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Self-supporting Microporous Layers (MPLs) for PEM fuel cells

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The main requirements of a gas diffusion layer (GDL) of polymer electrolyte membrane fuel cells (PEMFC) are the provision of a gas and water transport as well as a significant electrical and thermal conductivity. The development of membrane electrode assemblies (MEA) for a wide temperature range (-20°C until +130°C) still favours membranes that require a certain level of humidification for sufficient proton conductivity. The PEMFC diffusion media and their influence on water management is of crucial importance for these conditions, however, the detailed structure relations and especially the influence of the micro porous layer (MPL) needs further investigation. An important function of the cathode side MPL at high temperature operation of PEMFCs is the prevention of membrane drying. However, a flooding of porous structures in the GDL or catalyst layers at lower temperatures has to be avoided under all operation conditions.

To get an insight that could lead to an improved GDL design for a broad range of operating conditions, a self-supporting MPL was developed, because this allows the manufacturing and the following treatments of the MPL independent from the GDL substrate. This MPL consists of a thin nonwoven synthetics coated on one side with a mixture of carbon and PTFE produced with the dry spraying technology [1].

For in-situ experiments and some ex-situ measurements these layers are pressed with the non coated side on a commercial GDL without MPL (Sigracet® GDL25BA from SGL). To get a correlation of fuel cell performance to the global intrinsic properties of the MPL, like through-plane permeability, electrical conductivity or hydrophobicity, U_{cell}(i)-curves up to limiting current densities and electrochemical impedance spectra (EIS) are measured in a 5 cm² fuel cell setup. Figure 1 shows computer tomography images of the relevant components, in particular the GDL substrate, a nonwoven synthetics for mechanical support of the MPL and the completed MPL with nanometer primary particles. Figure 2 shows dependencies of limiting current densities and power densities on the composition of the MPL. Parameters that were varied are the hydrophobicity (PTFE content) and thickness of the MPL. The transport parameter were derived from EIS in an usual analysis with equivalent circuits. Important parameters with high significance for performance were found to be the electronical conductivity and hydrophobicity of the MPL. As expected the relevant properties of the MPL involve conflicting goals and requirements and a high-performance is a compromise between them.

A high PTFE content of in-house MPLs is found to be disadvantageous for the electrical conductivity and the gas permeability of the MEA at the same time. On the other hand, a low PTFE content and a high thickness of in-house MPLs decreases the ohmic resistance but high humidity constricts the gas transport.

Interestingly, the commercial GDL/MPL systems investigated were found to be a good compromising solution for providing the required permeability, electronic conductivity and hydrophobicity.

To obtain information about the influence of MPL structure on water distribution, synchrotron X-ray radiography studies were performed additionally. In such studies the importance of liquid water pathways through the porous structure for the water management is proven [2]. With artificial paths in a carbon fibre GDL produced by laser perforation an overall performance gain has been obtained [3]. With self-supporting MPLs it was feasible to investigate the liquid water transport of nonperforated GDL/MPLs compared to the perforation of both layers as well as to the exclusive perforation of MPL and the GDL, by means of in-situ synchrotron imaging.

References:
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[2] H. Markötter et al., Electrochemistry Communications 13 (2011) 1001.
[3] D. Gerteisen et al., Journal of Power Sources 177 (2008) 348.

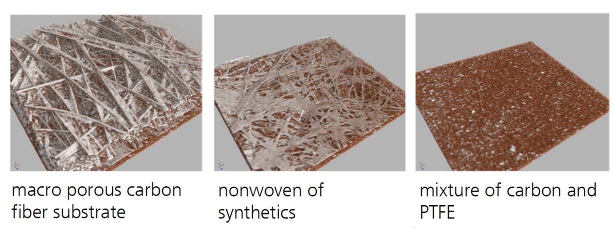

Fig. 1: 3D micrograph visualization of in-house GDL by computer tomography

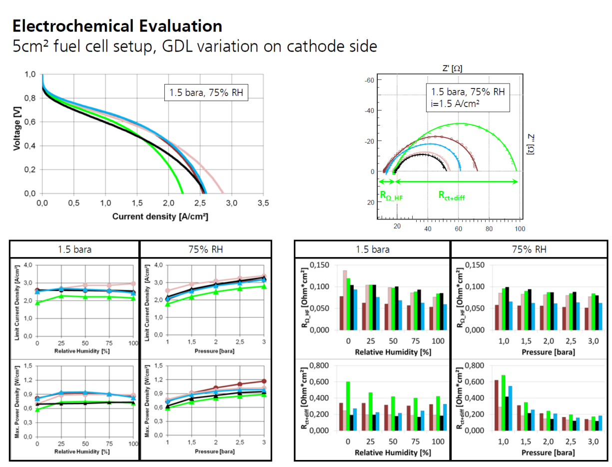

Fig. 2: Example of electrochemical evaluation of different MPLs according to the following colour code:

Commercial GDLs from SGL Carbon			In-house GDLs			
	name			name	MPL-PTFE content	MPL thickness
	GDL25BC			P40	40 wt.-%	40 µm
				P20	20 wt.-%	40 µm
	GDL25BA	GDL without MPL		P20D	20 wt.-%	80 µm