Post-doctoral fellow: Operation of proton exchange membrane fuel cells without air humidification system

The performances of proton exchange membrane fuel cells (PEMFC) in terms of power density (exceeding 3 kW / L for automotive application) or electrical efficiency (> 50% for stationary applications) are sufficient for the emergence of niche markets, but a large-scale deployment of the technology will only be possible if the sustainability of the systems is improved and the cost is reduced. One way of reducing the cost is to simplify the systems (Balance of Plant) and in particular to remove the air humidifier whose role is to control the moisture of the membrane. In a PEMFC cell, the membrane is the electrolyte that transports the protons (H^+) from the anode ($H_2 \rightarrow 2H^+ + 2e^-$) to the cathode ($2H^+ + 2e^- + ½ O_2 \rightarrow H_2O$) and this function can only be assured if it is sufficiently hydrated - a dry membrane exhibits a high resistance to proton transport. Removing the air humidifier therefore means implementing innovative water management strategies. At LEMTA, for the past ten years, we have developed instrumented fuel cells that allow the localized measurement of the current density generated and, through electrochemical techniques, the water content of the membrane between the inlet and the outlet of the gases. These tools, called "segmented cells", are perfectly suited to the study of the self-wetting of the membrane between the inlet and the outlet of air due to the water produced by the electrochemical reaction at the cathode. When a PEMFC cell is supplied with dry air, stable operation can occur - the water produced by the reaction is sufficient to moisten the membrane and maintain sufficient proton conduction - or unstable: drying of the membrane begins by the air inlet which then no longer generates current, and therefore no water, and then propagates towards the outlet. In the framework of the thesis of Thomas Gaumont (LEMTA-CEA supported on 8/02/2017) we have demonstrated that it is possible to operate a fuel cell under conditions respecting the specifications of the automobile without humidifier and even get better performance in terms of energy efficiency. This advance has been achieved using standard materials representative of the current state of the art and by optimally managing the recirculation of hydrogen and the stoichiometry of air. However, some constraints remain: -The current density must be sufficient (> 0.15 A / cm2) -The air pressure must be sufficient (> 1.5 barabs @ 80 ° C) And the impact on sustainability needs to be assessed. To reduce these constraints one solution is to choose or develop more hydrophilic materials and better protonic conductors with low humidity. It is also possible to use diffusion layers and feed channels whose geometry has the effect of increasing the diffusion resistance of the water between the electrode and the channels in order to conserve the water produced in the electrode. These two research ways will be conducted jointly with the IJL based on the results of the thesis of Yuzhen Xia (IJL-LRGP 2014) and the LEMTA. Yuzhen Xia has demonstrated that functionalization of the carbon support of the catalyst by sulphonate groups makes it possible to increase the hydrophilicity of the electrode and to improve its proton conductivity. The objectives of the project are in chronological order:

1. Understand the phenomenon of self-humidification: observe and characterize it using segmented cells, model it and determine the range of stability as a function of temperature, pressure, gas flow and average current density.

2. Improve the self-humidification by playing on the geometry of the diffusion layers and the feed channels, taking care not to penalize excessively the transport of oxygen.

3. Use new materials that are more hydrophilic and better protonic conductors with low humidity. The type of carbon will be tweaked to optimize the performances, with the use of nanocarbons such as nanotubes or graphene. Also, grafting of functional groups can be performed to modify the hydrophobicity and/or the ability to conduct protons. Characterization will be performed using routinely TEM and TGA/mass spectrometry.

4. Investigate the impact of dry operation on the durability of optimized membrane-electrode assemblies.

Candidate Profile: The position is open for several profiles as the topic is pluridisciplinar: transport phenomenon, material science and/or chemical engineering are important aspects of the project. Work will be mostly experimental. Experience in fuel cells and/or carbon materials is a plus. The post-doc must be motivated, autonomous and with the ability to communicate well as the work will be performed in 2 different labs.

Nancy, France, University of Lorraine

The salary range for this position is: € 2,000-2300 per month

18 months contract to start in January 2018

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