Honeycomb-type Solid Oxide Fuel Cells Using $La_{0.9}Sr_{0.1}Ga_{0.8}Mg_{0.2}O_3$ Electrolyte

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$La_{0.9}Sr_{0.1}Ga_{0.8}Mg_{0.2}O_3$ (LSGM)-based honeycomb cell was first time successfully built and power generation property of the single-wall and the 4-wall-used cells was measured. The achieved maximum power density is 390 and 250 mW/cm^2 at 1073 and 973 K, respectively, when the single wall is used for the cell fabrication. The power generations of 4-wall-used cell also succeed in this study, and about 200 mW/cm^2, which is high volumetric power density as high as 300 W/L, is achieved.

The "ideal SOFC" would combine the technical simplicity and reliability of tubular-type SOFCs with the low-cost and high performance of planar-type SOFCs.[1–3] A new and unique SOFCs structure named honeycomb-type fuel cells is now attracting much interest.[4] The concept of this kind of SOFCs stack is described as the "condensed tubes" like extruded honeycomb sections of ceramic electrolyte, and interconnectors of stainless steel manifold are key elements for this type cell. Up to now, several numbers of studies are reported for honeycomb-type SOFCs. However, the power generation property of honeycomb SOFCs is not high enough. This may come from the difficulty in current collection. The first honeycomb-type SOFC stacks were successfully built and operated based on the ZrO_2 electrolyte by ABB Groups,[2] which is achieved to about 100 mW/cm^2 maximum power density at 1273 K.

In this study, honeycomb-type SOFC based on the $La_{0.9}Sr_{0.1}Ga_{0.8}Mg_{0.2}O_3$ (LSGM) electrolyte, which is higher oxide ion conductivity than that of ZrO_2-based one,[2,5] is investigated. Considering that the honeycomb-type's SOFC is a kind of self-supported cell structure, the thick electrolyte wall would dominate the whole cell's power output. Therefore, the high conductive electrolyte should be effective for improving the power density of cell.

LSGM honeycomb prepared by slip casting method by Kikusui Chem. Co., Ltd. is used in this study. The honeycomb employed is self-supported LSGM electrolyte with typical dimensions of 19 mm in width, 20 mm in height, and 1 mm in wall thickness. The LSGM honeycomb cell is prepared by using NiO–Fe_3O_4 (9:1 in metallic weight ratio) as anode and $Sm_{0.5}Sr_{0.5}CoO_3$ (SSC55) as cathode. Humidified hydrogen (3 vol % H_2O, 150 mL/min) and oxygen (150 mL/min) were used as fuel and oxidant, respectively. Platinum mesh is used as current collector, and a lead Pt wire is connected to the Pt mesh. The schematic view of the 4-wall-used honeycomb cell setup is shown in Figure 1. In Figure 1, electrode setup for one wall is shown and in actual cell, the same electrode is fabricated on four walls in one channel. The anode and cathode materials are slurry coated on the opposite side of the interior LSGM honeycomb wall. The stainless steel manifold is used for feeding

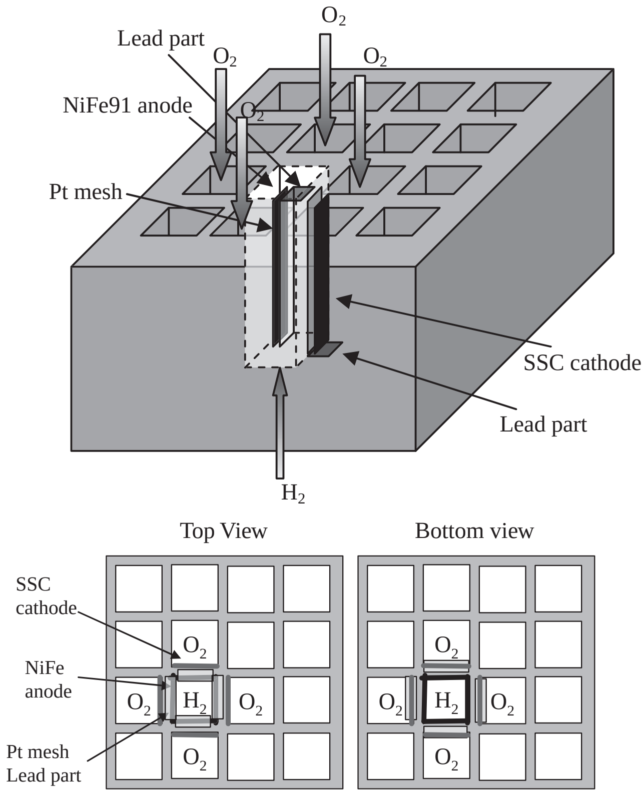

Figure 1. Schematic view of full 4-wall LSGM honeycomb cell.

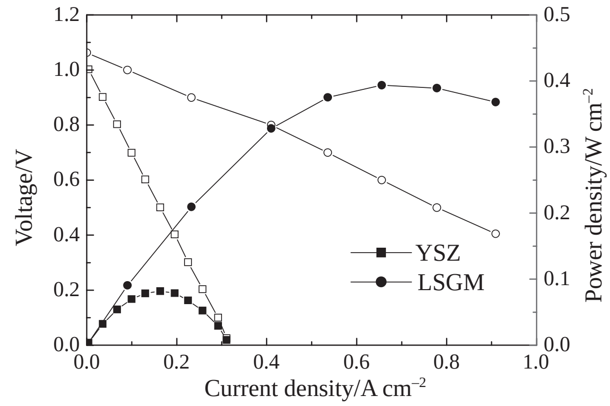

Figure 2. Power generation curves of NiFe91/3YSZ/SSC55 cell and NiFe91/LSGM9182/SSC55 cell at 1073 K.

