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FUEL CELL PROTON EXCHANGE MEMBRANE - PRESENT AND PERSPECTIVES

Victor CIUPINA[1], Eden MAMUT[2], Gabriel PRODAN[3],
Iuliana Mihaela OANCEA-STANESCU[4]

Abstract. *The fuel cells could contribute to the reduction of the pollution emission and the fossil fuels due to the conversion efficiency which is higher than the other energy conversion systems. There are many possibilities to improve the efficiency and to reduce the weight of the fuel cells by the integration of new nanostructured materials.*

Keywords: Fuel cells, membrane, Gibbs energy, cluster

1. Introduction

Achievement fuel cells as energy conversion systems, dates back to the mid-nineteenth century. Their operating principle was discovered by Christian F. Schobein. Together with Sir William Grove developed the technology to produce electricity this way. Fuel cells are one of the oldest energy conversion technologies, whose evolution has been slow due to abundant natural resources but which are the base of conventional devices to obtain energy.

An important factor which influenced the development of fuel cells is linked to concerns regarding the consequences of environmental degradation through the use of conventional fuels in electricity generation and propulsion motor field. Oil dependence of industrialized and super industrialized countries was evident from the moment of opening oil crisis. Fuel cells can influence the reducing dependence on conventional combustibles and can reduce emissions in the atmosphere.

Using pure hydrogen, electrochemical cells do not produce waste being also a source of pure water or heat. Energy production using wind power or solar energy waves develop in parallel with progress in fuel cells technology. Pooling the results based on these technologies for producing and storing hydrogen, which can be used in electrochemical cells for obtaining energy, will contribute substantially to maintaining environmental quality and public health.

[1]Prof., Ph.D., Senior Researcher, Faculty of Physics and Chemistry, Ovidius University of Constanta, Romania, Member of Academy of the Romanian Scientists, rectorat2@univ-ovidius.ro.
[2]Prof., Ph.D., Senior Researcher, Faculty of Mechanical Engineering, Ovidius University of Constanta, Romania, emamut@univ-ovidius.ro.
[3]Ph.D. student, Scientific Researcher, Faculty of Physics and Chemistry, Ovidius University of Constanta, Romania, gprodan@univ-ovidius.ro.
[4]Ph.D. student, Researcher Assistent, Faculty of Physics and Chemistry, Ovidius University of Constanta, Romania, istanescu@univ-ovidius.ro.

2. Types of Fuel Cells

Fuel cells operation is based on the process of direct conversion of chemical energy of a fuel into electricity and heat, by breaking the hydrogen atom into protons and electrons favored by conditions created in cell [1].

Scheme works of such fuel cells is shown in Fig1.

