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Effects of the porous structures in the porous flow field type separators on fuel cell performances

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ABSTRACT

Effects of separators' several different porous flow field structures consist of spherical alloy powders on the pressure loss characteristics and the single-cell performances were investigated for the purpose of achieving the porous structure which can satisfy the conflicting properties of lower pressure loss and higher power density. Although the separator with partitions in the porous flow field, aimed at improving the uniform oxygen supply ability, indicated higher power density, its pressure loss increased compared to the basic porous flow field type separator. The separator with evenly spaced linear grooves in the porous flow field lowered its pressure loss, however, the maximum power density decreased. On the other hand, the newly designed separator with finely dispersed open space networks in the porous flow field demonstrated lower pressure loss and higher power density; i.e., 50% lower pressure loss and 40% higher power density were obtained compared to the basic porous flow field type separator.

Introduction

The development of fuel cells, having great potential as a clean, environmentally friendly, and highly efficient future power source, is expected in a wide range of applications such as mobile devices, portable power supplies, small movable bodies, household generators, and automobiles [1]. A key challenge for their widespread commercialization is to make them cost effective. In particular, the development of the separators which enhance power density is strongly required [2,3], contributing to the cost reduction of fuel cell systems by reducing the usage of components such as proton exchange membranes (PEM), expensive Pt catalysts, gas diffusion layers (GDLs), sealing gaskets, and separators.

Conventional graphite separators with the groove type flow field are the current benchmark [2,3], however, difficulties in reducing their thickness due to their brittleness and expensive machining process applied for fabricating grooves are making formidable barriers to the widespread applications. The graphite polymer composite separators with improved toughness have been focused as well because their grooves can be prepared by costly effective stamping process instead of machining, however, their inferior electric conductivities due to polymers included increase their internal resistance and deteriorate power density [4]. In the meantime,

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the metallic separators using stainless steel have been extensively studied because of their excellent toughness, stamping formability, and high electric conductivity. Nevertheless, the interfacial contact resistances (ICRs) between ribs and GDLs are larger compared to the conventional graphite separators due to their passive oxide films formed on the surface of stainless steels, resulting in inferior cell performances. Therefore, the electric conductive coatings such as gold, carbon, and nitrides are examined to obtain lower ICR [5–10], however, they adversely increase manufacturing costs as well as degrading local corrosion resistances caused by the defects like pin holes in the coating layers.

In order to overcome these challenges, we have reported on the fuel cell separators applying the porous flow field consists of sintered spherical corrosion-resistant alloy powders, in which the interspaces between sintered powders are used for feeding oxygen/air and hydrogen as well as draining generated water [11,12]. In addition, sintered alloy powders are utilized as the electron paths corresponding to the ribs in the conventional separators; i.e., the outer surface of the porous flow field directly contacts with porous GDL made from carbon fibers. This contact mechanism between two porous bodies enables three-dimensional contact in a large area, totally different from the conventional groove type flow field separators, and lower ICR improving cell performance can be obtained without any conductive coatings. In fact, extensively increased power densities were demonstrated in our previous research by use of this developed porous flow field type separator, in both direct methanol fuel cell (DMFC) and proton exchange membrane fuel cell (PEMFC) [11,12].

The most important challenge of this powder porous flow field separator for its practical use is to satisfy the conflicting properties of lower pressure loss and higher power density. If pressure loss is large, expensive auxiliary machineries such as costly pumping device etc. are required. Various studies have been conducted regarding the optimization of conventional groove-type flow field design in order to improve those properties [13–21]. In this study, the enhancement of porous flow fields are focused and several porous flow field structures were examined for the purpose of decreasing pressure loss and simultaneously achieving higher power densities.

Experimental

Preparation of the porous flow field type separators

Fig. 1 shows the metal separators with different porous flow fields consist of spherical alloy powders and the conventional groove type graphite separator examined in this study. In the preparation of all porous flow field type separators, firstly, highly corrosion-resistant Ni-base alloy (Ni–16Cr–16Mo–5Fe–4W mass%) spherical powders and corrosion-resistant stainless steel (Fe–17Cr–12Ni–2Mo mass %) powders were produced by nitrogen gas atomization, and they were used to fabricate porous flow fields in the separator plates. Corrosion-resistant stainless steel (Fe–17Cr–12Ni–2Mo mass%) was selected as materials of separator plates in all the tests.

In preparing basic porous flow field type Separator-A-base shown in Fig. 1(a), Ni-base alloy (Ni–16Cr–16Mo–5Fe–4W mass%) spherical powders of 210–297 μm particle size were filled densely into a recessed portion, with 0.5 mm depth and 25 cm^2 area (5 cm × 5 cm),

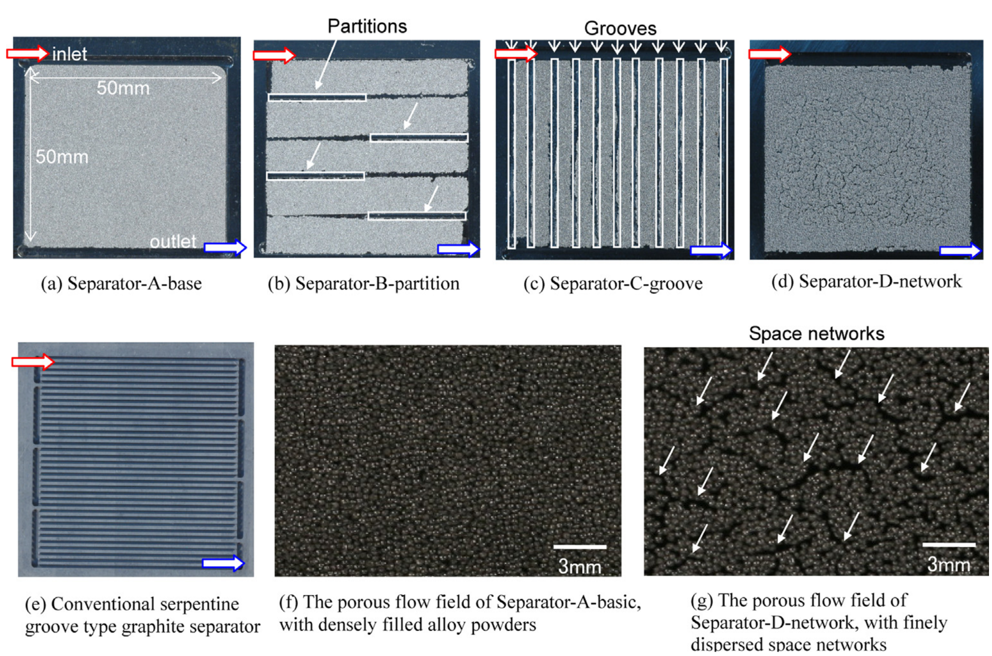

Fig. 1 – Appearances of tested powder porous flow field type separators, (a) Separator-A-base, (b) Separator-B-partition, (c) Separator-C-groove, (d) Separator-D-network, and (e) Conventional serpentine groove type graphite separator, and magnified photographs of porous flow fields in regards to (f) Separator-A-base and (g) Separator-D-network. Inlet and outlet of air in separators are indicated by bold arrows in (a), (b), (c), (d), and (e). Thin arrows in (b), (c), and (g) show partitions, grooves, and space networks, respectively.