Proceedings of EFC2013
Fifth European Fuel Cell Technology & Applications Conference - Piero Lunghi Conference
December 11-13, 2013, Rome, Italy

EFC13022

INNOVATIVE FLUORINATED POLYURETHANE BASED GAS DIFFUSION MEDIA FOR PEM FUEL CELLS

R. Balzarotti, S. Latorrata, P. Gallo Stampiono, C. Cristiani
and G. Dotelli
Dipartimento di Chimica, Materiali e Ingegneria Chimica "G. Natta",
Politecnico di Milano, Piazza Leonardo da Vinci 32, 20133 Milano

Abstract* – *Polytetrafluoroethilene (PTFE) is a widely used compound in the PEM-FC field, where it is usually used to make gas diffusion media (GDM) hydrophobic in order to improve electrochemical performance. Due to the polymer properties, it is necessary to work with high PTFE concentration as well as to achieve high temperature in heating processes. In order to overcome these problems, a new polymer (Fluorolink P56, a an anionic, segmented polyfluorourethane with high molecular weight) has been investigated as alternative to PTFE for both making Gas Diffusion Layer (GDL) hydrophobic and producing Micro-Porous layer (MPL). Samples were tested in a single cell in order to evaluate electrochemical properties. During test, temperature was set at 60 °C, while relative humidity (RH) was held constant at 80% on anode side and 100% on cathode side. Micro-porous layer properties were estimated by using Electrochemical Impedance Spettroscopy (EIS) of the running cell.

Index Terms* - *PEM-FC, perfluoropolyethers, Electrochemical Impedance Spectroscopy, micro-porous layer.

I. Introduction

Among the sustainable energy systems, fuel cells assume a crucial role considering their peculiar flexibility, modularity and "zero-emission" output. In particular, Polymer Electrolyte Membrane Fuel Cells (PEM-FCs) are considered one of the most promising devices due to the low operating temperature and fast start-up [1]. Water management is a well-known issue regarding PEM-FCs. Substantial performances improvement may be induced by preventing flooding both on anode and cathode side [2]. This result is achieved mainly by introducing both a macroporous gas diffusion layer (GDL) and a microporous layer (MPL), forming the so-called Gas Diffusion Medium (GDM), and by making them hydrophobic using PTFE [3]. The aim of this work was to evaluate a new diffusion medium completely based on Fluorolink® P56 (Solvay Solexis, Italy), an anionic, segmented polyfluorourethane with high molecular weight.

II. Experimental

A. Preparation of Gas Diffusion Media

An untreated carbon-cloth GDL (SCCG 5N, Seal Group) portion was dipped for 10 minutes in a Fluorolink P56/water emulsion (1%w), previously homogenized my magnetic stirring (10 minutes at 500 rpm); then it was drawn and heat-treated at 120 °C for 30 minutes to remove water and sinter the polymer.

In the procedure applied to produce GDM, the weighted quantity of carbon black (CB, Vulcan XC-72 R), wetting medium (IPA, isopropyl alcohol) and Fluorolink P56 were strongly mixed at 8000 rpm for 10 minutes by using Ultra Turrax (IKA, T25 homogenizer). The ink prepared was blade coated on the Fluorolink P56-treated GDLs, leaving a layer of the thickness needed (40 µm). The speed of the lab-scale coater (K Control Coater) was set at 153.8 mm/s, corresponding to a shear rate of about 350 s^{-1}. The samples were treated at 120 °C in order to remove the solvent and to bind the polymer.

GDM 5 and 8 share the same CB/IPA ratio (7.72 w/w) and differ in terms of Fluorolink P56 content (12% and 6% respectively). A previously produced [4] sample containing PTFE (STD PTFE) is used as term of comparison for new samples; the latter is prepared with a different procedure, as described in elsewhere [5].

B. Physical characterization

Rheological properties of slurry prepared were evaluated by using a lab-scale rheometer (Reologica Instruments AB, Stresstech 500). Dynamic viscosity was measured varying the value of the shear rate applied in the range 10^{-3} s^{-1} - 10^{3} s^{-1}.

Taking account the importance of hydrophobicity [3], static contact angle (CA) analyses were performed on each sample by using a OCA 20 Dataphysics Instrument in order to measure water repellence.

Surface properties of the samples were observed with a Stereo Zoom Microscope (Olympus SZ40).

C. Electrochemical characterization

In order to evaluate electrochemical properties, all samples were tested in a lab-scale single cell assembly where a commercially catalyst coated membrane (CCM) was used. Tests were performed using constant flow rates: 0.2 Nl/min for anodic hydrogen and 1 Nl/min for cathodic air. Polarization curves were obtained in galvanostatic conditions, from OCV to high current density (1.14 A/cm^2), with steps of 0.088 A/cm^2. Electrochemical Impedance Spectroscopy was employed to assess ohmic resistances and the different nature of voltage losses by using an equivalent circuit model [6]. For further details about the electric test refer to [4].

