



the **ENERGY** lab

## PROJECT FACTS

### Fuels

# Supported Molten-Metal Membrane for Hydrogen Separation

## Background

The U.S. Department of Energy (DOE) promotes research and development (R&D) of technologies that can produce affordable hydrogen (H<sub>2</sub>) from coal with near zero environmental emissions. Gasifying coal forms synthesis gas (syngas), a mixture of H<sub>2</sub>, carbon monoxide, and carbon dioxide (CO<sub>2</sub>). Pure H<sub>2</sub> can be separated from syngas for production of chemicals and use in stationary fuel cells or fuel cell vehicles. There are two key steps in this process: increasing the percentage of molecular H<sub>2</sub> in the syngas using the water gas shift reaction, and separating the pure H<sub>2</sub> from the other gases. Carbon dioxide can be captured at this point and transported for sequestration or storage.

Technologies available for separating H<sub>2</sub> include absorption, membrane separation, pressure-swing adsorption (PSA), and cryogenic distillation. The PSA and cryogenic distillation methods are most commonly used in industry; however, they are energy intensive, and it is estimated that 450 trillion British thermal units (Btu) per year could be saved with a 20 percent improvement in the H<sub>2</sub> separation train. Dense membrane separation is promising, but membranes used in H<sub>2</sub> separation have historically incorporated precious metals, and still fall short of the desired permeability, selectivity, economy, robustness, and durability.

The DOE National Energy Technology Laboratory (NETL) is partnering with Worcester Polytechnic Institute (WPI) to expand R&D of more innovative membrane materials, concepts, and strategies that can effectively separate H<sub>2</sub> from coal-derived syngas without using precious group metals (PGMs).

## Project Description

This project team will develop supported molten-metal membranes (SMMMs) using non-PGM metals for separating H<sub>2</sub> from coal-derived syngas. The ideal membranes will be less expensive, more robust to gases such as carbon monoxide, and substantially more resistant to contaminants such as sulfur than membranes currently available for H<sub>2</sub> separation. SMMMs do not experience issues associated with solid, dense membranes, such as sintering, hydrogen embrittlement, formation of pin-holes, and thermal mismatch between the membrane and the support material. The SMMMs developed will provide an alternative, low-cost method of separating H<sub>2</sub> from syngas.

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## PARTNERS

None

## PROJECT DURATION

### Start Date

10/01/2009

### End Date

09/30/2012

## COST

### Total Project Value

\$1,246,424

### DOE/Non-DOE Share

\$996,567 / \$249,857



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The molten metal film consists of two materials: a low-melting point metal to facilitate high permeability, and a non-PGM transition metal, present at less than five to ten percent, to enhance dissociation of  $H_2$ . WPI will start with tin as the main low-melting-point metal because of its low cost, resistance to poisons such as sulfur, and proven ability as a catalyst. Other possible metals for the film include indium, gallium, bismuth, and their alloys. Candidates for the transition-metal include nickel, silver, copper, iron, or cobalt. The films will be supported on a porous ceramic substrate such as zirconia or on porous stainless steel with an intermetallic diffusion barrier layer.

## Goals and Objectives

The goal of this project is to develop novel membranes for separating  $H_2$  from coal-derived syngas using non-precious metals to meet DOE's performance targets for  $H_2$  permeability and purity. The membranes will be made of a thin film of liquid metal (or metal alloy) supported on a porous ceramic or porous metal support. Important objectives include (1) building a dedicated permeation apparatus for testing the hydrogen permeability, selectivity, and durability of the SMMMs; (2) testing the various molten metal candidates and the porous supports; (3) developing optimized protocols for fabrication of the most promising SMMMs, including deposition of the intermetallic diffusion barrier; (4) performing a preliminary test on a broad range of SMMMs; (5) selecting those with the best performance and subjecting them to increasingly realistic conditions of temperature, pressure, gas composition, and contaminants; (6) characterizing the morphology, absorption, and transport aspects of the selected candidates; (7) subjecting the final SMMM candidate(s) to DOE test protocol; and (8)

comparing the performance, cost, and durability characteristics with the DOE Technical Targets. WPI will also supply samples to NETL for their in-house independent verification.

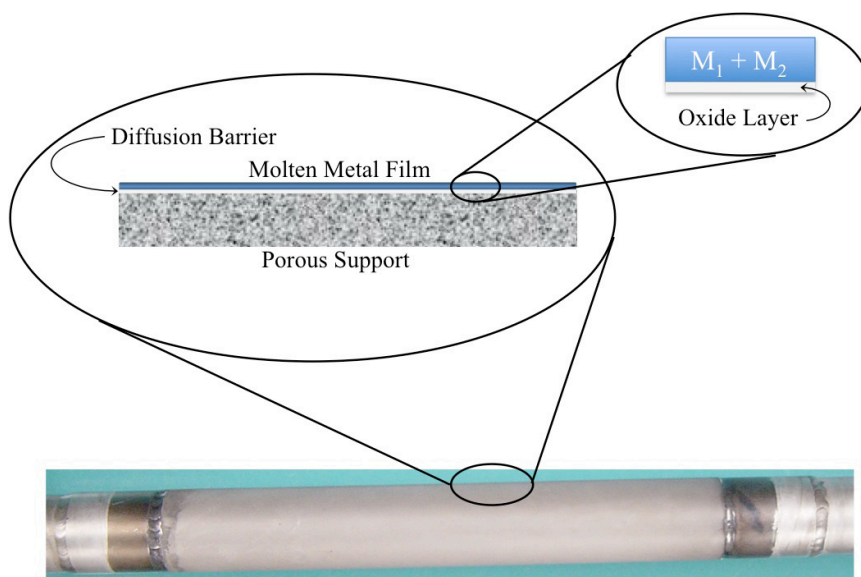
## Accomplishments

The research team has designed and built a new permeability apparatus for evaluating both tubular and disk (coupon) membranes capable of operating at temperatures up to 650 degrees Celsius ( $^{\circ}C$ ). The apparatus uses LabVIEW<sup>®</sup> software to automatically record permeation data over an extended period of time. In addition, a high-temperature Grieve furnace has been procured that allows work at temperatures of up to 1100  $^{\circ}C$  in an inert atmosphere.

Researchers are checking the suitability of the various porous metal and/or ceramic supports to allow fabrication of dense and stable SMMM composed of indium, gallium, and tin. The team is also testing the suitability of various intermetallic diffusion barrier layers, which have been found to have good wettability and inertness. Initial permeability experiments are being performed with the more promising SMMM candidates.

## Benefits

This project will contribute to U.S. energy security by facilitating the commercial availability of an affordable and reliable source of membranes for use in the production of  $H_2$  from coal-derived syngas. It will also demonstrate practical improvements to existing processes in U.S. coal-fired generators that could help meet carbon emission targets.



*A tubular supported molten-metal membrane (SMMM) includes a film consisting of two metals supported on a porous material. The film is designed to allow diffusion of hydrogen across the barrier while carbon dioxide continues flowing through the tube to be captured and sequestered. (Credit: WPI)*

