Performance study of Membranes on an Electrochemical Hydrogen Compressor

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ABSTRACT

The electrochemical hydrogen compression (EHC) is a scarcely explored alternative to conventional hydrogen compression methods. The EHC uses the transport phenomena presented in the operation of Proton Exchange Membrane (PEM) technologies, provides important advantages such as low energy demand to reach high compression rates, it is noiseless, low maintenance is required, and unpolluted hydrogen can be obtained. Like in a PEM fuel cell or PEM electrolyzer, the core of the compressor is a Membrane-Electrode Assembly (MEA). One of the main challenges is to find a membrane with a high ionic conductivity and capable of withstand a high pressure between anode and cathode. This work shows the evaluation of four different membranes Nafion, S-PEEK, F>N1, F>S in an EHC system based on an Electrochem PEMFC (5 cm^2). Potential pulses from 100 to 800 mV were applied to the EHC while the pressure increase in the compression chamber was monitored.

Keywords: **Hydrogen; Electrochemical Hydrogen Compressor; Fuel Cell;**

1. Introduction

The use of hydrogen as an energy carrier depends on the development of efficient technologies for production and storage. Water electrolysis in a solid polymer electrolyzer (SPE) is the most efficient method in terms of purity, its operation is exactly opposite to a Proton Exchange Membrane Fuel Cell, PEMFC , in which the oxygen reduction occurs at the cathode and hydrogen oxidation at the anode, resulting in the generation of energy available to do electric work, plus water and heat as the only byproducts, making it the ideal device for the utilization of the hydrogen energy (1 kg of hydrogen contains the same energy as 2.5 kg of gasoline). Regarding to the storage systems, the methods available to date require a high energy investment for either, compressing, liquefying and storing it as metal hydride. The level of the technology of hydrogen storage is not sufficient to satisfy the projected demand for infrastructure because it has many limitations [1]. Some of the limitations of the existing compressors are that they are inefficient and have many moving parts, resulting in the deterioration of the components and therefore excessive maintenance. Besides, using oils or lubricants to migrate wear into the compressor causes hydrogen contamination. An alternative unexplored is the electrochemical compression that has a close operating principle of the PEM fuel cell in terms of transport phenomena [2]. The energy investment in these devices is very low, since it is sufficient to apply a potential of 0.3 V or less to promote oxidation of hydrogen at the side of the compressor and reducing gas in the compression chamber. Like in a PEM fuel cell and solid polymer electrolyzer, the heart of the electrochemical compressor is a membrane electrode assembly (MEA), however; new challenges arise in materials and design, since the MEA's are not designed to operate under high pressure difference between anode and cathode (the maximum pressure difference the manufacturer indicates for ionic conductive membrane, is commonly lower than 10 psi). Besides requiring higher strength materials, it is stated that cell design should allow compressing hydrogen without increasing electrical contact resistance between flow diffuser plates [3].

The working principle of the electrochemical hydrogen compressor is shown in Fig. 1. Because of an applied potential difference, hydrogen at pressure (Pa) is oxidized at the anode to H+, transported through the PEM and reduced at the cathode to hydrogen at pressure (Pc). If the cathode compartment is hermetically sealed, the formation of hydrogen at the cathode results in the increase of the pressure Pc [4].