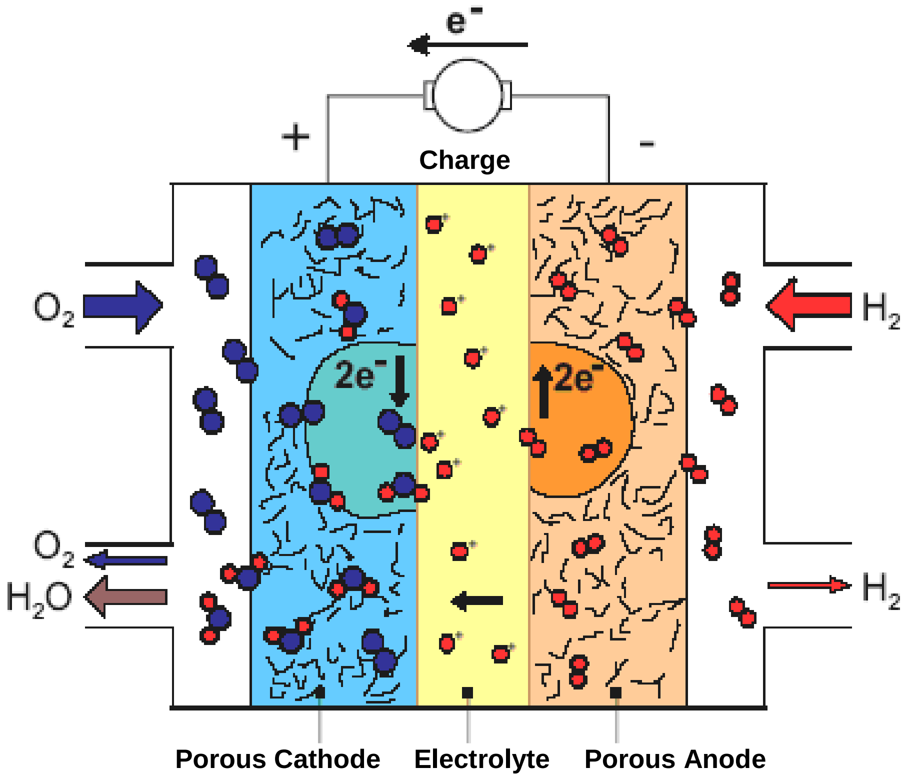

Fig. 1. – Scheme works of a fuel cells.

Fuel cells generally have a similar structure: containing two electrodes separated by an electrolyte and is connected to an external circuit.

The anode is fed with gaseous fuels, direct oxidation taking place, the cathode being supplied with an oxidant (i.e. oxygen from the air).

The electrodes are permeable, thus having a porous structure. Electrolyte has a low permeability as possible.

To realize a comparison of fuel cell, on the one hand, and other energy production systems, on the other hand (e.g. internal combustion engine) system output is used as a criterion. Regarding the internal combustion engine, maximum efficiency is expressed by Carnot cycle efficiency, meaning:

$$\eta_C = 1 - \frac{T_2}{T_1},$$

where T_1 is the warm source temperature and T_2 cold source temperature. For fuel cell efficiency is defined by the maximum free energy change (Gibbs energy) ΔG and enthalpy change ΔH in the electrochemical reaction:

$$\eta_{PC} = \frac{\Delta G}{\Delta H}.$$

Overall power conversion efficiency in case of fuel cells is higher efficiency heat engine based systems.

A comparison of overall efficiency power conversion is shown in Fig.2.

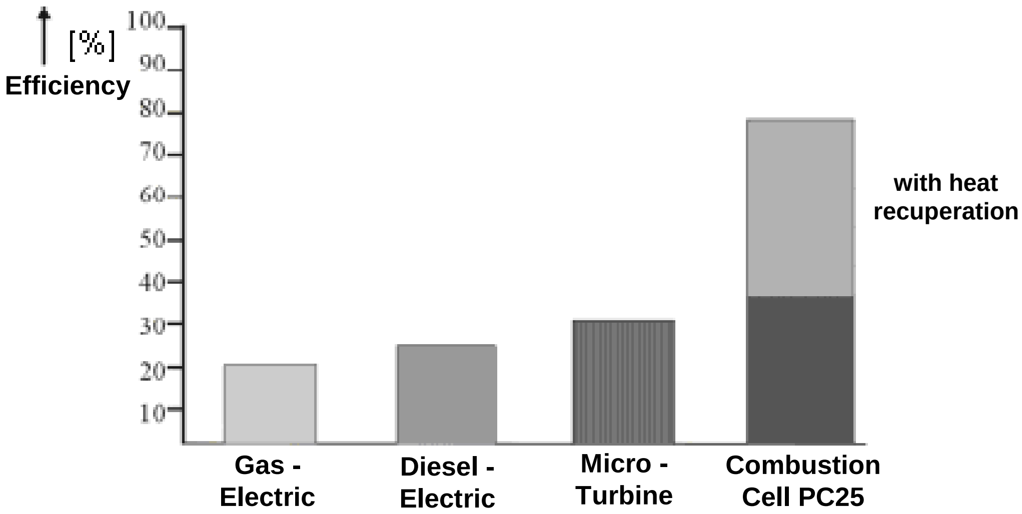

Fig. 2. Comparison between electric conversion efficiency of fuel cells and other energy conversion systems.

Fuel cells can be classified by type of electrolyte used; an exception is the DMFC (Direct Methanol Fuel Cell), where methanol is introduced directly into the anode. Electrolyte of the fuel cell does not lead the class to which that belongs.

