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INVESTIGATION AND ASSESSMENT OF BASIC FLOW FIELD DESIGNS FOR THE CATHODIC GAS SUPPLY IN LOW TEMPERATURE FUEL CELLS

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INTRODUCTION

One of the main problems in the commercialization of polymer electrolyte membrane fuel cells (PEFCs) are the specific costs. Beside the reduction of the costs for the components and for assembling cells, costs can be reduced by increasing the performance. For this purpose, the major challenges in the development of PEFCs is to exploit the maximum potential that inheres a given membrane electrode assembly. An important factor, which determines the performance of polymer electrolyte fuel cells, is the mass transfer of the reactant gases and the vaporous or liquid water inside the cells. Consequently, the flow field structure has a significant influence on the performance, which can be maximised by optimising the flow field design with regard to the intended operating point.

EXPERIMENTAL

As a prerequisite for such an optimization, the electrochemical performance of PEFCs with various cathodic flow fields (parallel, serpentine, spiral and interdigitated channels) has been investigated. In addition, the influence of the rib width was studied by utilising each structure with rib widths of 0.5, 1.0 and 2.0 mm. In doing so, the width and the height of the channels remained constant at 1.0 mm.

The investigations of these gas distributor structures were performed in segmented laboratory cells (single cells) with an active area of 5.0 x 5.0 cm^2 by measuring overall polarization curves and local current density distributions. On the anode side a segmented flow field with a chocolate wafer structure was used in order to analyze the generated current locally resolved. A detailed description of the equipment used for the current density measurement is given in ref. [1].

As electrodes commercial ELAT electrodes from E-TEK were used. These electrodes have a platinum loading of 0.4 mg/cm^2 and a NAFION loading of 0.6-0.8 mg/cm^2. The membrane electrode assemblies contain a V2 gas diffusion layer consisting of a carbon cloth and a hydrophobic layer, which were hot pressed together with a NAFION 1135 membrane.

RESULTS AND DISCUSSION

Polarization curves for the different flow field types with various rib widths were measured at different operating conditions. A variation of the hydrogen flow rate shows no significant influence on the V-i characteristic, with exception of high current densities, at which the hydrogen is almost completely consumed. Exemplary, in figure 1 a selection of the measured polarization curves for a hydrogen flow rate of 4.0 cm^3/s and air flow rates of 6.67, 13.33 and 33.33 cm^3/s is displayed for the interdigitated gas distributor structure.

In order to obtain an approximate V-i behavior for the free and the covered areas of the electrode and to elucidate the corresponding tendencies the following extrapolation was performed: For each flow field design, polarization curves were measured for different rib widths (0.5, 1.0 and 2.0 mm). The average current densities at each potential were plotted versus the ratio of the area over the channels to the total area of the MEA. Then a best fit straight line was calculated and current density values for a completely free (100 %) and totally covered (0 %) area were extrapolated. In this way, hypothetical polarization curves for a total area over the channels (free area) and for a flow field with a completely covered area were determined. By plotting these V-i characteristics as a function of the air flow rate an assumed activity of the different parts of the electrode was derived.

At low current densities, for all flow field types – excluding the one with parallel channels – the areas over the channels have the same activity like the areas over the ribs. For higher current densities the current density in the covered area saturates, whereas the current density in the free area over the chan-

