IONIC TRANSPORT MEMBRANE TECHNOLOGY FOR OXYGEN SEPARATION AND SYNGAS PRODUCTION

Paul N. Dyer, Robin E. Richards and Steven L. Russek
Air Products & Chemicals, Inc.
7201 Hamilton Boulevard, Allentown PA 18195-1501

ABSTRACT

Ion Transport Membranes (ITMs) are made from ceramic materials that conduct oxygen ions at elevated temperatures. Successful application of ITM technology will allow significant improvement in the performance of several large scale industrial processes. The ITM Oxygen process, in which ITMs are used to separate high purity oxygen from air, has the potential for significant advantages when integrated with advanced power generation cycles such as Integrated Gasification Combined Cycle (IGCC). The ITM Syngas process, by combining air separation and high-temperature syngas generation processes into a single compact ceramic membrane reactor, has the potential for substantially reducing the capital investment for GTL (gas to liquid) plants and for distributed hydrogen. The development efforts are major, long-term and high risk, and place severe demands on the performance and property requirements of the ITM materials. In addition, Air Products is developing SEOS an electrically-driven, small scale, oxygen generation and removal technology using ITMs, which could have a significant impact in the global market for distributed oxygen and inert gases.

INTRODUCTION

Air Products is a global leader in the supply of oxygen, hydrogen, carbon monoxide, synthesis gas and related gas production equipment. The company’s corporate strategy is to be a full-line industrial gas and equipment supplier with a proprietary technology position in all significant production technologies. Toward this end, Air Products’ has invested significant resources in oxygen Ion Transport ceramic Membrane (ITM) technology for over a decade, and today, in partnership with U.S. government agencies, Air Products is developing three key ITM technologies.

ITM OXYGEN WITH ELECTRIC POWER CO-PRODUCTION

In a project with the Department of Energy’s Office of Fossil Energy, Air Products is leading the development of a new air separation technology. ITM Oxygen - for the application to Integrated Gasification Combined Cycle (IGCC) technology and other coproduction applications for which tonnage oxygen are required(Figure 1). Examples are iron/steel, metallurgical, glass, pulp and paper, and oxygen-enriched chemical/refining processes.
Complex metal oxide ceramics, so-called Ion Transport Membranes (ITMs), separate oxygen from air selectively and quickly. They operate by adsorbing and dissociating oxygen molecules onto the compressed air-side surface of an ITM, where the dissociated oxygen is ionized and transferred through the ITM at temperatures above 700°C.

Driven by the oxygen partial pressure difference, the oxygen ions travel through the ITM at remarkably high flow rates and recombine at the permeate side to produce high-purity oxygen. The electrons released by the recombination of the oxygen ions are transported back to the air side through the electronically conducting ITM. The energy available in the oxygen-depleted air stream is delivered to an expander to recover electrical power. Thus, ITM Oxygen technology is a step change for producing large tonnage oxygen and coproducing power.

**LIQUIDS FROM NATURAL GAS VIA ITM SYNGAS**

Air separation and reforming processes could be combined into a single process operation using an ITM (Figure 2), and this would have a dramatic impact on the cost of producing synthesis gas (a mixture of carbon monoxide and hydrogen), the building block of many premium chemical products and alternative liquid transportation fuels. Air Products calls this process "ITM Syngas". The key is a novel Ion Transport Membrane that separates oxygen from air and uses it to break apart methane, the chief constituent of natural gas. In simplest terms, natural gas flows along one side of the membrane, where it combines with oxygen molecules migrating through the membrane from air on the other side. The natural gas reacts (a process called "partial oxidation") to form carbon monoxide and hydrogen, or synthesis gas.

Air Products is leading an 8-year project with the DOE’s Offices of Fossil Energy and of Energy Efficiency and Renewable Energy to develop ITM Syngas technology as a key, low-cost step in the conversion of natural gas to liquid products and hydrogen. Vast reserves of remote natural gas on the Alaskan North Slope, as well as many offshore reserves in deep waters, may be recovered and converted economically into liquid products using ITM Syngas.

**SOLID ELECTROLYTE OXYGEN SEPARATOR (SEOS)**

Air Products and Ceramatec, a company based in Salt Lake City, Utah, are jointly developing a small compressed oxygen generator based upon electrically driven ITMs (Figure 3). Part of the development has been conducted under the National Institute of Standards and Technology (NIST) Advanced Technology Program. The SEOS system enables simultaneous air separation and oxygen compression without the need for a mechanical compression device. Such small production systems are expected to provide a more efficient means of producing ultra-high-purity oxygen for a diverse range of applications including respiratory therapy and metal fabrication.
Figure 1. Integration of ITM with conventional gas turbines results in attractive process economics.

Figure 2. ITM syngas technology will dramatically impact the cost of producing synthesis gas.
Figure 3. SEOS oxygen generators can provide a more efficient and lower cost way to produce ultra-high-purity oxygen.