Another classification accepted is taking into account the operating temperature. From this point of view we can speak about low and high temperature fuel cells. Between low temperature fuel cells is AFC (Alkaline Fuel Cell), PEMFC (Polymer electrolyte Fuel Cell), DMFC (Direct Methanol Fuel Cell) and PAFC (Phosphoric Acid Fuel Cell) and in the high temperature fuel cells that operate between 600-1000°C can be found MCFC (Molten Carbonate Fuel Cell) and SOFC (Solid Oxide Fuel Cell).

In Tab.1 are shown different types of fuel cells.

Table 1. Different types of fuel cells

	AFC	PEMFC	DMFC	PAFC	MCFC	SOFC
Operating temperature (°C)	<100	60-120	60-120	160-220	600-800	800-1000
The anode reaction	$H_2+2OH^- \rightarrow 2H_2O+2e^-$	$H_2 \rightarrow 2H^+ +2e^-$	$CH_3OH+H_2O \rightarrow CO_2+6H^+ +6e^-$	$H_2 \rightarrow 2H^+ +2e^-$	$H_2+CO_3^{2-} \rightarrow H_2O+CO_2+2e^-$	$H_2+O^{2-} \rightarrow H_2O+2e^-$
The cathode reaction	$\frac{1}{2}O_2+H_2O+2e^- \rightarrow 2OH^-$	$\frac{1}{2}O_2+2H^+ +2e^- \rightarrow H_2O$	$\frac{3}{2}O_2+6H^+ +6e^- \rightarrow 3H_2O$	$\frac{1}{2}O_2+2H^+ +2e^- \rightarrow H_2O$	$\frac{1}{2}O_2+CO_2+2e^- \rightarrow CO_3^{2-}$	$\frac{1}{2}O_2+2e^- \rightarrow O^{2-}$
Applications	Transportation Space program Military Energy storage systems			Electricity and heat in decentralized stationary power systems	Electricity and heat in decentralized stationary energy and transport systems (trains, ships, ...)	
Power achieved	Small installations 5-150kW Modular	Small installations 5-250kW Modular	Small installations 5kW	Small and medium installations 50kW-11MW	Small installations 100kW-2MW	Small installations 100-250kW
Charge carriers in the electrolyte	OH^-	H^+	H^+	H^+	CO_3^{2-}	O^{2-}

3. Fuel cell proton exchange membrane

About 30 years ago, Dupont has made an acid copolymer PTFE perfluorosulfonic acid form, known as the Nafion.

DuPont Company, based on Nafion solution, made Nafion® membrane using Nafion® PFSA polymer. Nafion®PFSA membranes are widely used in fuel cells proton exchange membrane (PEM).

Membrane acts as a separator and as a solid electrolyte in a variety of electrochemical cells that require selective cations transport by cell junction.

Polymer is characterized by a high chemically resistant, presenting a high degree of sustainability.

Using a solid polymer eliminates the need for a watertight compartment for the liquid electrolyte and simultaneously removes corrosion, limited security elements linked to it. An advanced version of a PEM cell assemblies deposited catalyst is shown in Fig. 3.

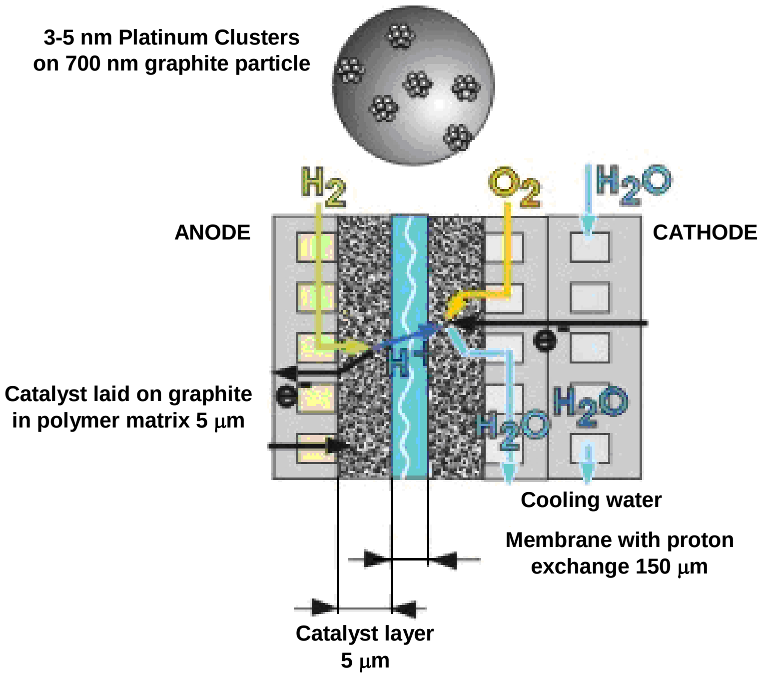

Fig. 3. An advanced version of a PEM cell assemblies deposited catalyst.

