Effect of GDC Electrolyte Thickness on the Performance of Anode Supported Micro Tubular SOFC

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Effect of GDC Electrolyte Thickness on the Performance of Anode Supported Micro Tubular SOFC

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Anode supported micro tubular SOFC has been studied because it has high energy density and thermal shock resistance. Relationship between the performance of micro tubular cells and thickness of the GDC electrolyte was examined at temperatures between 500°C and 650°C. Performance of the cell with 15.5 μm thick electrolyte was higher than the cell with 40 μm thick at lower temperatures, but lower at higher temperatures. At lower temperatures, ohmic loss is dominant in the voltage drop, but at higher temperatures, leakage of electron through the GDC electrolyte is main reason for the voltage drop.

Introduction

Micro tubular SOFC has a great potential for APU or residential CHP applications because of its high energy density and high thermal shock resistance (1-6). Gadolinium doped ceria (GDC) is one of the candidates for the electrolyte of micro tubular SOFC, because it has high oxygen ion conductivity and can reduce the operation temperature. On the other hand, GDC has electronic conductivity in the reducing atmosphere and it causes a decrease in the cell voltage due to the leakage of electrons through the electrolyte. Although the ohmic loss decreases with decreasing thickness of the electrolyte, leakage increases with decreasing thickness. Thus, performance of the cell depends on the thickness of the electrolyte. In this study, the performances of two cells with different thickness electrolytes were measured as a function of temperature.

Experimental

Anode supported micro tubular cells were fabricated by the dip coating method (7). The GDC slurry was coated to the extruded NiO-GDC tube. Thickness of the GDC electrolyte was controlled by the number of dip coating times. Then the tube was sintered at 1400°C for 2 hours in air. The (La, Sr)(Co, Fe)O_3 (LSCF) cathode slurry was also dip-coated to the tube and fired at 950°C for 2 hours. The photograph of the cell is shown in Figure 1(a). The outer diameter of the single cell was 2.3 mm and the cathode length was

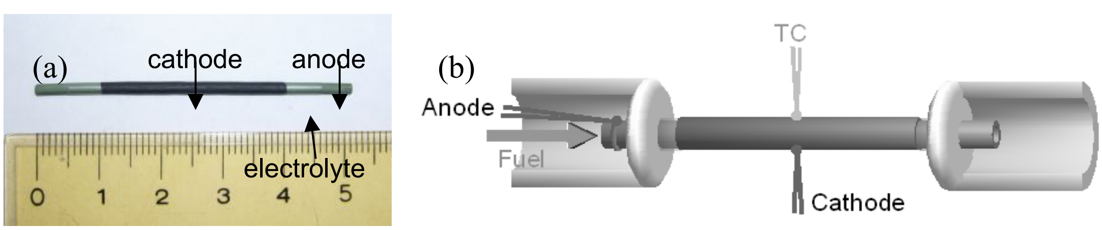

Figure 1. (a) Photograph of micro tubular cell. (b) Schematic illustration of the single cell test. The current corrector for the cathode was Ag mesh.

30 mm. Figure 1(b) shows the experimental set up of the single cell test. Ag wire was bonded to the edge of the cell for current correction of the anode. For the cathode current collection, Ag mesh was fixed on the cathode by conductive paste and Ag wire was bound as lead. The single cell was situated in an electric furnace and fixed by ceramic adhesive to seal the anode gas.

At first, the conductive paste on the cathode was fixed and the anode was reduced at 800^{o}C. Then the current-voltage (*I-V*) characteristics were measured at 650, 600, 550 and 500^{o}C. The anode gas was humidified 14 ccmH_2+42 ccmN_2 mixed gas. The fuel utilization U_f was calculated from the flow rate of the gas. The temperature of the surface of the cathode was measured by a thermocouple.

Results and Discussion

Figure 2 shows the scanning electron microscope (SEM) image of the cross section of the tube after experiment. GDC electrolyte was fairly dense and the thicknesses of the electrolyte for one and five times dip coating were 15.5µm and 40 µm, respectively. Thickness of the LSCF cathode of both cells was about 1µm.