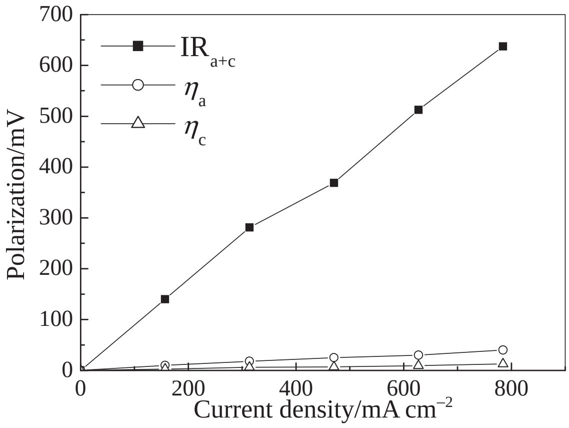

Figure 3. IR drops and overpotentials of NiFe(9:1)/LSGM honeycomb (single wall)/SSC honeycomb cell at 1073 K.

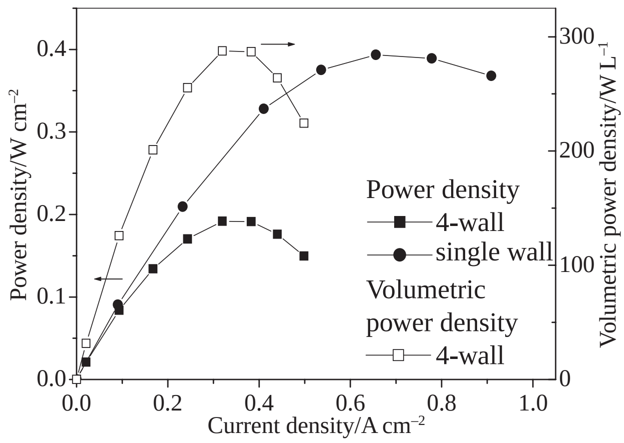

Figure 4. Power generation curves of the 4-wall LSGM honeycomb cell at 1073 K.

gas into the honeycomb, and single channel is used as 4-wall honeycomb single cell. Internal resistance was measured with current interruption method.

Figure 2 shows the comparison of the power generation curves of NiFe91/LSGM honeycomb (single wall)/SSC55 and NiFe91/3YSZ honeycomb (single wall)/SSC55 electrolyte honeycomb. The power density of LSGM cell is much higher than that of YSZ cell at 1073 K, LSGM honeycomb cell is achieved to about 0.4 W/cm^2, but YSZ is only 0.1 W/cm^2. This high power density results from the small IR loss by high ionic conductivity of LSGM electrolyte.[6–9] The open circuit voltage (OCV) of LSGM honeycomb cell is around 1.070 V at different temperatures, and it increases slightly with decreasing temperatures. The observed OCV is close to that of theoretical value, suggesting that the gas sealing of the cell is high enough. The maximum power density (M.P.D.) value is lower than that reported on planer-type one in the previous study,[6–9] because the thickness of honeycomb wall is 1 mm; however, the cell performance is almost repeated that of the planar-type one and reasonably high.

Figure 3 shows the internal resistance of the honeycomb cell. Obviously, the main reason for the potential drop is IR loss. According to the result of electrochemical analysis, the IR loss of the sample is much higher than those of the anodic and cathodic overpotentials. Therefore, the power generation of the LSGM honeycomb cell is dominated by IR loss, which is caused by use of the thick electrolyte wall. Decreasing the electrolyte thickness is desirable for further improving cell power density, but it is limited by the strength of the LSGM material. On the other hand, as for the electrode overpotential, anodic overpotential is much larger than that of cathodic one. Therefore, at this temperature, anodic reaction is slower than that of cathode.

Power generation property of 4-wall-used cell was measured and compared with that of single wall one in Figure 4. The maximum output power of around 0.7 W is achieved at 1073 K, which is correspondence to the active area power density of about 0.2 W/cm^2, and the volumetric power density is estimated to be about 0.3 kW/L (one for fuel and four for air channel). The 4-wall cell power density is lower than that of the single wall's result, i.e., it is almost a half value compared with that of single wall one. This may suggest that the contact resistance and the current collection are still not high enough for 4-wall cell. Therefore, power density of the 4-wall cell could be improved by increasing the current collection. If 4-wall cell can be achieved that of the single wall one and the large number of channel is used, then the one channel for fuel and oxidant could be enough for single cell and the estimate volumetric power density could be 1.2 kW/L. This high volumetric power density is a great advantage of honeycomb-type fuel cell.

This study reveals that the LSGM-based honeycomb cell was first time successfully built, and the power density of the single cell using single channel is successfully achieved about 0.2 W/cm^2 at 1073 K using 1 mm thick wall honeycomb. Decrease in wall thickness is possible and the power density of thinner thick wall honeycomb is now under measurement. Results will be reported future.

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