Typically, platinum acts as a catalyst, which is deposited in the form of nano-clusters (3-5 nm) supported on graphite or graphite particles of 0.7 to 1 µm partially embedded in a graphite sheet of paper. On both sides of the membrane are applied to two sheets forming the anode and cathode catalyst layers. Such an assembly is known PEM membrane with catalyst deposited (CCM).

Graphite paper can be eliminated completely by deposition of a catalyst layer greater thickness (e.g. 5 µm); this layer is a good electrical conductor on the membrane causing a drop in performance of platinum catalyst.

In Fig.4 is shown a model of assembly membrane - electrode (MEA) using the CCM. Gas supply and collection of electrons is shaped like a gas pipeline of cells forming the outer limit. Gas is introduced laterally through the electrode edges to inside, while electrons are transported by the electro plate to the next cell. At higher power densities, between two successive cells, is inserted an additional electro plate with channels for water cooling.

Proton exchange membrane based on Nafion usually works at lower temperatures of 70-85°C. Low operating temperature provides a quick start and does not require thermal protection for staff. At room temperature approximately 50% of maximum power is available almost instantly. Under normal conditions in about three minutes total power is reached. Recent discoveries in architecture and performance allow cost reduction of PEM fuel cells under the cost of any other cell.

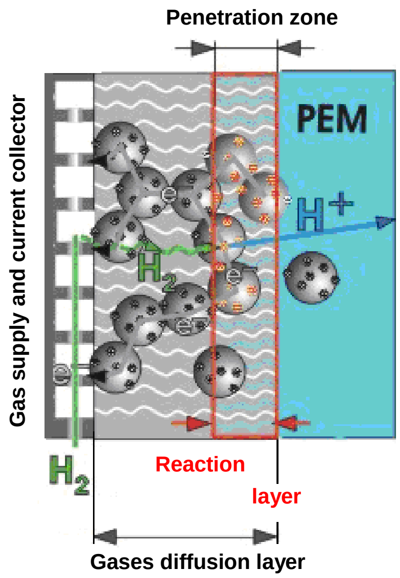

Fig. 4. Electrocatalytic layer model of CCM.

The experimental study set-up for PEM type fuel cells contains: fuel cell (1), temperature control unit (2), hydrogen (3) and oxygen (4) storage cylinders, together with pneumatic circuits of the two gas, and electric variables measurement sections(5).

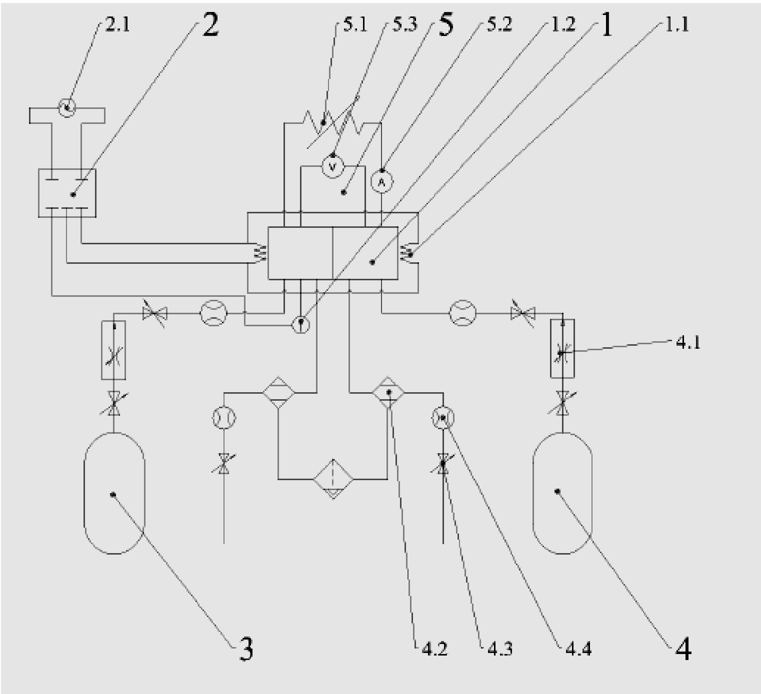

Fig. 5. Experimental set-up.