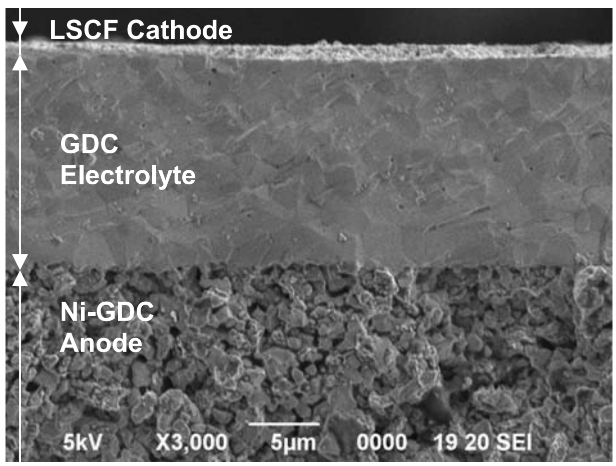

Figure 2. SEM image of the cross section of the anode supported micro tubular cell with one dip-coated GDC electrolyte.

Figure 3 shows the current-voltage (*I-V*) and the current-power (*I-P*) characteristics of the single cell with 15.5 µm thickness electrolyte at temperatures between 500 and 650^{o}C. The open circuit voltage (OCV) was lower than the theoretical value (e.g. 1.11 V at 500^{o}C), because the GDC electrolyte has electronic conductivity in a reducing atmosphere and electrons leak through the electrolyte. The temperature of the surface of the cathode was 668^{o}C when the furnace temperature was 650^{o}C and this temperature difference was also caused by the leakage of electrons.

When the current was applied, the voltage dropped because of the ohmic loss and overpotential of electrode. Since the oxide ionic conductivity increases with increasing temperature, the ohmic loss is lower at higher temperatures. This is one of the reasons why the slope of the *I-V* curve is steeper at lower temperature. The output power was highest at 600^{o}C. Leakage of electrons is significant at temperatures 650^{o}C or higher because the electronic conductivity is higher at higher temperatures and it causes the voltage drop.

At high U_f, voltage dropped severely because of the depletion of the fuel. When anode gas was humidified 14 $ccmH_2$+42 $ccmN_2$ mixed gas, maximum output power was 0.39 Wcm^{-2} and U_f was 75% at 600°C. But in this condition, voltage was 0.65 V and Ni in the anode could be oxidized. In order to prevent the oxidization of anode, the cell operating condition such as temperature and flow rate of the fuel should be well controlled.

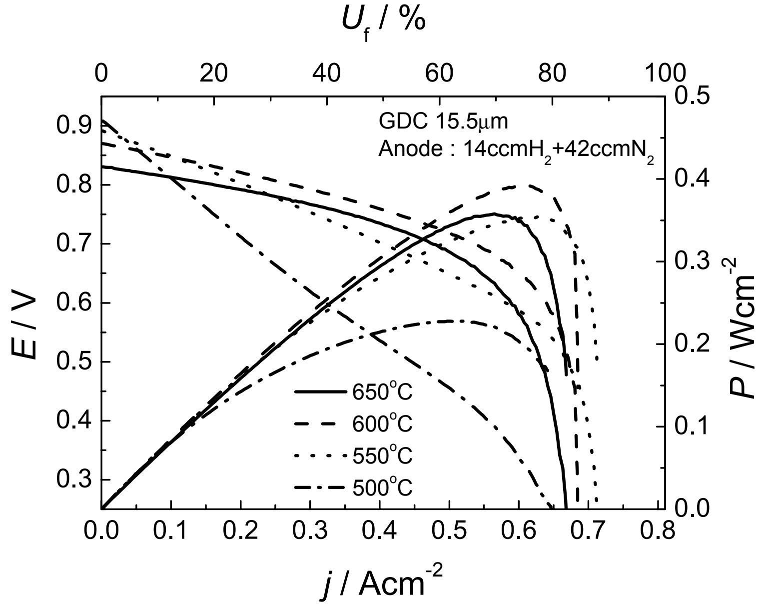

Figure 3. *I-V* and *I-P* characteristics of the single tubular cell with 15.5μm thickness electrolyte at temperatures between 500°C and 650°C.

Figure 4 shows *I-V* characteristics of the cells with 15.5 μm and 40 μm thick electrolytes at 500 and 650°C. The OCV of the thicker electrode cell was higher at both 500 and 650°C, but *I-V* characteristics showed different behavior. At 500°C, the voltage drop of the thinner electrolyte cell was smaller (This behavior was also observed at 550°C).