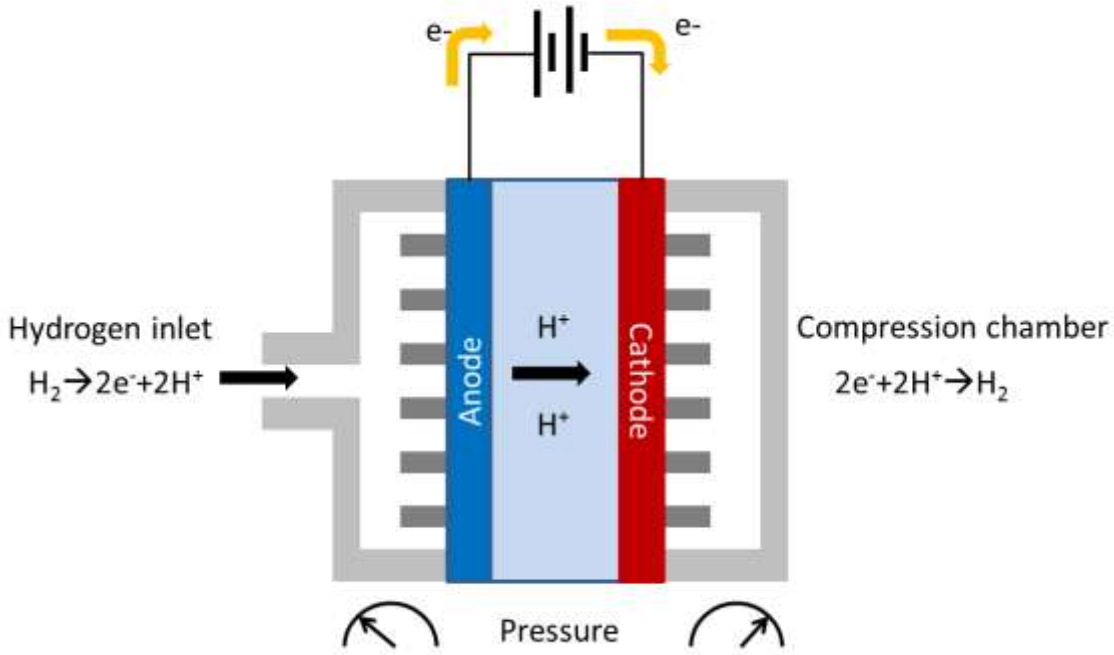

Fig. 1. Electrochemical Hydrogen Compressor

2. Experimental

The experimental section used for this work is schematized in Fig. 2. A regular Proton Exchange Fuel Cell by ElectroChem® was used as a platform for the hydrogen compressor. The Membrane Electrode Assembly for this Fuel Cell has an electrode area of 5cm^2, platinum was used as electrocatalysts (20 % wt., supported on Vulcan carbon XC-72) and Sigracet 35 BC gas diffusers were employed. The hydrogen flux is fixed at 120 ml/min, 100% humidified by ElectroChem® Fuel Cell Test Station. The catalytic ink was spray deposited on the Sigracet 35 BC. The membranes utilized were Nafion 115 (Dupont) 127 µm, S-PEEK (Sulfonated Polyeter-eter-ketone) 73µm, F>N1 (Xergy Incorporated) 26 µm and F>S (Xergy Incorporated) 15µm. A potentiostat/galvanostat Autolab PGSTAT 302 coupled to a Booster 20 A was used for the evaluation tests.

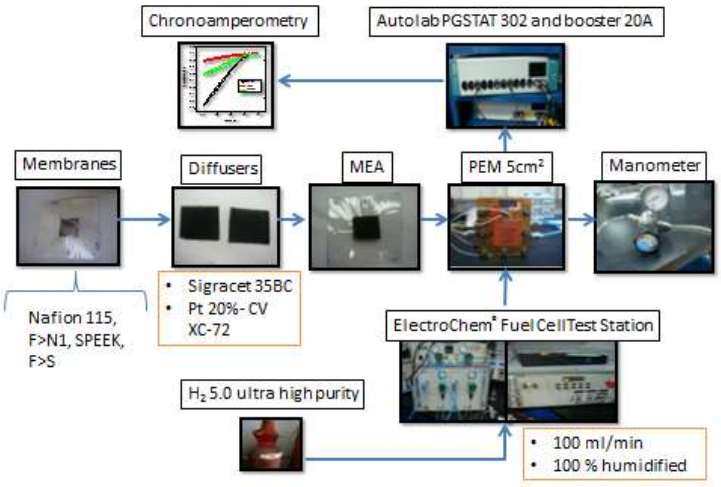

Fig.2 Experimental set-up for the electrochemical hydrogen compressor.

3. Results and discussion

Each membrane performance was observed during a period of 10 min, which is the time at which the highest pressure is reached and stabilized when a potential from 100 to 700 mV is applied. Analysis of the pressure behavior was observed for each membrane.

