Fractal Flow Fields: A New Design of Gas Flow Channels in Polymer Electrolyte Fuel Cells

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Introduction

Design of gas flow channels is a crucial factor that determines the overall performance of polymer electrolyte fuel cells PEFCs). Conventional design is the serpentine flow field where the anode or the cathode gas flows through a zigzag patterned groove machined on the surface of carbon plate [1]. The problem of this design is that under the rib the gas distribution is low and also water flooding tends to occur at high current density.

Recently, T. V. Nguyen et al. developed a new design of flow field where a pair of comb like groves, inlet and outlet channels, are carved on serarator carbon meterilas [2]. This design has an advantage of realizing a forced gas flow from one channel to the other, effective removal of generated water and so on.

In this work we report a new flow field that can eliminate the flow channel groove in the separator, make it into a mere thin sheet and thus improve drastically the volume and weight power density of the PEFC system. This design is called fractal flow field, because it is based on the repetitive patterns of same geometric form, subdivided into smaller ones, as shown in Fig. 1.

Experimental

The triangular pattern is tested for the pressure drop measurement using a carbon paper sheet (TORAY TGP-H-120, 0.35 mm thick, 76% porosity) through which oxygen gas is flown from one apex to the opposite base. The gas flow was controlled and pressure measured with a mass flow controller (MKS Instruments, Type M100B and Type 223).

The size of the triangular pattern is optimized by measuring the current density for several sizes of single cell with MEA made of Nafion 112 membrane, 50 wt% Pt/C catalyst (Tanaka Kikinzoku Kogyo K.K., TEC10E 50E, 0.3 mg Pt cm^{-2}) and TORAY carbon paper. At the same time, the heat generated from the cathode side end plate (Au foil as a current collector put on an acrylic resin block) was measured by a thermo-tracer (NEC TH5104) through a MgF_2 window.

Power measurement with single cell was performed for 1.76×1.76 cm cell with fractal flow field at 50 °C. H_2 and O_2 gas were flown at 70% ad 40% utilization rate, humidified with 60 °C gas bubblers. The polarization curves were measured also for the serpentine type cell with 5 cm^2 area to compare the performance.

Results and discussion

The pressure drop experiment showed a linear dependence on the gas flow rate. Most of the pressure drop was distributed around the apex, and a larger opening of the gas inlet was effective in reducing the pressure drop.

Polarization curves for single cells of various electrode area are measured at 25 °C. The results show that the best value of power density at 0.6 V was attained around 0.08 W cm^{-2} with a size of 1.76×1.76 cm cell, and this value decreased to about half for 5.0×5.0 cm cell. This is because of the un-uniform gas flow pattern for larger cell sizes. The thermograph also supported the results, and non-uniform heat generation on the end plate was observed for cells larger than 2×2 cm size.

The single cell experiments resulted in a power of 0.11 W cm^{-2} for the fractal flow field and 0.12 W cm^{-2} for the serpentine flow field per electrode area. However, when the performance was expressed as volume power density, it was calculated to be 820 W dm^{-3} for fractal flow field in comparison with 500 W dm^{-3} for serpentine flow field, because in the former case the separator can be made thinner (0.5 mm) than in the latter case (2 mm).

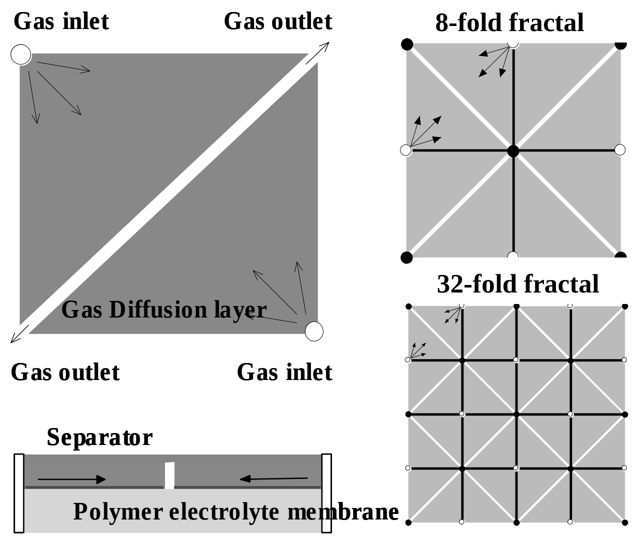

Fig. 1 Fractal flow field for triangular patterns. Each of the anode and the cathode gas diffusion layer has the same patterns, but oriented in perpendicular position.

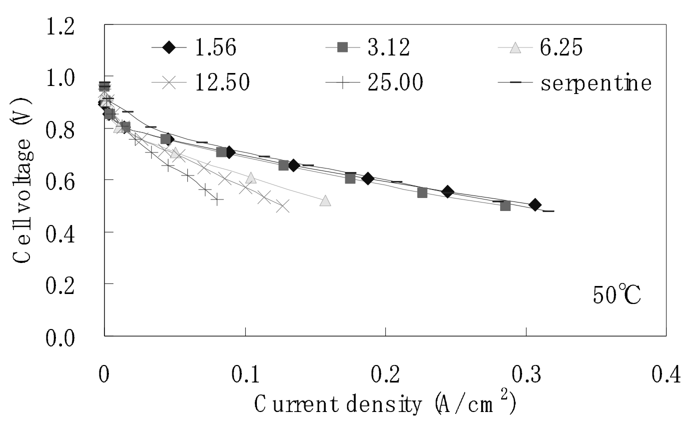

Fig. 2 Polarization curves of single cells measured at 50 °C with various kinds of configurations for fractal flow fields. The numbers are the electrode area (cm^2). The serpentine flow field type is of the 5 cm^2 cell.

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References

1. V. Vielstich, A. Lamm, and H. Gasteiger (Eds.), Handbook of Fuel Cell Technology, John Wiley & Sons, England, 2003, Vol. III, Chap. 27-28.
2. W. He, J. S. Yi, and T. V. Nguyen, *AIChE Journal*, 46, 2053 (2000).