Electrochemical Properties of High-Temperature SOFCs

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Introduction

Solid oxide fuel cells (SOFCs) have many advantages because of high temperature operation; internal reforming of hydrocarbon fuels are possible and combined systems integrated with gas turbine can exhibit high energy conversion efficiency. Conventional SOFCs employing yttria-stabilized zirconia (YSZ) are operated at around 1000ºC. However, YSZ reacts with $La_{0.6}Sr_{0.4}MnO_3$ (LSM), and then produces products of low conductivity at electrolyte/electrode interface during long-term operation [1, 2, 3]. Consequently, the power generation performance will be deteriorated because of the electrical insulators.

Recently, $Nd_{0.7}Sr_{0.3}MnO_3$ (NSM) and $Pr_{0.7}Sr_{0.3}MnO_3$ (PSM) were reported to exhibit high electrical conductivity and showed low reactivity with YSZ at around 1400ºC [1, 4]. On the other hand, LSM reacts with YSZ and produces the electrical insulator at 1400ºC, easily. Furthermore, fuel cells employing NSM and PSM as cathode showed high performance comparable to that of LSM at 1000ºC. Accordingly, NSM and PSM are promising cathode materials for high-temperature SOFCs. However, the electrochemical properties and power generation characteristics of high-temperature SOFCs have not been examined yet. In this study, we have fabricated high-temperature SOFCs and investigated the power generation properties in the temperature range of 1000-1400ºC.

Experimental

An 8 mol% YSZ tube (thickness 0.2 mm) was used as an electrolyte. Anode slurry consisting of NiO and YSZ with a weight ratio of 4:1 or 3:2, was painted onto the inner surface of the tube, and subsequently fired at 1400ºC for 5h in air. Then, cathode slurry of LSM, NSM, or PSM was painted onto the outer surface of the tube and fired at 1150ºC for 5h in air. The electrode area was 0.28 cm^2. Hydrogen humidified at 0ºC and air was supplied as fuel and oxidant, respectively. The electrochemical properties were evaluated by current-voltage characteristics and ac impedance spectroscopy at 1000-1400ºC. The thermal stability of the SOFCs at 1400ºC was studied by the variation of the terminal voltage by drawing current of 200 mA / cm^{-2} continuously for 7h.

Results and discussion

Figure 1 shows the current-voltage characteristics of the fuel cell employing Ni-YSZ (NiO:YSZ = 4:1) and LSM as anode and cathode, respectively. The open circuit voltage (OCV) showed a good agreement with the electromotive force calculated from the Nernst equation at 1300ºC and lower. However, the OCV at 1400ºC deviated from the theoretical value because of the electronic conduction, which was originated from the partial reduction of the YSZ electrolyte. The current density consistently at 0.5 V increased with the operating temperature. At 1300 and 1400ºC, the power generation was possible with drawing current up to about 0.8 A cm^{-2}. This result is acceptably high by considering that the measurement was conducted on thicker electrolyte. Accordingly, the SOFC employing LSM as cathode showed the highest power generation efficiency at 1300ºC.

The time-voltage characteristics for the fuel cell consisting of various cathode materials (LSM, NSM and PSM) with drawing 200 mA cm^{-2} continuous current are shown in Fig. 2. The Ni-YSZ (3:2) cermet was used as anode. The fuel cell with PSM cathode showed the highest terminal voltage and stability among the cathode materials investigated. On the other hand, the fuel cells with LSM and NSM cathode showed the deterioration with time. Consequently, it can be concluded that PSM have a good compatibility with YSZ, and it can be seen that is one of the promising cathode material for high-temperature SOFCs.

References

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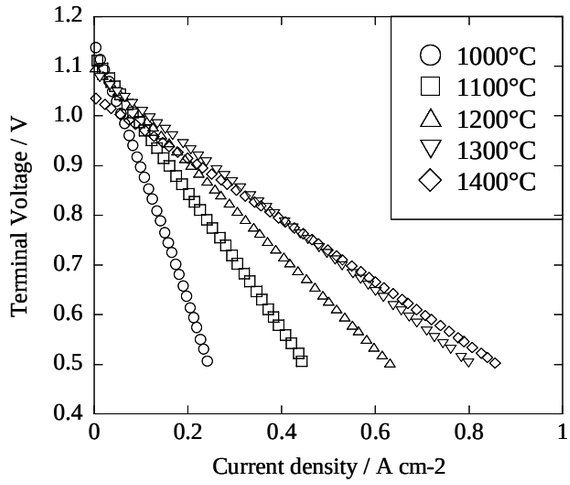

Fig. 1 Current-voltage characteristics for a cell; H_2, Ni-YSZ | YSZ | LSM, 20% O_2/N_2. The results were measured at 1000-1400°C.

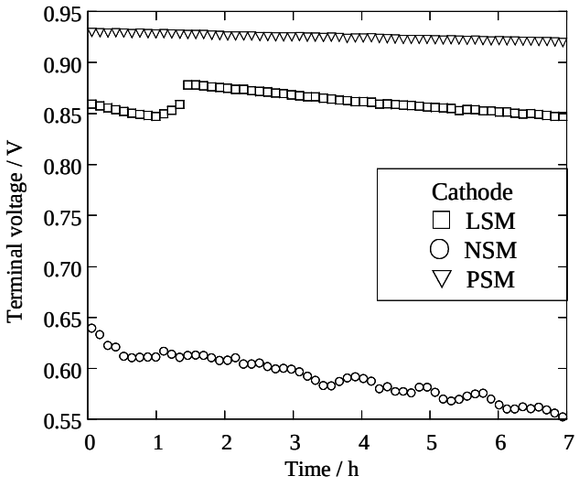

Fig. 2 Time-voltage characteristics at 1400°C with drawing 200 mA cm^{-2} continuous current for cells; H_2, Ni-YSZ | YSZ | perovskites, 20% O_2/N_2. Perovskites are LSM, NSM, and PSM.