Proceedings of the Second European Fuel Cell Technology and Applications Conference
EFC2007
December 11-14, 2007, Rome, Italy

EFC2007-39047

MECHANICAL INTERACTIONS BETWEEN GAS DIFFUSION LAYERS AND BIPOLAR PLATES IN LOW TEMPERATURE FUEL CELLS

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INTRODUCTION

In low temperature fuel cells the reaction and product gases have to be transported along the channels of the bipolar plates and through the porous structures of the gas diffusion layers (GDL). In general, all components of a fuel cell are optimized independently from each other, whereby the interactions between them are frequently neglected. The function of both, bipolar plate and gas diffusion layer, is to distribute and to collect gases and liquids on different geometrical scales. Therefore, the interaction and the matching of both components are vitally important for the performance of fuel cells.

EXPERIMENTAL SET-UP

At the DLR it was started to investigate the interactions between the GDL and the flow field. For this purpose, the work was focused on the mechanical effects of the compression of the gas diffusion layers and their impression into the channels of the flow field. Thereby, the impression of the GDL into the flow field channels as a function of the mounting/contact pressure was determined by three different methods:

- Optically by inspection with a microscope,
- Electronically by measuring the change of the capacitance upon the contact pressure and
- Mechanically by measuring the pressure drop.

OPTICAL MEASUREMENT OF THE IMPRESSION

For the optical measurement of the GDL impression into the channels of a gas distributor, the GDL was positioned on a flow field structure, which has parallel channels up to the end of the plate. The impression depth as a function of the mounting pressure is measured at the face side of the GDL. The optical microscopy gives information about the maximum and the average depth of impression as well as the compression of the GDL over the ribs. A problem of this technique is, that the impression depth can be optically determined only at the face side of the GDL. Hence, compressive forces parallel to the direction of the channel may be not the same as at a position in the middle of the GDL. In addition, a local inhomogeneity of the compressibility of the GDL at the edge may be induced by cutting. Hence, it is not sure, if these results are representative for the total area of the GDL.

ELECTRICAL MEASUREMENT OF THE IMPRESSION

For the interactions between the GDL and the flow field the average impression depth is important. To this end, at DLR an experimental set-up was developed, that consists of a copper plate with spark-eroded channels, ridges of acrylic glass therein and the gas diffusion layer on the ribs. This configuration acts as a parallel circuit of different capacities in which the distance between the electrodes varies by the impression of the gas diffusion layer into the channels (Fig. 1). Hence, the depth of impression of the GDL can be determined by measuring the change of the electrical capacity, if the material is pressed into the channel structures.

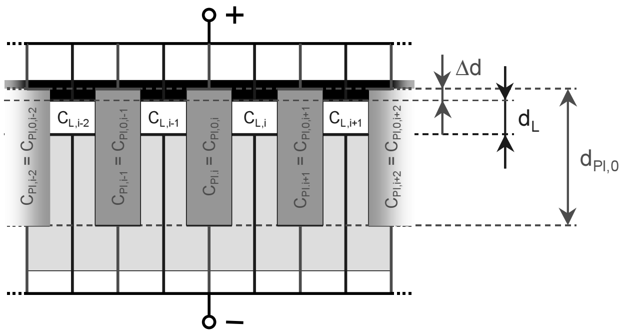

Fig. 1: Equivalent circuit diagram for a deformed backing material in the measurement set-up for the electronical determination of the depth of impression

ELECTROCHEMICAL CHARACTERIZATION

The influence of the backing materials' compression on the electrochemical performance was investigated by measuring the generated current density at a cell potential of 500 mV and the corresponding current density distributions. The equipment for this measurement technique is described in detail in ref. [1]. In this set-up a segmented flow field with a chocolate wafer structure was used on the anode side in order to analyze the current locally resolved. On the cathode side the gas distributor had a serpentine flow field design with vertical channels. The influence of the rib width was studied by measurement of flow fields with rib widths of 0.5, 1.0 and 2.0 mm, and constant width and height of the channels of 1.0 mm.

RESULTS AND DISCUSSION

Hard and soft backing materials were investigated with the methods described above. Thereby, it was observed that the thickness and the shape of the hard GDL material (Toray paper) remains nearly constant when the PEFC is assembled. In contrast, a softer one (E-TEK single sided V2) is impressed into the channels of the gas distributor and compressed over the ribs (Fig. 2). For higher contact pressures the backing thickness seems to approach asymptotically to a lower limit. The minimum value of 0.13 mm corresponds to the total elimination of the complete porosity of the impregnated carbon cloth. As it can be seen in Fig. 3, the maximum depth of impression is correlated to the compression over the ribs: In the middle of the channel the carbon cloth is almost uncompressed. The higher the impression depth, the lower is the backing thickness over the ribs. Consequently, the porosity of the GDL declines from the center of the channel to the area above the ridges, which leads to a continuous increase of the diffusion resistance from the channel to the rib. At a contact pressure of 300 Nm/mm^2 e.g. the average porosity is reduced of at least 30 %.

