Promises and Problems of PEM Fuel Cell Industry

Ralph Draper
University of New Hampshire
Manchester, New Hampshire 03101
Tel: 603-641-4323
Fax: 603-641-4353
Email: rwd@cisunix.unh.edu

V.K.Mathur
University of New Hampshire
Durham NH 03824
Tel: 603-862-1917
Fax: 603-862-3747
Email: vkm@cisunix.unh.edu

Hydrogen has the potential to solve many of the energy challenges that confront America today, such as reducing dependence on petroleum imports and decreasing pollution and green house gas emissions. There is general agreement that hydrogen could play an increasingly important role in America's energy future. Currently, we have a hydrocarbon economy but we lack the know-how to produce hydrogen from hydrocarbons or water and deliver it to consumers in a clean, affordable, safe and convenient manner as an automotive fuel or for power generation. One devise that uses hydrogen is the fuel cell.

Fuel cells are electrochemical devices that convert chemical energy of a reacting fuel directly into electricity. Proton Exchange Membrane (PEM) fuel cells are amongst one of the most promising energy sources for transportation, heating and power sources.

Why the interest in Fuel Cells?

- Very high fuel conversion efficiencies
- Direct conversion avoids the combustion process—allows for very low to zero emissions
- High reliability—fewer moving parts
- Modularity—scaleable to many sizes from 0.1 kw to 10 MW-offering a wide range of applications
- Quiet operation--<60 dba
- High power quality—due to use of DC to AC power conditioning equipment
- Waste heat –which can be used in cogeneration applications enabling higher overall fuel efficiencies
- Fuel cells are ideal distributed generators, enabling power to be sited at the ‘point of use’

On the other hand there is a general awareness amongst the scientific and industrial communities that the cost of fuel cell materials must be reduced so that the hydrogen economy can be realized. Some of these materials are membranes, electrodes with associated catalysts, bipolar plates, etc. Other critical needs are in the area of hydrogen production, hydrogen storage and methanol as a hydrogen provider.

Membranes

The perfluorinated polymer electrolyte membranes such as Nafion TM (DuPont), Aciplex (Ashahi Chemicals Co.), Flemin (Ashahi Glass Co.) and Dow (Dow Chemical Co.) have been extensively used as polymer electrolytes for fuel cells because of their stable electrochemical and mechanical properties. However, the perfluorinated polymer electrolyte membrane is not appropriate for use in DMFC as it allows methanol crossover to cathode. Its penetrability is up to 40%. To overcome this problem, the development of new proton-conducting polymer electrolytes is necessary for practical applications.

Gas diffusion layers (GDLS)

Another component that it is vital to the performance and durability of the fuel cell is the gas diffusion layer or media or electrode (GDL or GDM or GDE). The GDL consists of a carbon substrate that can either be woven or non-woven, onto which is coated a carbon catalyst layer, usually consisting of a mixture of carbon black and PTFE – controlling hydrophobicity while ensuring conductivity.

The various substrates used to produce GDLs result in very different physical characteristics and therefore in the performance of the fuel cell. Probably the most well known GDL substrate used during the development of the PEM fuel cell was that produced by Toray of Japan. This substrate is produced by pyrolysing a non-woven carbon-fiber sheet which gives a sheet very good conductive properties and low elongation but limited resistance to brittle fracture. In general, the carbon/PTFE layer is applied by the end-user with the amount depending on the hydrophobicity required.

Bi-polar plates

These days bipolar plates are mostly made of graphite which is brittle, difficult to machine and expensive. There is a great need for a suitable replacement material.

Hydrogen and other fuels

Hydrogen can be produced through thermal, electric or pyrolytic processes applied to fossil fuel, water or biomass. Nuclear-based systems can produce hydrogen from water using thermal or electrolytic processes but are not as efficient or cost effective as fossil fuels. The thermal production procedure that uses steam to produce hydrogen from natural gas or other light hydrocarbons is most common. Methane or steam reforming is typically carried out over a nickel-based catalyst, that involves reacting natural gas or other light hydrocarbons with steam. Ninety-five percent of the nine million tons of hydrogen produced every year in the USA is produced via methane reforming. Most of the hydrogen produced is used mainly for chemical, petroleum refining and electronic industries and space applications. It can be stored in tanks or distributed from production and storage sites via trucks, railroad cars or pipelines. The use of hydrogen as an energy carrier will require development in several industrial segments, including production, delivery, storage, conversion and end use. The use of hydrogen for transportation systems such as internal combustion engines, fuel cells, and fuel additives are under various stages of development. Another fuel methanol has great promise to be used in PEM fuel cells.

Pacing technology issues

- Alternate catalyst materials to Platinum
- Lower cost membranes
- Low cost MEA manufacturing
- Higher conductivity Bi-Polar plates
- Demonstrated repeatability/reliability

Pacing business issues

- Regulations/Codes for selected fuels
- • Transportation
- • Storage
- Insurance
- Warranties
- Infrastructure for refueling

Barriers to market adoption

- High initial capital cost—systems needed <$700 per kw installed
- Durability and life—fuel cell stack life ~8 to 10 years
- Low cost electricity—vs. other distributed generation options and bulk power systems
- Technology risk—competitive markets will not adopt until fuel cells are proven
- High installation costs—including permitting and interconnection
- Regulatory framework –enable electric utilities to become early adopters and take risks in implementing new energy forms

In the USA, probably just like in other countries, the factors adversely affecting hydrogen's potential as a major energy source are our inability to build and sustain national consensus on energy policy priorities; the lack of a hydrogen infrastructure and substantial cost of building one; the high cost of hydrogen production, storage and conversion devices such as fuel cells; and hydrogen safety issues. In his State of the Union address, President Bush proposed $1.2 billions in research funding "so that America can lead the world in developing clean, hydrogen-powered automobiles." This money essentially will be the first significant investment by the government in automobile fuel cell R&D, but it is still small compared to what is needed to solve the problems before our children and grandchildren can enjoy the benefits of electric vehicles.

Acknowledgements:
The authors thank EPRI and Johnson and Matthey for some of the information included in this paper.

References:

Mathur, V.K., Jim Crawford, “Fuel Cell Technology and Its Global Impact”, Indian Chemical Engineering Congress, Bhubaneswar, Orissa, India, Dec. 2003