Development of Nafion Recast membranes for Polymer Electrolyte Fuel Cells

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The low proton conductivity and the poor mechanical properties at high temperatures (above 100°C) of the Nafion membranes used as an electrolyte in PEFC are the main problem for an immediate practical application of these systems. A possible solution has been found in the development of composite inorganic/organic membranes through the introduction of hygroscope and/or proton conductor inorganic compounds in the Nafion recast films [1-4] to improve the characteristics for high temperature operation.

The preliminary step in this activity is the preparation of Nafion recast membranes with similar or better properties than the commercial ones, based on a procedure able to realise an easy scale-up of the film.

In this work, a study on the Nafion recast membranes realization and characterization was carried out with the aim of using this procedure for the composite membranes development, successively.

The first approach was the selection of three different commercial dispersions (Aldrich, Du Pont, Ion Power) to use in the preparative and, after the screening, the 5%wt Ion Power Nafion solution was chosen as the starting material because membranes that were less brittle and with a higher mechanical resistance were obtained. The original solution was dried until reaching desiccation and the dry residue was dissolved in dimethylacetammide (DMAc) as a solvent (10% wt). Two re-cast Nafion membranes were prepared by the Doctor-Blade casting technique. Such a method guarantees a homogenous thickness and good mechanical properties of the film.

The developed membranes, N15 and N16, with a thickness of about 55μm and 70μm respectively, were characterized by a chemical-physical point of view in terms of water uptake (gravimetric method) and IEC (titration method).

The N16 solution underwent an ultrasonic treatment before the casting to evaluate its influence on the membrane properties. This treatment will be used as an additional step in the composite membrane development for a better inorganic compound dispersion.

The nanostructure of dry and water-swollen Nafion membranes, both commercial N115 and recast ones, was investigated by means of SAXS analysis. For the native Nafion 115, the small-angle scattering curve shows two broad peaks. Only very recently such evidence was pointed out and a new structure model was proposed for the perfluorinated materials N115 and N117 [5,6]. Commonly, the peak at small-angles is called the "matrix peak" and the peak at a highest scattering angle is called the "ionomer peak".

From SAXS results on the N16 sample, the water-swollen membrane shows only one SAXS peak, and no two-peaks SAXS structure was encountered. This peak arises from the swelling due to the water uptake process and can be considered as a "cluster" reflection, resulting essentially from the density contrast between microscopically phase-separated domains of fluorocarbon matrix and absorbed water. In the fully-hydrated structure of recast N16 membrane, the intercluster distance is 5.1 nm.

In table 1, the results of chemical physical characterization are reported and compared to the commercial Nafion membrane (N112).

Tab.1: Chemical physical data

Membrane	Thickness, μm	Wup, %	IEC, meq/g
N112	51*	38*	0.89*
N112	47	21§	0.92§
N15	55	23§	0.96§
N16	70	20§	0.89§

* *by DuPont*

§*experimental value*

The measured characteristics of the recast membranes are very similar to those of commercial Nafion: the difference in the water uptake value is due to the different conditions of the measurement, which in this work was carried out by swelling the membrane at room temperature, while the DuPont value was determined at 100°C.

Electrochemical characterizations of the membranes were carried out in a 5 cm^2 H_2/air single cell at T=80°C with humidified gases (100% RH) at P=3 abs. bar. Home-made electrodes [7] with 0.5mg Pt/cm^2 were used for MEA preparation.

Fig.1 shows polarisation curves of the tested membranes compared to N112. A current density of 0.725 A/cm^2 and of 0.788 A/cm^2 for N15 and N16 at 0.6 V, respectively was obtained. These values are very promising if compared to the value of 0.506 A/cm^2 for commercial N112 membrane in the same operative conditions.

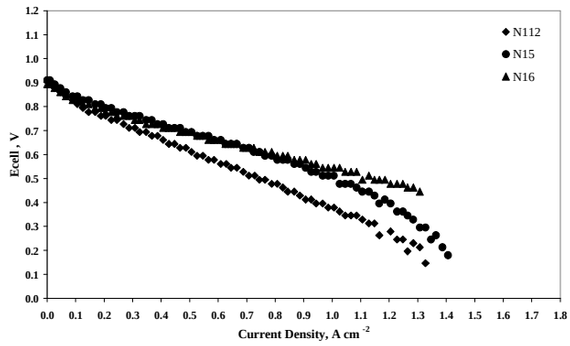

Fig. 1 – Polarization curves at 80°C for the two recast membranes and commercial N112.

The obtained results show good reproducibility and performance for the developed Nafion recast membranes. The ultrasonic treatment slightly influences (N16) the membrane characteristics, but in any case a very high performance is obtained compared to commercial N112.

References

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