Hybrid Organic-Inorganic Membranes Synthesized via Electrospinning and Sol-gel Chemistry. Proton Transport characterized by Electrochemical Impedance Spectroscopy

Leslie Dos Santos[1,2], Ozlem Sel[1], Hubert Perrot[1], and Christel Laberty-Robert[2]

[1] Laboratoire Interfaces et Systèmes Electrochimique, UPR15 du CNRS, Université Pierre et Marie Curie 4 place Jussieu, 75252 PARIS CEDEX 05

[2] Laboratoire de Chimie de la Matière Condensée de Paris, Université Pierre et Marie Curie, Collège de France 11 place Marcelin Berthelot, 75231 PARIS CEDEX 05

Proton exchange membrane fuel cell (PEMFC) is one of the most promising alternative power sources. PEMFC has recently received increasing attention as a clean renewable power source due to its high operational efficiency and minimal environmental impact. Moreover, the PEMFC system is suitable for mobile applications because its operating temperature is relatively low and its power range is appropriate for automobiles and electric components. The currently well-developed PEMFC technology is based on perfluorosulfonic polymers acid membranes as electrolyte. The reference membrane is Nafion due to their excellent chemical, mechanical, and thermal stability as well as their high electrochemical properties under high humidity content. However, Nafion presents several drawbacks as high cost, relative low operational temperatures, high methanol permeability… One way to improve and permits the development of PEMFC is to replace it. Consequently, research efforts have been focused on developing methods to create new membranes.

An alternative to replace commercials membranes is the development of organic-inorganic hybrid membranes for fuel cell applications. The advantage of these membranes compared to Nafion is the decoupling of the proton transport from the mechanical properties. This hybrid membrane combines the intrinsic physical and chemical properties of both the inorganic and organic components allowing desirable properties. The swelling of the membrane can be adjusted via the composition of the membrane. Recently, a new hybrid membrane composed of silica and polymer PVDF-HFP is synthesised by combining sol gel chemistry and electrospinning. The association between the sol gel process and electrospinning permits the creation of an inorganic network within the polymer membrane, and morphological control to tune the proton pathway. This process recreated the nanoseparation observed in hydrated Nafion while being in dependent of water quantity. Yet this organisation is strongly correlated with high conductivity of nafion. These news membranes are made of polymer fibbers surrounded by a functionalized (-SO_3H) inorganic network. This microstructure conduces to membranes with conductivity values comparable to Nafion (figure 1) with better mechanical properties.

To optimize the sol-gel chemistry and the electrospinning parameters, there is a need to understand proton mechanisms in these multiscale materials. Several characterisation techniques are used to explain the microstructure and to understand the link with conductivity values. This presentation discusses the dynamic properties of H^+ and water in these hybrid membranes by Electrochemical Impedance Spectroscopy (EIS). Impact of differents parameters will be studied. In particular, the role of additives added in the sol-gel chemistry on H^+ diffusion mechanisms will be highlighted. The conductivity results obtained on electrospun membranes will be compared with cast membranes to point it out the benefit of using electrospinning approach for synthesizing hybrid membranes.

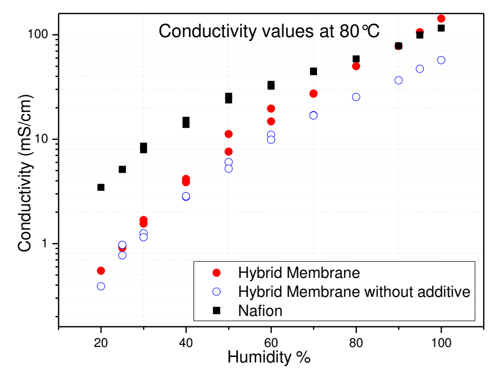

Fig. 1: Comparison of proton conductivity for electrospun hybrid membrane (filled red circles), electrospun hybrid membrane without additive (open blue circles) and Nafion (black square) at 80°C.

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