

IV.B.7 Advanced Hydrogen Transport Membranes for Vision 21 Fossil Fuel Plants

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NORAM Engineering and Constructors

CoorsTek

Sud Chemie, Inc.

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Objectives

- Develop an environmentally responsible, cost-effective, and efficient method for separating hydrogen from gas mixtures produced during industrial processes, such as coal gasification.
- Discover new hydrogen separation membrane materials.
- Design, construct, test, and conduct economic assessments of a prototype hydrogen separation module separating hydrogen from coal-derived synthesis gas at industrially relevant hydrogen separation flux.
- Design a pre-commercial demonstration unit.
- Optimize the composition and microstructure of ceramic materials for hydrogen conductivity and develop thin-film ceramic structures that enable hydrogen separation rates in excess of 10 ml/min/cm².

Technical Barriers

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

- L. Durability
- M. Impurities
- N. Defects
- O. Selectivity
- P. Operating Temperature
- Q. Flux

- R. Testing and Analysis
- S. Cost

The project also addresses one or more of the barriers described in Section 5.1.5.1., Technical Barriers – Central Production Pathway in the Hydrogen from Coal – Research, Development, and Demonstration Plan of the DOE Office of Fossil Energy.

Technical Targets

Table 1 lists the targets that the project will attempt to meet during its implementation.

Table 1. Technical Targets: Ion Transfer Membranes for Hydrogen Separation and Purification^a

Performance Criteria	Units	2003 Status	2005 Target	2010 Target	2015 Target
Flux Rate	scfh/ft ²	60	100	200	300 ^b
Cost	\$/ft ²	2,000	1,500	1,000	<\$500
Durability	Hours	<8,760	8,760	26,280	>43,800
ΔP Operating Capability	psi	100	200	400	400-1000
Hydrogen Recovery	% of total gas	60	>70	>80	>90
Hydrogen Purity	% of total (dry) gas	>99.9	>99.9	>99.95	99.99

^a Targets are derived from Table 3.1.5. from the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan, March 2005.

^b Flux upper limit for ion transport membranes.

Approach

- Adjust ceramic crystal lattice constituents to achieve an optimal compromise between material mixed conductivity and stability under anticipated operating conditions.
- Develop multiphase materials with maximum ambipolar conductivity. Supported thin-film membranes of promising materials will be fabricated and tested.
- Conductivity characteristics and hydrogen separation rates will be measured for selected membrane structures, and candidate formulations will be employed in laboratory-scale high-pressure hydrogen separation units.
- Information gained during laboratory testing will be used to develop a prototype hydrogen separation unit and generate a strategy for technology scale-up in the final stages of the project.

Accomplishments

- Developed selection criteria for selecting membrane composition for scale-up, such as flux, ease of fabrication, and cost.
- Selected membrane compositions for scale-up to move from materials development and characterization to manufacturing feasibility and scale-up.
- Identified raw materials and process equipment suppliers and determined specifications.
- Compiled relevant hydrogen permeation, stability, manufacturability, and cost data for candidate membranes from each of the three categories to resolve engineering scale-up issues.

Future Directions

- Initiate the development of metal alloy preparation techniques, fabrication of metal alloy tubes, and fabrication methodologies for cermet membranes.
- Complete construction of the 1.3 lb/day high-pressure apparatus.

- Initiate hydrogen permeation testing studies with cermet membrane disks.
- Complete hydrogen permeation tests at anticipated commercially relevant operating conditions using current membranes.

Introduction

Hydrogen separation by membranes fabricated from mixed proton electron conductors can provide an effective, low-cost method to separate hydrogen from synthesis gas made from coal. The hydrogen can be used for electricity production and as a transportation fuel, while the technology will also provide a concentrated CO₂ product stream easily amenable for capture and sequestration.

The project will focus on the development of dense ceramic membranes based in part on Eltron-patented materials that have demonstrated their ability for rapid proton and electronic conduction. An objective is to develop a cost-effective method for separating hydrogen from gas mixtures. Areas of investigation include catalysis, ceramic processing methods, and the design of a separation unit operating under high pressure. Multiphase materials with maximum ambipolar conductivity will be developed. Supported thin film membranes of promising materials will be fabricated and tested. Information gained during laboratory testing will be used to develop a prototype hydrogen separation unit and generate a strategy for scale-up.

Approach

This project will appropriately adjust ceramic crystal lattice constituents to achieve an optimal compromise between mixed conductivity and

stability under anticipated operating conditions. Concurrently, multiphase materials with maximum ambipolar conductivity will be developed, and supported thin-film membranes of promising materials will be fabricated and tested. The conductivity characteristics and hydrogen separation rates will be measured for selected membrane structures, and candidate formulations will be employed in laboratory-scale high-pressure hydrogen separation units. Information gained during laboratory testing will be used to develop a prototype hydrogen separation unit (see Figure 1) and generate a strategy for technology scale-up in the final stages of the project.

Results

Eltron has developed selection criteria for membrane composition for scale-up, such as flux, ease of fabrication, and cost. They have also been able to identify the raw materials and process equipment suppliers and determine specifications. Finally, the candidate membranes from each of the three categories were examined for relevant hydrogen permeation, stability, manufacturability, and cost data to resolve engineering scale-up issues.

Discussion

Two main components of a coal-to-hydrogen plant are the coal gasifier and the hydrogen separation device. While coal gasifiers for power production are commercially available, an enabling technology for separating hydrogen from coal gas is a key requirement for the success of future coal-to-hydrogen production plants. This effort will significantly contribute to achieving the DOE Hydrogen from Coal program goals and provide a viable step forward to enter the hydrogen economy using abundant domestic coal resources. Affordable hydrogen fuel from coal will be used in fuel cells and hydrogen turbines for power production, and as a zero-emission transportation fuel for cars.

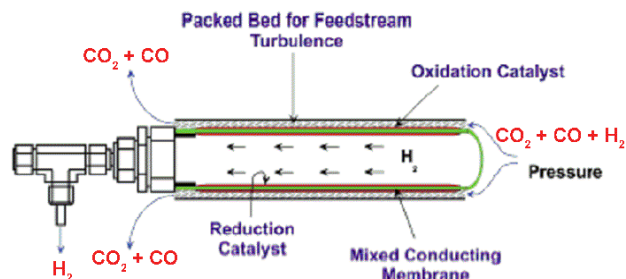


Figure 1. Tubular Hydrogen Transport Membrane Configuration Being Developed at Eltron for Spontaneous Hydrogen Separation from Integrated Gasified Combined Cycle Derived Syngas Feedstreams

Special Recognitions & Awards/Patents Issued

1. M. V. Mundschau, Hydrogen Transport Membranes, U.S. Patent 6,899,744 B2, May 31, 2005.
2. M. V. Mundschau, Hydrogen Transport Membranes, U.S. Patent Application 2003/0183080 A1, October 2, 2003.
3. S. E. Roark, R. Mackay, M. V. Mundschau, Dense, Layered Membranes for Hydrogen Separation, U.S. Patent Application 2004/0129135 A1, July 8, 2004.
4. S. E. Roark, R. Mackay, M. V. Mundschau, Dense, Layered Membranes for Hydrogen Separation, PCT International Application 60-03 WO, April 2, 2005.
5. 2005 R&D 100 Award, entitled, "Intermediate Temperature Hydrogen Transport Membranes," R&D Magazine, Oak Brook, Illinois, July 2005.