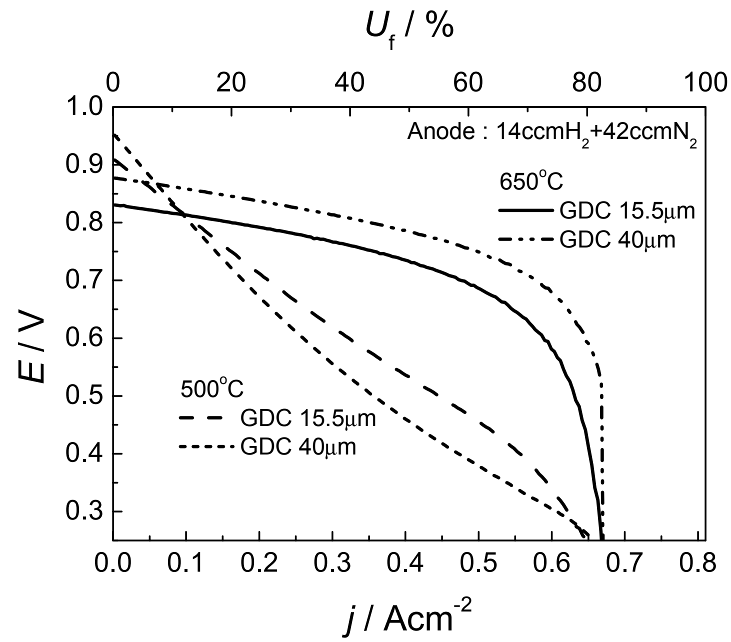

Figure 4. *I-V* characteristics of the tubular cells with different thickness electrolyte at 500°C and 650°C.

The main reason for the voltage drop at this temperature is the ohmic loss of the electrolyte because the electronic conductivity is so low that the leakage of electrons is small. Because the ohmic loss increases with increasing thickness of the electrolyte, voltage drop of the cell with the thinner electrolyte is smaller. On the contrary, the voltage drop of the thicker electrolyte cell was smaller at 650^{o}C (This behavior was also observed at 600^{o}C). This is because the leakage of electrons through the electrolyte increases with decreasing thickness of the electrolyte. At higher temperatures, it is considered that the effect of the ohmic loss on the voltage drop is smaller than that of the leakage of electrons.

There is therefore an optimum thickness of the GDC electrolyte at each temperature. At 550^{o}C or lower, thin electrolyte is appropriate to improve the performance of the cell. On the contrary, the thick electrolyte is appropriate at 600^{o}C or higher. The balance between the ohmic loss of the electrolyte and the leakage of electrons at the operating temperature is important to determine the thickness of the GDC electrolyte.

Conclusions

Performance of anode supported micro tubular cell was measured and the effect of the thickness of the GDC electrolyte on performance was examined at temperatures between 500 and 650^{o}C. The output power was highest at 600^{o}C and the voltage drop was significant at 650^{o}C because of the leakage of electrons through the electrolyte. Performance of the cell with 15.5 μm thick electrolyte was higher than of the cell with 40 μm thick electrolyte at lower temperatures. On the contrary, performance of the cell with 40 μm electrolyte was higher at higher temperatures. At lower temperatures, the ohmic loss is dominant in the voltage drop, but at higher temperatures, leakage of electrons through the electrolyte is the main reason for the voltage drop. In order to improve the performance of the micro tubular cells, thickness of the GDC electrolyte should be determined by considering the balance between the ohmic loss of the electrolyte and the leakage of electrons at the operating temperature.

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References

1. K. Kendall, M. Palin, *J. Power Sources*, **71**, 268 (1998).
2. T. Ota, M. Koyama, C. Wen, K. Yamada and H. Takahashi, *J. Power Sources*, **118**, 430 (2003).
3. Y. Du, N. M. Sammes, G. A. Tompsett, D. Zhang, J. Swan, M. Bowden, *J. Electrochem. Soc.*, **150**, A74 (2003).
4. Y. Du, N. M. Sammes, *J. Power Sources*, **136**, 66 (2004).
5. N. M. Sammes, Y. Du, and R. Bove, *J. Power Sources*, **145**, 428 (2005).
6. N. Sammes and Y. Du, *Solid Oxide Fuel Cells IX (SOFC-IX)*, 384 (2005).
7. Y. Funahashi, T. Shimamori, T. Suzuki, Y. Fujishiro and M. Awano, *J. Power Sources*, **163**, 731 (2007).