DEVELOPMENT OF SELF-SUPPORTING AIR ELECTRODE SOFC

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ABSTRACT

We are studying a self-supporting SOFC using the spray coating method, etc.
A high-performance self-supporting air electrode has successfully been produced by the extrusion-sintering method, and a cell with its electrolyte and fuel electrode manufactured by the plasma spray coating method on the air electrode proved to have good performance. The maximum output density of a single cell is 0.31W/cm².
Furthermore, we are developing a FGM (Functionally Gradient Material) film as the fuel electrode produced by the plasma spray coating method.

INTRODUCTION

Much is expected of SOFC as a high-efficiency and clean energy system. Fujikura Ltd. is studying the manufacture of SOFC by the spray coating method, etc, in order to improve the cell performance(1,2,3,4). We are developing a cell with high performance and long life. The air electrode, as its support, is produced by the extrusion-sintering process, while the electrolyte, fuel electrode and interconnection are produced by the spray coating method. The maximum output density is 0.31W/cm². In this paper, we will report on the study of electrodes and cell characteristics.

DEVELOPMENT OF COMPONENT ELEMENTS

Air electrode

The manufacture of a self-supporting air electrode by using the extrusion-sintering process enabling mass production at low cost is being studied.
The support made of La(Sr)MnOx is manufactured by extruding, drying and firing as shown in Fig. 1. In order to evaluate the support, porosity, compressive strength and cathodic overpotential are measured and a spray coating test is performed.

The relationship between porosity and compressive strength for materials with different powder sizes is shown in Fig. 2. As is evident from the relationship between them, the strength of the support depends on the porosity. It is confirmed that the support endures the low-pressure plasma spray coating test if its compressive strength is over about 2100 kg/cm². The result of overpotential measurement is shown in Fig. 3. As one can see from Fig. 3, as compared with the air electrode manufactured by spray coating, overpotential at a current density 300 mA/cm² is reduced by 80-90% and the point of current density carried out the increase at overpotential due to gas diffusion is shifted to the high-current density side. The reduction in overpotential can be attributed to the increased effective reacting area and improved gas permeability of the support.

Fuel electrode

Ni/YSZ cermet is generally used for the fuel electrode. However, because of the operating temperature (approximately 1000 °C) of SOFC, it is necessary to pay attention to matching the thermal expansion with the electrolyte, and to take preventive measures against the sintering of Ni. As for the matching of the thermal expansion with the electrolyte and high electrical conductivity, a gradient electrode of Ni/YSZ cermet composition in the direction of thickness, which consists of a YSZ rich layer at the electrolyte/electrode interface and a Ni rich layer at the surface, that is a FGM electrode, is being studied. As a preventive measure against Ni sintering, powders with improved surface quality, etc, are being studied. Here we will report the FGM electrode manufactured by atmospheric pressure plasma spray coating.

In order to confirm the gradient of YSZ and Ni ratio, EPMA of the FGM electrode is performed. To evaluate the match of the thermal expansion of the FGM electrode with YSZ, the heat cycle test (temperature rise/fall rate: 100 °C/h, holding temperature and time: 1000 °C for 1 h) is performed. The result of EPMA is shown in Fig. 4. It shows that the YSZ content in the FGM electrode is reduced and Ni content is increased as one moves away from the YSZ electrolyte. Furthermore, a SEM photograph of the FGM electrode/YSZ interface after performing heat cycle test is shown in Fig. 5. No exfoliation is observed at the interface. From the result of the heat cycle test, it is obvious the FGM electrode excels in matching the thermal expansion.

CELL CHARACTERISTICS

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The cell is composed of thin films coated on the self-supporting air electrode. YSZ electrolyte is deposited on the self-supporting air electrode by the low-pressure plasma spray coating method. The fuel electrode is porous Ni/YSZ cermet produced by the atmospheric pressure plasma spray coating method. Table I shows the component elements, materials and the fabrication method.

The result of initial I-V & I-W characteristics is shown in Fig.6. Table II shows the shape and size (effective area) of the cell tested in Fig.6. It shows that the maximum power density of 0.31W/cm² is obtained. Compared with the all-spray coating type cell (spray coating air electrode type), the self-supporting air electrode type cell has an open circuit voltage improved from 0.85V to 0.95V, the short-circuit current density from 400mA/cm² to 800mA/cm², and the maximum power density will be attributed to the following items.

1. Because using the air electrode as the support upgrades the porosity and makes the pore size uniform, the effective reaction area is increased and the gas permeability is improved, and overpotential is reduced.

2. The ohmic loss of YSZ is reduced by approximately 40% by making the YSZ electrolyte thinner (from approximately 250 μm to 150 μm).

CONCLUSION

A single cell performance with a maximum power density of 0.31W/cm² was obtained. In order to improve the open circuit voltage and to ensure a longer life, we are determined to make a study of denser YSZ films and long term stability of the fuel electrode.

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Table. I  Cell Components, Materials and Fabrication Processes

| Component     | Material     | Fabrication Process                        |
|---------------|--------------|--------------------------------------------|
| Air electrode | La(Sr)MnOx  | Extrusion-sintering                        |
| Electrolyte   | 8YSZ         | Low pressure plasma spray coating          |
| Fuel electrode| Ni/YSZ       | Atmospheric pressure plasma spray coating  |

Table. II  Cell Shape and Size

| Shape | Size  |
|-------|-------|
| Tubular | 4cm²  |
Fig. 1  Process flow for Self-supporting cathode

Fig. 2  Relationship between porosity and compressive strength
Fig. 3 Overpotential of cathode

Fig. 4 EPMA of electrolyte/FGM fuel electrode interface
Fig. 5  SEM of electrolyte/FGM fuel electrode interface

Fig. 6  I-V & I-W characteristic of Self-supporting cathode type SOFC