



Technology Readiness Level: **5**
Component and/or Breadboard Validation
in Relevant Environment

Production of Syngas Using Oxygen Transport Membranes

Eltron Oxygen Transport Membranes are used to produce synthesis gas, a mixture of carbon monoxide and hydrogen, by partial oxidation of methane: $\text{CH}_4 + \frac{1}{2} \text{O}_2 = \text{H}_2 + \text{CO}$. Synthesis gas is critical for the production of synthetic fuels including low-sulfur Fischer-Tropsch liquids, used for making synthetic gasoline and diesel fuels. Synthesis gas is also used for methanol production and production of other alcohols. Calculations estimate that oxygen transport membranes could reduce the cost of production of synthesis gas from natural gas by over 30% relative to conventional technology.

A cross section of a planar oxygen transport membrane is shown below. The membrane is fabricated from a ceramic oxide material with the perovskite crystal structure. The membrane material is designed to conduct both oxygen anions (O_2^-) and electrons (e^-). The membrane consists of a porous perovskite layer onto which methane steam reforming catalysts (including noble metal catalysts) are dispersed, a dense perovskite layer which is essentially 100% selective towards oxygen, and a slotted region used for mechanical support.

Air is streamed past the slotted side of the membrane. Molecular oxygen selectively adsorbs and dissociates at surface vacancy sites on the perovskite air-side surface ($\text{O}_2 + 4e^- = 2\text{O}_2^-$). The perovskite materials are designed to contain oxygen-site vacancies on surfaces as well as in the bulk. Although the materials are ceramic oxides, they are designed to be good conductors of electrons. Electron conduction is required for reduction of molecular oxygen as well as catalytic reactions on the fuel side.

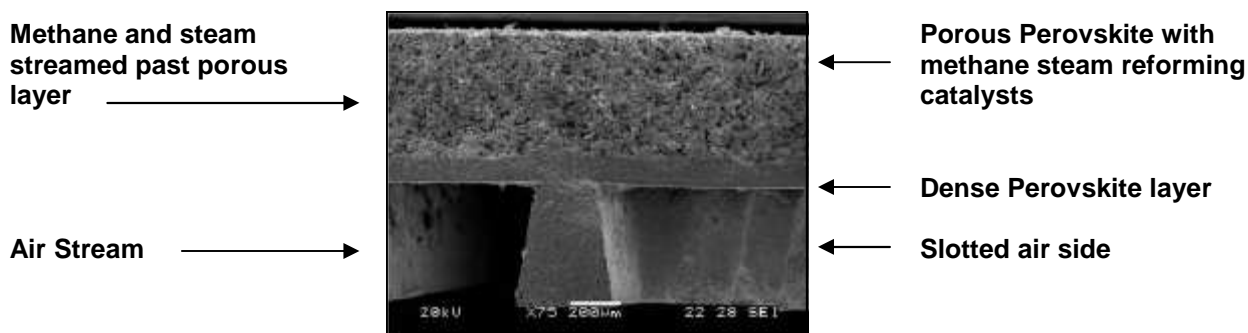


Figure 1. A cross section of a planar oxygen transport membrane. The top, porous layer supports steam reforming catalysts. The middle, dense layer allows diffusion only of oxygen anions and gives the membrane essentially 100 % selectivity for oxygen. The lower slotted region is used for mechanical support in resisting differential pressures of 250 psi.

Methane and steam are streamed past the porous layer on the fuel side of the membrane. Steam and methane react on steam reforming catalysts, which are dispersed in the porous layer: $\text{CH}_4 + \text{H}_2\text{O} = 3\text{H}_2 + \text{CO}$. The porous layer is designed so that approximately one-third of the hydrogen produced in the steam reforming reaction diffuses through the porous layer and reacts with lattice oxygen diffusing through the membrane: $\text{H}_2 + \text{O}_2^- = \text{H}_2\text{O} + 2\text{e}^-$. The reaction between molecular hydrogen and lattice oxygen is highly exothermic. The heat produced by formation of steam drives the endothermic steam reforming reaction. The membrane is operated near the thermal neutral point, with little net external energy consumed. Steam consumed in the steam reforming reaction is replaced by steam formed by reaction of molecular hydrogen with lattice oxygen, so that no net steam is consumed or produced.

The membrane is operated at temperatures between 850°C to 1000°C. If the ratio of C:O:H in the system is properly controlled, operation in this temperature range ensures that H_2 and CO are the overwhelmingly favored thermodynamic products. Deep oxidation products, such as H_2O and CO_2 , if formed, cannot remain thermodynamically stable at equilibrium under these reaction conditions. Although the reaction mechanism involves an intermediate steam reforming step, the overall net reaction is as if methane were directly partially oxidized: $\text{CH}_4 + \frac{1}{2} \text{O}_2 = 2\text{H}_2 + \text{CO}$.

Tubular membranes have been operated continuously for up to nine months under reaction conditions with differential pressures of 250 psi (17.2 bar). The Perovskite materials remained stable under the test conditions.

Stage of Development

Eltron's research and development on mixed conducting ceramics and membrane-based reactors has led to several U.S. and foreign patents.

The technology has been licensed to commercial partners for use in certain fields.

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Contact Us

To discuss the possibility of entering into a business relationship with Eltron, contact the Business Development Group at business@eltronresearch.com.

To learn more about Eltron Research & Development's hydrogen technologies under development and the many other technologies that the company is commercializing, visit www.eltronresearch.com.



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