Nafion 115

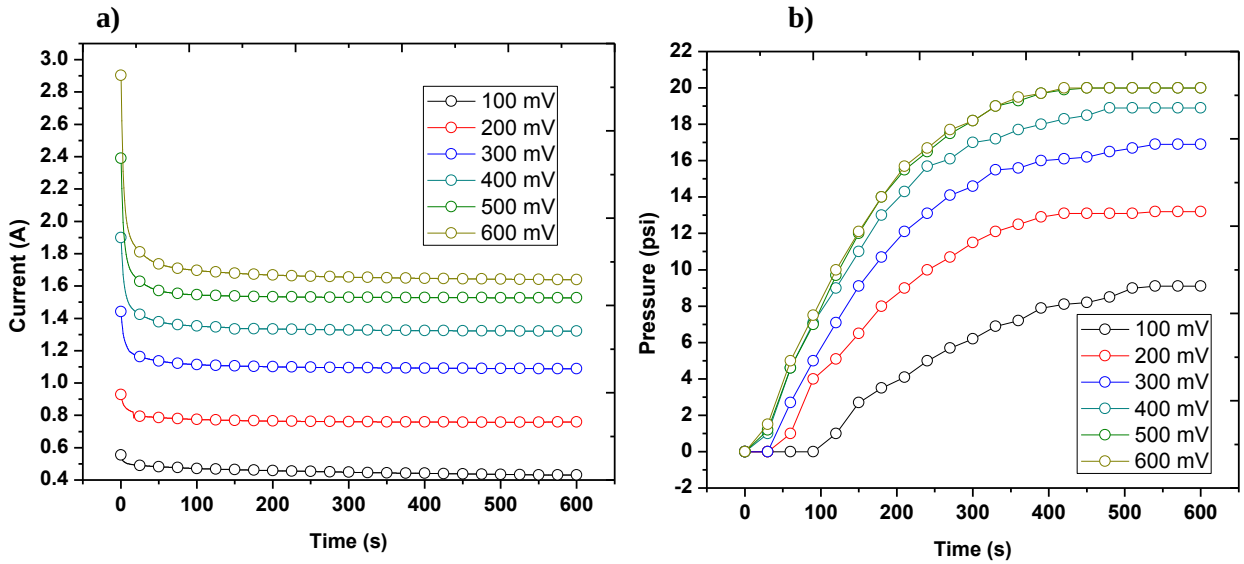

Fig.3 a) Chronoamperogram of Nafion 115 at different potentials on the HEC. b) Pressure vs time graphs obtained from the Nafion 115 assembly in the HEC through a period of 600 s at different potentials.

