienced in the syngas stream, but current materials do not provide the desired performance.

This project will develop a promising, polymer composite membrane that will improve the effectiveness and efficiency of hydrogen purification and carbon capture, potentially reducing CO_2 emissions and producing clean fuel from U.S. feedstocks.



A simplified model of a single-tube membrane module shows a mixed gas stream (composed of hydrogen, carbon dioxide [CO_2], and other gases) entering the outer tube. Hydrogen is separated from the mixed gas stream via the membrane and then passes out of the inner tube, while the carbon-rich stream is retained and exits through the outer tube.

Illustration courtesy of Los Alamos National Laboratory.

Benefits for Our Industry and Our Nation

The development of low-cost, efficient membranes for hydrogen purification and carbon capture will produce environmental, energy, and economic benefits. Commercialization of this technology has the potential to achieve the following:

- Substantially reduce the cost of capturing and sequestering CO_2 in IGCC power plants (realize a cost-of-energy increase of <15% based on in-house systems analysis)
- Enable more-efficient and cleaner energy, fuels, and chemicals production from the nation's abundant recoverable coal reserves
- Facilitate increased biomass/waste gasification and correspondingly hydrogen production from renewable energy sources

Applications in Our Nation's Industry

The power generation and chemical and petrochemical production industries, which use membranes for gas separation today, will benefit from improved hydrogen purification technology. Hydrogen or hydrogen ratio adjusted purified syngas obtained from gasification can be used in many important applications, including the following:

- Electricity generation via gas turbines or fuel cells
- As a feedstock to produce a range of high-value liquid or gaseous fuels and chemicals (such as methanol and ammonia)
- As a transportation fuel (in the form of gaseous hydrogen) or converted into a synthetic gasoline or diesel fuel

Project Description

The primary project goal is to achieve a major improvement in the combined economics and performance of polymenzimidazole-based (PBI) membrane technology in the application of hydrogen separation from syngas. This project will also develop a commercialization plan and build a partnership with a potential end user to establish industry performance and economic goals.

Barriers

- Developing a polymer with a high glass transition temperature to withstand exposure to hot syngas
- Developing a membrane that is resistant to syngas contaminants from the original coal or biomass fuel

Pathways

Testing will be conducted to understand the underlying scientific principles that control the material properties and, ultimately, will dictate the free volume architecture and permselectivity of the membrane. Results will be organized in a library of polymerization conditions, film formation conditions, and chemistry combinations to optimize the attainable polymer material properties.

A pre-pilot-scale module will be designed and fabricated. Baseline performance evaluations of the module will be conducted in a simulated syngas environment.

Milestones

- Finalize comprehensive test plan and design of experiments (Completed)
- Engage potential industry partner(s) from the technology value chain (Completed)
- Assess ability of the proposed technology to meet preliminary commercial viability targets (Completed)
- Down-select and rank industrial processes with highest potential energy efficiency gains and environmental impact mitigation from implementation of this technology
- Demonstrate membrane performance that is ≥ 90% of the project targets at realistic process environments as established by application specific systems and economic analyses
- Complete design, fabrication, and evaluation of a pre-pilot-scale module in a simulated syngas environment

Commercialization

The project will include steps to enlist the participation of potential partners in the technology value chain to assist in the development of a separation system that meets the performance and economic needs of industry. Pre-pilot-scale testing will be conducted to ensure that real-world performance meets commercial requirements.

A detailed commercialization plan for the PBI-based polymer composite membrane technology under evaluation will be developed. The commercialization plan will comprise market and application analyses, development work consisting of laboratory testing and membrane optimization based on test results, economic analyses including manufacturing scale-up, identification of a partner engineering design firm for future design and construction efforts, and relationship development with potential customers for advanced pilot testing and process development.

Project Partners

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(endnotes)

[1] Jared Ciferno et al., DOE/NETL Advanced Carbon Dioxide Capture R&D Program: Technology Update (Washington, DC: U.S. Department of Energy, May 2011), http://www.netl.doe.gov/technologies/coalpower/ewr/pubs/CO2CaptureTechUpdate051711.pdf.

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