On each fuel cell collector plate is positioned an electric heater (1.1) in order to bring the cell to the operating temperature (up to 70°C). In the anode is placed a thermometer (1.2) which indicate operating temperature fuel cell. Electric heaters and the thermometer are connected to the control unit of temperature, which is fueled by the power source (2.1).

Temperature control unit can show the actual operating temperature of the cell, shown on (1.2) thermometer or the temperature at which the cell wants to be achieved.

Pneumatic circuits for hydrogen and oxygen are identical, will be described only oxygen flow: between the cylinder and low pressure circuit is placed a Messer pressure regulator (4.1). It is equipped with pressure gauges and valves for each circuit.

Connection between the pressure regulator and fuel cell is achieved by flexible pipes. At the exit of the fuel cell is placed a decanter of water (4.2).

The reaction water obtained is collected in settling being measured at the end of a cycle. After settling the water valve (4.3) and gauge (4.4) are situated.

To measure electrical variables are used: a variable resistance (5.1), an ammeter (5.2) and a voltmeter (5.3).

4. Results

Measuring two variables can be traced voltage-current characteristic of the fuel cell as shown in Fig.6.

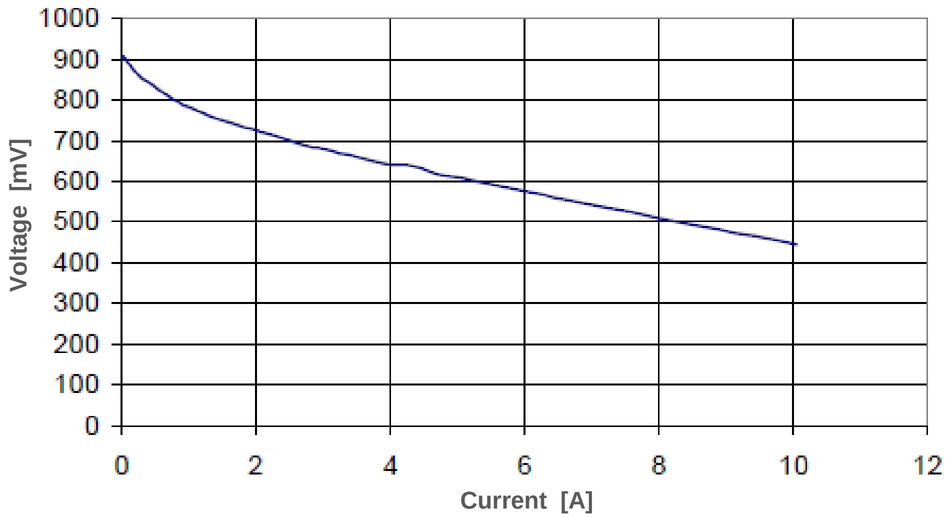

Fig. 6. Current-voltage characteristic of experimental fuel cell.

Experimental set-up is shown in Fig.7.

Fig. 7. Experimental set-up**.**

Conclusions

1. Fuel cells have proven to be one of the most promising solutions for energy conversion, if are taken into account efficiency and environmental impact.

2. There are still many opportunities for increasing efficiency and reducing the weight of fuel cells by incorporating new materials (nanostructured materials).

3. In order to integrate fuel cells into electrical distribution systems performance and characteristics are expected to use it experimental study set ups.

R E F E R E N C E S

[1] E. Mamut, E. Budevski, *Hierarchical Processes in Fuel Cells*, 1st Int. Seminar on Thermofluid Design, Gabrovo, Bulgaria (2004);

[2] L. Carrette, K. A. Friedrich, U. Stimming, *Fuel Cells – Fundamentals and Applications,* Fuel Cells 2001, 1, (2001).

[3] http://www.fuelcells.ro.