F>N1

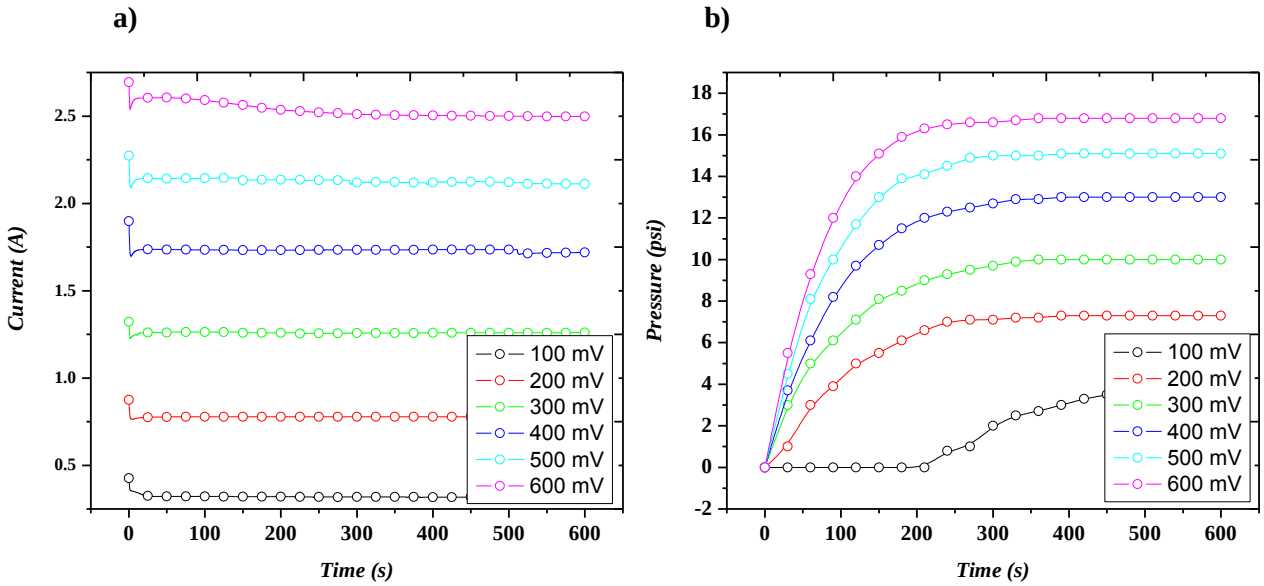

Fig.4 a) Chronoamperogram of F>N1 at different potentials on the HEC. b) Pressure vs time graphs obtained from the F>N1 assembly in the HEC through a period of 600 s at different potentials.

F>S

a) **b)**

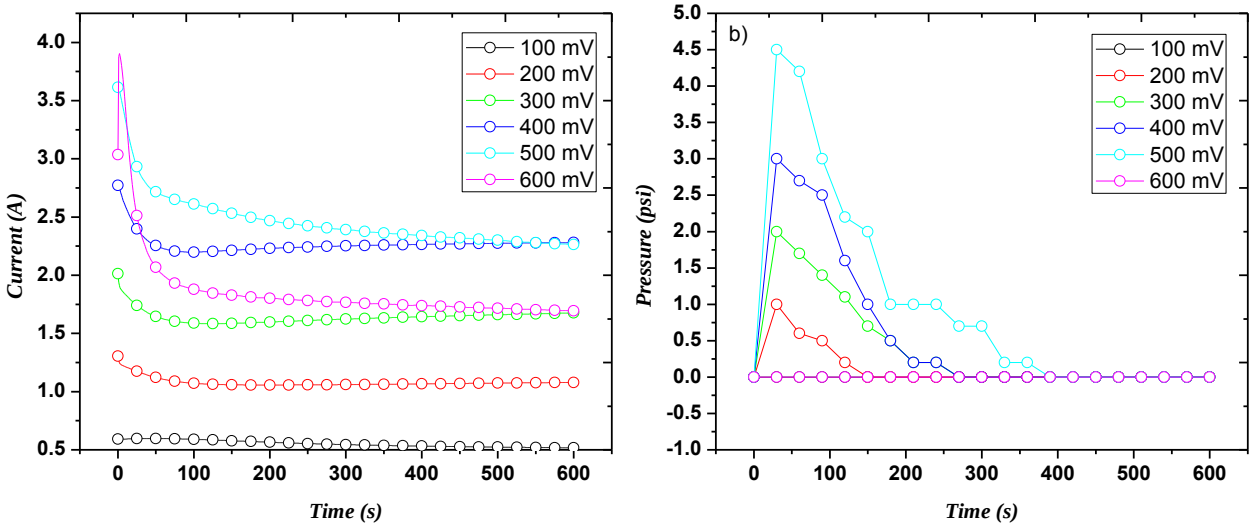

Fig.5 a) Chronoamperogram of F>S at different potentials on the HEC. b) Pressure vs time graphs obtained from the F>S assembly in the HEC through a period of 600 s at different potentials.

