The effect of Nafion content on DMFC electrode characteristics

A. Glüsen, M. Müller, D. Stolten
Institute of Energy and Climate Research, IEK-3
Electrochemical Process Engineering, Forschungszentrum Jülich GmbH
52425 Jülich, Germany

In this work the influence of the ionomer content in the electrodes on DMFC operation is studied. Nafion content in the anode can be used to control permeation of methanol and water, whereas Nafion content in the cathode can be used to improve tolerance towards low air stoichiometry and operation with humidified air.

Introduction

Fuel cell electrodes have a very complex structure. All reactive sites need to have an electron conductive connection to the gas diffusion electrode as well as a proton conductive connection to the membrane. Furthermore reactants must be able to reach the reactive sites through pores in the structure. The Nafion content is a key parameter to control transport properties. While a higher Nafion content improves proton conductivity it may reduce electron conductivity or block pores, so that access of reactants is limited.

Experimental details

CCMs were fabricated by the decal transfer process in order to avoid changes of the gas diffusion layer during the wet-coating process. Carbon supported catalysts by Johnson Matthey (anode: HiSpec 12100, cathode: HiSpec 9100) and an aqueous Nafion solution by DuPont (DE1021) were used to make an ink by ultrasonic dispersion. When comparing carbon-supported catalysts with different Platinum loading it was found that the optimum Nafion content was different, while the optimum Nafion to carbon ratio was equal. The weight of Nafion in the catalyst layer divided by the weight of carbon in the catalyst layer was defined as the Nafion to carbon ratio and was used to describe the Nafion content in a catalyst layer. MEAs were characterized in a purpose-built test-rig which allowed studying the effect of humidified air at the cathode. Measurements were performed at 70°C with 0.5 molar methanol solution at ambient pressure

Results

The effect of the Nafion content in electrodes must be distinguished between Nafion content in the anode and Nafion content in the cathode.

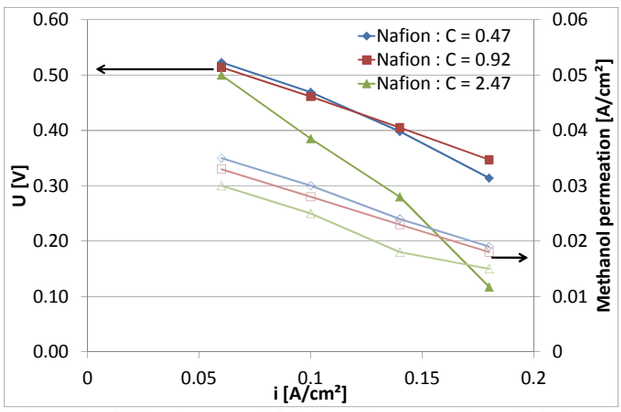

Figure 1: Cell voltage and Methanol permeation of MEAs with different anodic Nafion content. 10 ml/cm²min air

In the anode the Nafion content has a significant influence on permeation of water and methanol through the MEA as well as on the cell voltage. Generally in the range of Nafion to carbon ratios from 0.41 to 2.47 studied in this work it was found that cell voltage generally increased with decreasing Nafion content. Permeation of Methanol and water also increased with decreasing Nafion content. This in turn may lead to a reduced cell voltage when the cell is operated with low air stoichiometry, because excess water may block oxygen from reaching the cathode catalyst and high methanol permeation. This becomes evident in Figure 1. At lower current densities cell voltage is highest for the anode with Nafion to carbon ration 0.47 and at higher current densities cell voltage is highest for the anode with 20% Nafion to carbon ration 0.92.

For the Nafion content in the cathode it was shown that higher Nafion contents can be connected to reduced porosity and therefore can lead to mass transport problems. [1]

The experience gained in this work was used to study, how the optimum Nafion content in DMFC cathodes changes as a function of operating conditions. For a simplified DMFC system water from the cathode exhaust can be transferred to the cathode inlet through a membrane. This requires an MEA which can be operated with humidified air. Therefore experiments were made with air which was saturated with water to a dew-point of 57°C.

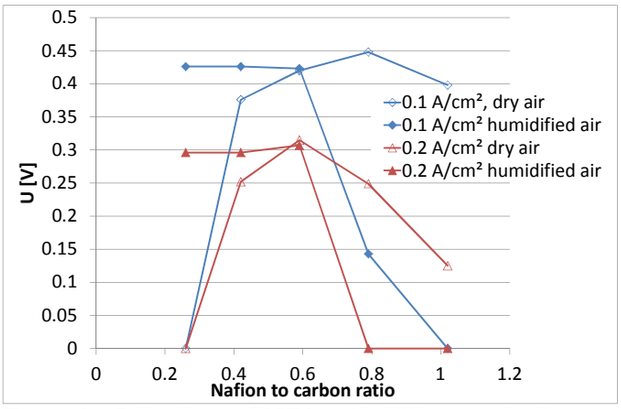

Figure 2: Cell voltage of MEAs with different cathodic Nafion to carbon ratio. 36 ml/cm²min air

It could be shown that for humidified air the highest cell voltage was obtained when the Nafion to carbon ratio of the cathode was 0.2-0.6, whereas for dry air, the highest cell voltage was obtained when the Nafion to carbon ratio of the cathode was 0.6-0.8 (see Figure 2).

Conclusions

The Nafion content in DMFC electrodes can be used to fine-tune MEA-properties in order to adjust the MEA for specific operation requirements. In the anode a balance has to be found in order to limit methanol permeation as far as possible without compromising cell voltage.

In the cathode electrodes can be optimized for operation with humidified air by reducing the Nafion content compared to electrodes optimized for operation with dry air.

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[1] A. Glüsen, M. Müller, D. Stolten „Influence of Nafion content on structure and performance of DMFC cathodes“ Poster presented at GDCh Electrochemistry 2012, Munich, September 17-19, 2012