As a consequence of the changing pressure conditions the compression of the GDL also influences the electrical properties and the performance of the fuel cell. At a constant cell voltage of 500 mV an increasing pressure initially causes an increase in the generated current (Fig. 4). This behavior is a consequence of the reduction of the contact resistance between the GDL and the flow field. A further increase of the pressure leads to a decline of the current density, because the corresponding reduction of the porosity hinders the mass transfer in the GDL more and more. The influence of the porosity on the gas supply in the area over the ribs is reflected in the pressure dependency of the maximum current density. At higher rib widths higher porosity and accordingly lower contact pressures are needed.

In addition, the contact pressure effects not only the global current generation but also its local distribution. For low contact pressures the current density distribution show the highest values on a direct line from the gas inlet to the outlet, which indicates a bypass of the channels by the backing (Fig. 4a.). In contrast, higher contact pressures reduce the current density distribution as a whole, because of the increasing diffusion resistance (Fig. 4c.).

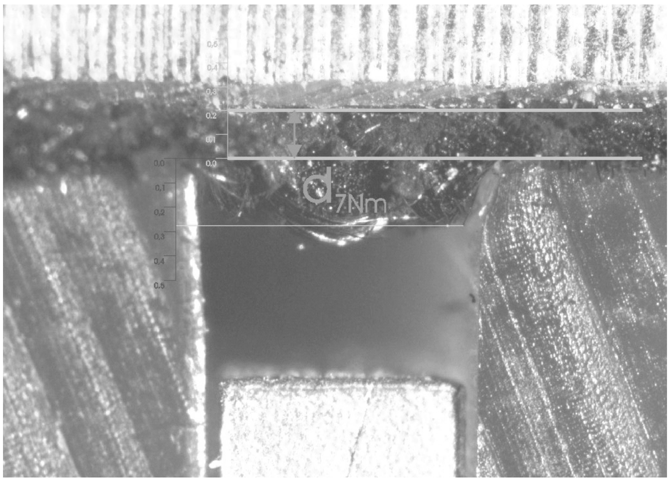

Fig. 2: Photograph of the impression of a soft GDL (E-TEK carbon cloth V2) into a gas channel under high pressure

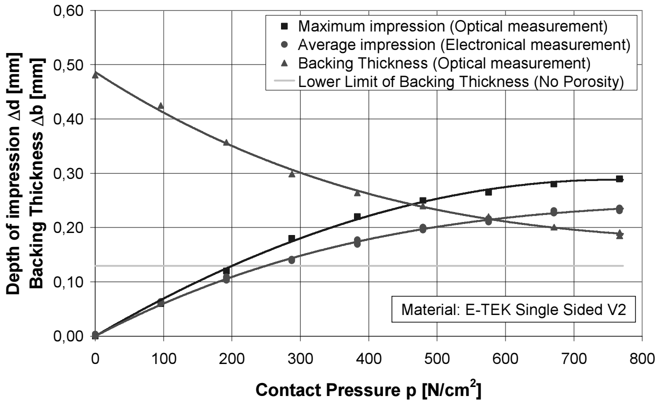

Fig. 3: Impression of the GDL into the flow field channels as a function of the contact pressure measured by electrical and optical methods (Rib width/channel height: 1.0 mm)

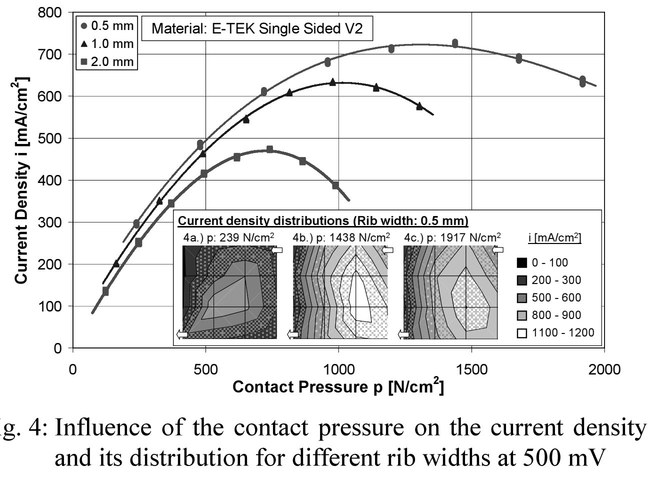

Fig. 4: Influence of the contact pressure on the current density and its distribution for different rib widths at 500 mV

REFERENCES

[1] Gülzow, E.; Kaz, T.; Reißner, R.; Sander, H.; Schilling, L., Bradke, M. v.; J. Power Sources, 105 (2002) 261