S-PEEK

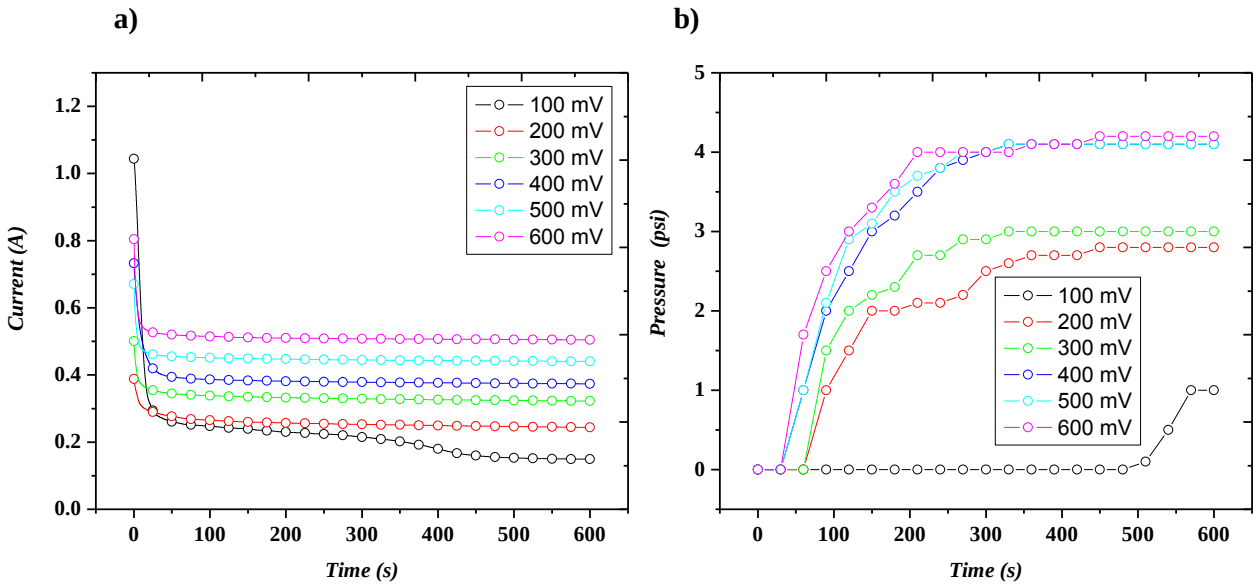

Fig.6 a) Chronoamperogram of S-PEEK at different potentials on the HEC. b) Pressure vs time graphs obtained from the S-PEEK 115 assembly in the HEC through a period of 600 s at different potentials.

Membranes F> N1 and F> S provided by Xergy Inc. shown the highest values of current when were used in MEAs in the compression system, besides they also present the quickest stabilization (around 300 s) however they failed at high pressure due their low mechanical resistance. In contrast the S-PEEK membrane, presents high mechanical resistance, but low conductivity not achieving high pressures. Nevertheless, the high conductivity and mechanical resistance of Nafion allowed to reach an elevated pressure but with a stabilization time of 500 s.

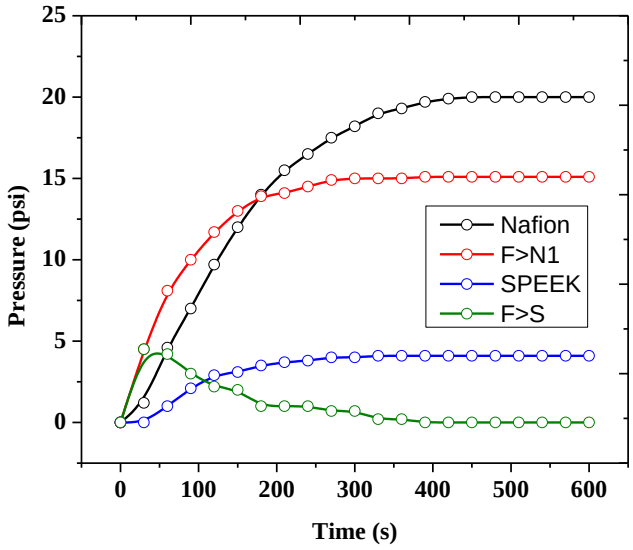

Fig. 7 shows the EHC performance on every membrane at 500mV (the most efficient potential observed).

4. Summary and perspectives

According to tests performed in the membrane evaluation, it was demonstrated that the Nafion ® 115 is the polymer with better efficiency for fuel cell and hydrogen compression applications, however, this research is focusing on find other alternatives for the electrochemical compression system with high mechanical strength, humidity retention and high proton conductivity that could substitute Nafion®.

Acknowledgements

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