

# Power Generation Characteristics of SOFCs for Alcohols and Hydrocarbon-based Fuels

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The multi-fuel capability of solid oxide fuel cells (SOFCs) is of technological interest, as various kinds of carbonaceous fuels could be used directly or via simple reforming. This advantage may enable to design a simple and flexible power generation system.

Among various possible SOFC fuels, alcohols such as ethanol and methanol can be obtained from biomass, so that their use may enable to realize a carbon-neutral zero-emission energy system based only on natural resources. It should be noted that methanol is one of the possible fuels for polymer electrolyte fuel cells (PEFCs), and SOFCs have also been considered for possible automobile applications. Therefore, direct-methanol SOFCs could be an alternative to direct-methanol fuel cells (DMFCs) with polymer electrolytes, if a considerable reduction of SOFC operational temperature could be realized [1]. Hydrocarbons are also considered as possible SOFC fuels, especially methane, the main constituent of natural gas. However, it has been considered that the use of (inexpensive) higher hydrocarbons such as kerosene is difficult mainly because of carbon deposition. The aim of this study is therefore to examine the applicability of various alcohol- and hydrocarbon-based fuels by analyzing and comparing the electrochemical properties of SOFCs. For alcohols, fuels are directly supplied to the fuel electrodes. We also apply n-dodecane ( $C_{12}H_{26}$ ) as a model higher-hydrocarbon (kerosene) to analyze its applicability via external reforming.

Planar-type cells were used in this study. Sintered electrolyte plates of 8mol%  $Y_2O_3$ - $ZrO_2$  (YSZ) with a thickness of 200  $\mu m$  and a diameter of 20 mm (supplied by Tosoh Corp.) were used, on which anode layers (80 wt% NiO-YSZ) were deposited via screen-printing and were sintered at 1400°C for 5 hours. The cathode layers ( $La_{0.6}Sr_{0.4}MnO_3$ ) were then deposited, followed by sintering at 1150°C for 5 hours. The area of both electrodes was 5×5 mm<sup>2</sup>.

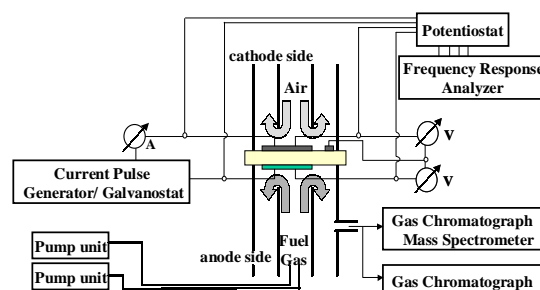
Figure 1 shows a schematic drawing of the electrochemical cell configuration used in this study. For electrochemical characterizations, air was supplied as oxidant, while various kinds of (evaporated) fuel gases were supplied to the anode. For alcohol-based fuels, the mixture of alcohol and water was supplied using a liquid chromatograph to an evaporator connected to the inner gas tube on the anode side. For hydrocarbon (n-dodecane)-based fuels, n-dodecane and a corresponding amount of water were supplied to the evaporator and via reforming catalyst ( $Ru/Al_2O_3$ ) layer to the anode. Nitrogen gas was used as a carrier gas. Electrochemical properties were examined by measuring current-voltage (I-V) characteristics and cell impedance.

Power generation characteristics for alcohols are shown in Fig. 2. For all these alcohol-based fuels, the C-H-O ratio

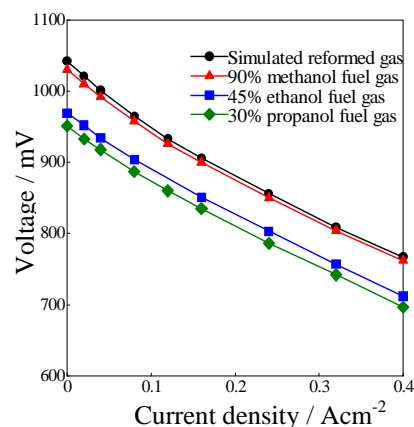
was fixed to the same value for comparison. It has been demonstrated that direct-alcohol SOFCs can be realized, at least, for alcohols with carbon number up to 4 (butanol). In case that methanol was directly supplied, the I-V characteristics were similar to those with the simulated reformed gas. However, with increasing carbon number of alcohols, a decrease in cell voltage is observed. From our gas analysis by gas chromatograph, it has been revealed that the compositions of simulated reformed gas and methanol-derived fuel gas were almost the same, explaining the similar I-V characteristics. However, increasing carbon number of alcohols, a decrease in  $H_2$  and CO gas concentrations was observed, associated with the decrease in cell voltage.

Power generation characteristics for n-dodecane-based fuels with various steam-to-carbon ratios are shown in Fig. 3. We have demonstrated relatively stable power generation, at least within 10 hours, using  $Ru/Al_2O_3$  as a reforming catalyst.

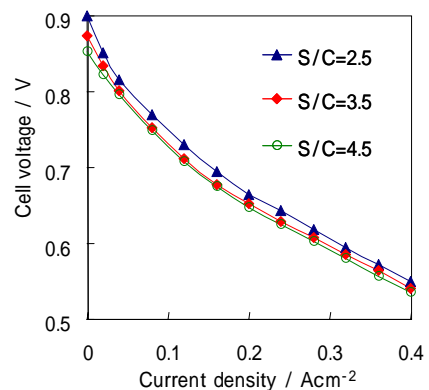
- 1) K. Sasaki, H. Kojo, Y. Hori, R. Kikuchi, and K. Eguchi, *Electrochemistry*, **70**[1] 18-22 (2002).



**Fig. 1:** Schematic drawing of the electrochemical measurement and gas analysis setup.



**Fig. 2:** Current-voltage characteristics of a cell for alcohol-based fuels at 1000 °C.



**Fig.3:** Current-voltage characteristics of a cell for n-dodecane-based fuels at 1000 °C.