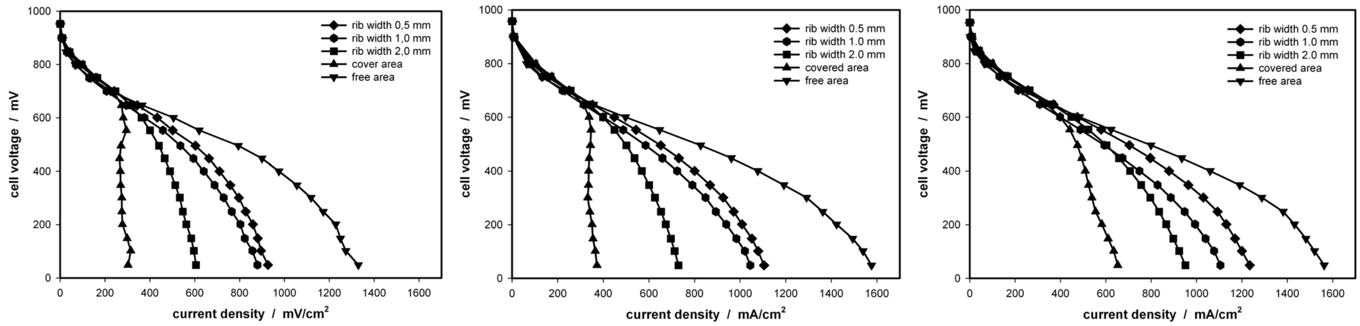

Fig 1: V-i characteristics for a gas distributor structure with an interdigitated flow field design with various rib width and for various gas flow rates operated with hydrogen and air (Hydrogen flow rate: 4.0 cm^3/s, air flow rates: 6.7, 13.3 and 33.3 cm^3/s)

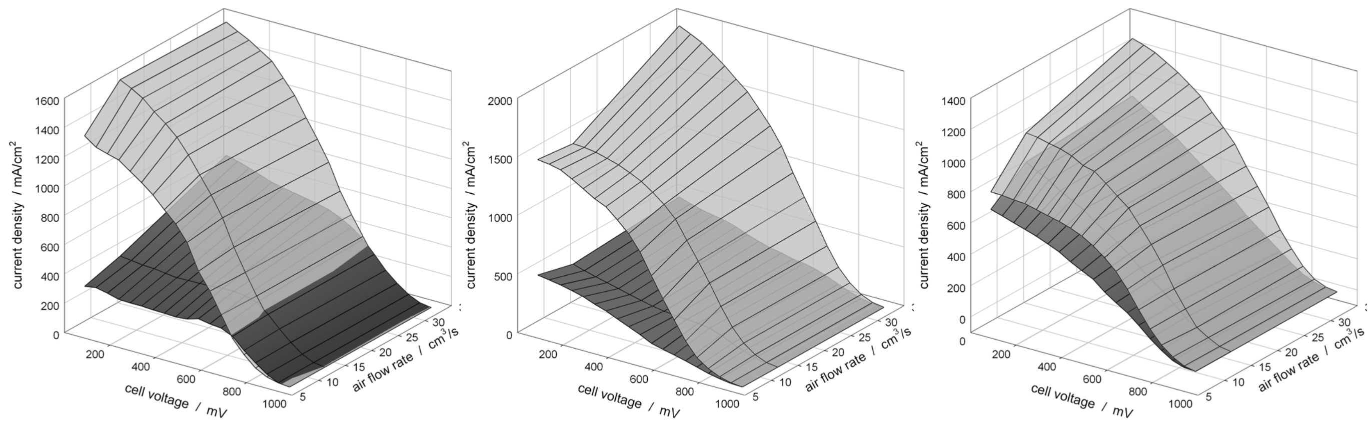

Fig 2: Extrapolated current densities over channels (bright) and ribs (dark) as a function of the air flow rate (Flow fields from the left to the right: interdigitated, serpentine and spiral)

nels increases. Hence, at high current densities the free area has a significantly higher activity than the covered area, which can be explained by a hindered mass transfer in the covered regions. For the interdigitated flow field the difference in the activity of the covered area and the free area decreases slightly with increasing air flow rate. The difference in the performance for the free and the covered area has the least difference for the spiral flow field. For the other types the differences increase. In contrast, for the flow field with parallel ribs the covered area has a higher activity than the free area.

For the extrapolated performances of the "free" and the "covered" surfaces the performance is displayed for the different flow field types as a function of the air flow (Fig. 2). For the interdigitated one the activity on the free area does not vary significantly with the air flow, but the activity of the covered area increases with increasing flow rate. For the serpentine and the spiral flow field the performance of the covered areas shows no significant dependency on the flow rate; in contrast the performance of the free areas increases with the gas throughput.

CONCLUSIONS

The optimum gas distributor structure strongly depends on the particular operating point. Consequently, each basic structure has to be adapted for the intended operating conditions. For example, a serpentine flow field generates the highest current densities for high air fluxes, whereas an interdigitated structure is preferred for small flow rates. In the same way, it can be shown that a spiral structure produces the most uniform current density distributions, whereas the current density distribution of a flow field with parallel channels is extremely inhomogeneous and becomes unsteady for higher water generation rates.

The variation of the rib width shows, that all areas with a high catalytic activity are situated directly over the gas channels. In contrast, the covered areas represent only a small fraction of the overall performance, whereby the general tendency is independent of the basic structure of the flow field.

REFERENCES

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