III. Results and Discussion

A. Physical characterization

CA values obtained for the samples before cell testing (BCT) and after cell testing (ACT-A and ACT-C for anode side and cathode side respectively) are reported in Table I.

TABLE I

INKS COMPOSITION (NOTE: ALL THE NUMBERS REFERS TO W/W RATIO)

Sample	BCT	ACT-A	ACT-C
STD PTFE	145.18 ± 4.08	145.67 ± 1.83	146.47 ± 2.30
GDM 5	148.11 ± 3.91	150.35 ± 2.31	146.45 ± 5.27
GDM 8	150.80 ± 1.80	147.14 ± 5.31	148.87 ± 2.78

All samples show nearly a super-hydrophobic behavior. The change in polymer doesn't affect hydrophobicity both before and after cell testing.

Rheological properties of the inks used are reported in Fig. 1.

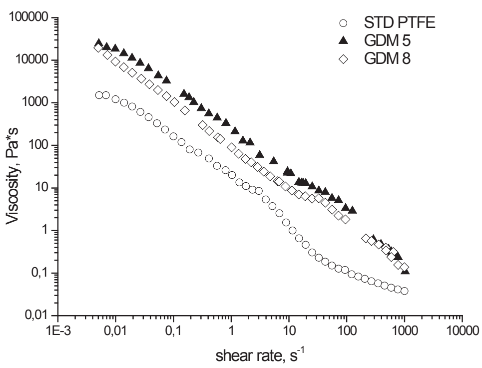

Fig. 1. Flow curves of inks used for deposition

Switching from PTFE to Fluorolink P56 the ink keeps the shear-thinning behavior and only a small increase in viscosity values can be observed. Therefore, blade coating remains a good deposition technique even for Fluorolink P56 slurries.

B. Electrochemical characterization

Results of electrochemical tests are reported in FIG. 2; the polarization curves obtained with Fluorolink P56 are similar to the one of the PTFE sample.

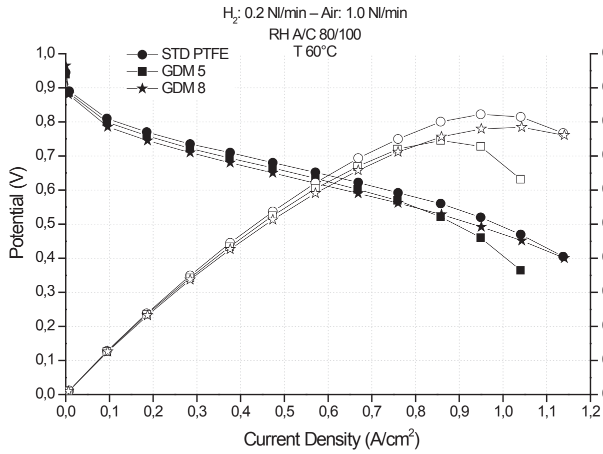

Fig. 2. Polarization curves at 60 °C and high RH condition (80-100)

Power density and polarization curve tendencies are validated by EIS analysis; for the sake of brevity, EIS analysis is not reported in this paper.

IV. Conclusion

Results obtained lead to the following conclusions:

- Fluorolink P56 doesn't affect GDM hydrophobicity;
- inks display still shear thinning and are then suitable for blade coating deposition;
- performance are comparable with PTFE;
- temperature during MPL heat-treatment decreases from 350 °C (PtFE) to 120 °C (Fluorolink P56).

References

[1] F. Barbir, Pem Fuel Cells: theory and practice, Elsevier, 2005.

[2] Weber A. Z., Newman J., Effects of micro porous layers in polymer electrolyte fuel cells, Journal of the Electrochemical Society, Volume 152, 2005, Pages 677-688.

[3] Gallo Stampino P., Cristiani C., Dotelli G., Omati L., Zampori L., Pelosato R., Guilizzoni M., Effect of different substrates, inks composition and rheology on coating deposition af microporous layer (MPL) for PEM-FCs, Volume 147S, 2009, Pages S30-S35.

[4] Latorrata S., Gallo Stampino P., Amici E., Pelosato R., Cristiani C., Dotelli G., Effect of rheology controller agent addition to Micro-Porous Layers on PEMFC performances, Solid State Ionics, Volume 216, 2012, Pages 73-77

[5] Lee E.S. et al., US patent number 2009/0011308 A1

[6] X.Z. Yuan et al., Electrochemical impedance spectroscopy in PEM fuel cells: fundamentals and applications, Springer, London, 2010.