Development of accelerated stress tests to assess durability of FEP- and carbon nanotubes-based gas diffusion media for PEM fuel cells

S. Latorrata[1], F. Ponti[1], R. Pelosato[1], P. Gallo Stampino[1], C. Cristiani[1], G. Dotelli[1]

[1] Politecnico di Milano, Dipartimento di Chimica, Materiali e Ingegneria Chimica, Piazza Leonardo da Vinci 32, 20133, Milano, Italy

Water management in polymer electrolyte membrane fuel cells (PEMFCs) is a crucial aspect which must be properly addressed in order to have high and constant efficiency during device operation. In this respect, gas diffusion medium (GDM) is a fundamental component for a PEMFC because it is inserted between the flow field (bipolar plate) and the catalytic layer aiming to avoid flooding both of channels of the device and of porous components; thus it has to guarantee a correct balance between the inlet water with humidified reactants and water generated by the electrochemical process. Indeed, an excessive accumulation of water could rise mass transfer limitations which in turn result in a decrease of reactant gases supply. This phenomenon can lead to water flooding, above all at high current densities values, namely when a higher amount of water is being produced. For these reasons GDM needs to be made hydrophobic [1, 2].

GDM is formed by a carbon cloth macro-porous substrate (gas diffusion layer, GDL) and a micro-porous layer (MPL) made from an ink and coated onto GDL. Such a coating improves the smoothness of the GDL surface allowing a better contact with the catalytic layer [2].

Currently, MPLs are mainly prepared from inks containing carbon black particles and PTFE, the latter used as a hydrophobic agent. Recently, authors demonstrated the effectiveness of replacing PTFE with fluorinated ethylene propylene (FEP) in order to improve hydrophobic properties of MPLs and consequently the water management of the whole system [3]. Moreover the use of FEP allows to reduce sintering temperature from 350 °C (for PTFE-based GDMs) down to 260 °C.

In this work different amounts of FEP were employed, both for GDL and for MPL hydrophobization, in order to identify the optimal composition for obtaining performing and durable materials. In inks preparation a fixed amount of carbon nanotubes was employed together with conventional carbon black in order to have a higher conductivity of the final components. MPLs were deposited onto GDLs and then they were together thermal treated (260 °C for 30 minutes).

Durability is still a critical issue to be faced in fuel cells field in order to have a widespread commercialization of these devices and a real competition with conventional energy generators. Thus, ex-situ chemical accelerated stress tests were developed: GDMs were prepared and then submerged into concentrated sulphuric acid in order to induce harsh chemical stress and to accelerate chemical degradation of materials. Morphological (static contact angle, SEM analysis and mercury intrusion porosimetry) and electrochemical tests were carried out on GDMs upon different times of acidic treatment, up to 1000 h. Electrochemical tests were performed in a single cell with Nafion 212, a platinum loading 0f 0.3 mg/cm^2 at the anode and 0.6 mg/cm^2 at the cathode, and an active area of 23 cm^2. The cell testing was run at two temperatures (60 °C and 80 °C) with different relative humidities (RH 80/100 and 80/60, hydrogen/air). Electrochemical Impedance Spectroscopy (EIS) was carried out using a Frequency Response Analyzer. The experimental data were analyzed and fitted using an equivalent circuit model from ZView® software.

The highest amount of FEP in GDMs allowed to get the best results in terms of maximum power density and water management since mass transfer resistances, related to diffusion limitations, were very low. Moreover a satisfying durability can be claimed since all the significant parameters related to GDM quality, such as porosity, hydrophobicity (i.e. contact angle values), ohmic and diffusion resistances, kept quasi-constant after the different ASTs, even though a general decrease of output power was observed. However, such a behaviour can be ascribed to catalytic layer degradation because a dramatic increase of activation polarization together with a decrease in exchange current density was found after ASTs.

Keywords: PEM fuel cells; micro-porous layers; durability, accelerated stress tests

References

[1] S. Park, J.W. Lee, B.N. Popov, International Journal of Hydrogen Energy, 37, 7, 2012, 5850-5865.

[2] M.B. Ji, Z.D. Wei, Energies, 2, 4, 2009, 1057-1106.

[3] S. Latorrata, P. Gallo Stampino, C. Cristiani, G. Dotelli, International Journal of Hydrogen Energy, 39, 10, 2014, 5350-5357.