PROJECT facts

Hydrogen and Clean Fuels from Coal

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U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory

High Flux Metallic Membranes for Hydrogen Recovery and Membrane Reactors

Description

The separation of hydrogen from coal gasification gases (syngas) is typically accomplished by membranes. Pd-Ag alloy membranes have been used for decades for this purpose, but these alloys are costly and too malleable for commercial applications. This project will investigate new alloys of lower-cost transition elements as alternatives to Pd-Ag membranes. Foils of Group 5B metals and alloys coated with palladium show promising results in being superior to Pd-Ag alloys in terms of hydrogen flux, uncontrolled membrane failure, and cost. About 100 alloys and intermetallic compositions will be fabricated and tested for toughness, embrittlement, permeation, and ease of manufacture. The most innovative of these are the B2 intermetallics with a coating of either palladium or B2 phase palladium copper. Both materials dissociate and permeate hydrogen readily, the B2 phase alloy is sulfur tolerant, and is expected to exhibit less inter-diffusion. The first alloy samples will be produced as foil coupons, and later as tubes. The first few membrane samples will be coated by vacuum vapor deposition while subsequent membranes and tubes will be coated by electroless deposition or cladding, since these methods are amenable to commercial use.

Primary Project Goal

- Investigate new alloys of lower-cost transition elements to achieve improvements in metallic membrane technology for hydrogen separation.
- Identify a replacement for palladium ($370/ounce) that is stable at 350 ºC, with near 100 percent selectivity, cost around $\$100/ft^2$, a minimum 15-year life, no embrittlement, and produces 50 $scfh/ft^2$ of ultra-high purity hydrogen at $\Delta P = 200$ psi.
- Prepare additional alloys and employ screening tests to determine the optimum candidates for hydrogen membranes in harsh environments while ensuring that the behavior of the alloys match flux, cost, and durability goals.
- Produce welding tubes and continue braze testing to prepare alloys for commercial testing.
- Fabricate and test a membrane reactor using the two best alloys identified earlier.

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Accomplishments

- Fabricated and tested several alloy and intermetallic compositions for toughness, embrittlement, permeation, and ease of manufacture.
- Prepared foil coupons of alloy samples of palladium and B2 phase palladium copper based on tests that showed both materials dissociate and permeate hydrogen readily with added sulfur tolerance from the B2 phase alloy.
- Successfully brazed the alloy to steel (see Figure 1).
- Tested the manufacturability and embrittlement of the first 50 alloys using a Charpy hammer
- Obtained a hydrogen flux of 51 scfh/ft^2 at 44 psi pressure differential and 400 ºC, which approaches the 2007 DOE stipulated flux targets.

Figure 1. Successful Braze of Membrane Alloy to Stainless Steel

Benefits

Lowering the cost/flux of hydrogen in hydrogen permeation membranes lowers the cost of hydrogen production. Palladium will be eventually replaced by a base metal at a cost differential of \$100/ft^2 vs. \$3000/ft^2 with selectivity similar to Pd and can produce hydrogen at 51 scfh/ft^2 at $\Delta P = 44$psi with no embrittlement. These results show a promising path for the commercialization of a hydrogen membrane that is superior to palladium-silver.

Figure 2. Commercial REB Hydrogen Generator