II.A.6 Integrated Ceramic Membrane System for Hydrogen Production

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Research Triangle Institute, Research Triangle Park, NC

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Projected End Date: TBD

Objectives

- Develop an integrated ceramic membrane system using an oxygen transport membrane (OTM) in the first stage to produce syngas and a hydrogen transport membrane (HTM) in the second stage to produce hydrogen at a low cost on a scale of 1,000-5,000 SCFH; OTM development is being done outside this project.
- Develop a palladium-based HTM that can meet performance goals for flux, selectivity, life, and cycling on a bench scale.
- Develop the substrate materials, coating materials, and appropriate manufacturing technology.
- Confirm membrane performance.
- Confirm that the process is cost-competitive for distributed hydrogen production.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Production section (3.1.4.2) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(A) Fuel Processor Capital Costs
(B) Fuel Processor Manufacturing
(C) Operation and Maintenance
(F) Control and Safety
(L) Durability
(M) Impurities
(N) Defects
(O) Selectivity
(P) Operating Temperature
(Q) Flux
(S) Cost
(T) Oxygen Separation Technology

Technical Targets

	Praxair Status	2005 DOE Target	2010 DOE Target
Flux (scfh/ft^2)	60-100 scfh/ft^2 at 20 psid and 400°C	100	200
Cost (\$/ft^2)	<\$1,000/ft^2	1,500	1,000
Durability (yrs)	demonstrated 600 hours, test stopped as planned	1	3
ΔP Operating Capability	demonstrated 40 psi, working on higher-pressure reactor design	200	400
Hydrogen Recovery (%)	N/A	>70	>80
Hydrogen Quality (%)	>99.9%	99.9	99.95

Introduction

Natural gas is one of the primary resources for production of hydrogen. Natural gas is reacted with steam, oxygen, air, or a combination of these to produce syngas, which contains hydrogen. One potentially low-cost, efficient way to produce syngas is to use a ceramic membrane to separate oxygen from air. The separated oxygen reacts with natural gas and steam over a catalyst to produce syngas. The membrane, which can be integrated into the syngas generator, eliminates the need for a large, expensive air separation plant. (The work on oxygen membranes is being done in a different project.) Implementing membranes to produce hydrogen is one of the goals of this project. To produce hydrogen, the product syngas is typically sent to another reactor, where most of the CO and some of the steam in the syngas react to produce additional hydrogen. Using conventional existing technology, the hydrogen in the product stream from the second reactor must be purified using additional large, expensive equipment. The goal of the current phase of this project is to simplify hydrogen production by combining the second reactor and the hydrogen purification into a single step in a single vessel. This process could significantly reduce the capital cost of producing hydrogen, and consequently, reduce the price of hydrogen produced. Because of the way the reaction and separation are combined, it is also possible to produce more hydrogen than would be possible using the conventional two-step approach. A diagram of the process is shown in Figure 1.

Phase I of this project analyzed and compared several different processes. Based on projected cost, efficiency, and likelihood of success, a two-stage process wherein each stage is comprised of a membrane reactor was selected. The analysis indicated that this process has the potential to be the least expensive hydrogen production method of those evaluated. Phase II has focused on developing the hydrogen purifier to put this process into practice. Membranes have achieved satisfactory performance and continue to improve.

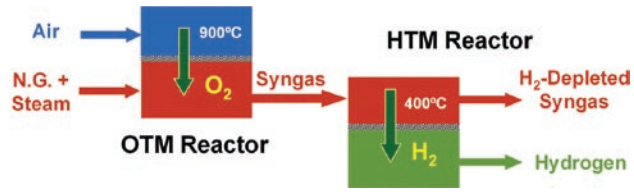

FIGURE 1. Integrated Membrane Reactor System

Approach

This phase has emphasized developing a hydrogen membrane that will have a much lower cost than competing membranes while providing acceptable performance. Praxair's experience and expertise in making porous ceramic membrane substrates will be applied to making substrates for Pd membranes. This requires applying the techniques used for other materials to produce substrates from materials that have thermal expansion properties very similar to the Pd alloy to avoid thermal stress when cycling. To keep the total cost down, the membranes must be thin because of the high cost of Pd, and the substrates must be produced using simple processes that can be easily scaled up to produce large quantities. The goal is to maximize HTM performance while restricting ourselves to low-cost, scalable substrate production methods. Once these membranes are made, they will be tested under ideal, realistic, and harsh conditions to determine their performance. The actual HTM performance will be used to develop a conceptual reactor design and determine the cost of producing hydrogen at a scale appropriate for distributed, on-site production.

FY 2006 Progress

This project did not receive funding in FY 2006. DOE plans to restart project funding in FY 2007.

FY 2006 Publications/Presentations

1. Damle, A., Schwartz, J., and Apte, P. Palladium-Alloy Based Membrane Reactor Process for Hydrogen Generation; 2005 Fuel Cell Seminar, Palm Springs, CA, November 17, 2005.