

FUEL FLEXIBILITY IN POWER GENERATION BY SOLID OXIDE FUEL CELLS

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Solid oxide fuel cell (SOFC) has been actively investigated as a highly efficient power generation system. The current status of SOFC research activity in Japan will be reviewed in the presentation. Both tubular and planar design has been actively investigated in Japan. The activity of SOFC in our research group was mainly focused on the fuel flexibility of SOFC. In addition to the high efficiency, another attractive feature of SOFC is its capability of utilizing various fuels, e.g., H₂, CO, hydrocarbons, alcohol and bio-fuels. Especially, internal reforming of natural gas and hydrocarbons should give rise to a simple design of the system as well as high conversion efficiency. The present investigation summarizes power generation characteristics of SOFC for several kinds of fuels.

A planar-type cell was fabricated by slip casting process. Cathode, electrolyte, and anode were made of Sr-doped lanthanum manganese oxide, yttria-stabilized zirconia, and Ni-cermet, respectively. Oxygen was supplied to the cathode. H₂, CO, alcohol, and hydrocarbon were used as fuel and were supplied to the anode after mixing with H₂O, CO₂ and or N₂. The current-voltage (I-V) characteristics were measured at 1000°C.

A thermodynamic calculation has been carried out to determine the carbon deposition region in a C-H-O diagram. The carbon deposition region lied in carbon rich region from the H₂-CO line in the diagram. The equilibrium partial pressure of oxygen was estimated from the H₂/H₂O and CO/CO₂ ratios in the diagram. I-V characteristics of the cell were measured by supplying a fuel gas (CH₄+H₂O) to the anode. In this experiment, the steam to carbon ratio (S/C ratio) was fixed, whereas the fuel gas was diluted with different proportions of N₂. The open circuit voltage, which was expected to be unchanged from the equilibrium calculation, tended to decrease with decreasing concentration of fuel gas / N₂ ratio. This low open circuit voltage implies that the equilibrium conversion of steam reforming was not achieved for high dilution rate due to slow reaction rate of reforming reaction. Low steam reforming conversion may result from insufficient contact time with the Ni-YSZ catalyst or slow supply of the fuel gas to the catalyst layer.

The power generation characteristics were compared by supplying pre- and post-reforming fuels with the same equilibrium composition. An external reformer was equipped to supply the post-reforming gas in the equilibrium composition. The open circuit voltage and the voltage at a given current density was always higher for the case of the external reforming than for the internal reforming because of the incomplete conversion of methane. For the internal reforming of CH_4 , the open circuit voltage for $\text{S/C}=1$ was high, but the terminal voltage dropped significantly in low current density region. This implies that the reactivity of methane in the electrochemical reaction is expected to be low to attain the equilibrium conversion in the electrode layer. The gas phase analysis indicated that the outlet gas was not in the equilibrium. Thus, the open circuit voltage was always higher than that estimated from the outlet $\text{H}_2/\text{H}_2\text{O}$ ratio, since the reforming reaction proceed toward the equilibrium state, as the fuel gas diffuses in the electrode pore. Characteristic future of dry internal reforming of CH_4 with CO_2 was almost similar to the case of the internal steam reforming.

Power generation by C_2 fuel was possible, whereas use of ethylene and ethane led to carbon deposition during operation. Especially, a small amount of ethylene always resulted in carbon deposition even in the presence of a large fraction of H_2 .