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Solid Oxide Fuel Cell as a Multi-fuel Applicable Power Generation Device

Ryuji Kikuchi[1)] and Koichi Eguchi[1)]

1) Dept. of Energy and Hydrocarbon Chemistry, Graduate School of Engineering, Kyoto University

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The solid oxide fuel cell (SOFC) has high conversion efficiency, and is quite attractive from the viewpoint of fuel flexibility, especially the possibility of internal reforming of methane and other hydrocarbons for power generation. The high temperature operation of SOFCs allows the reform of hydrocarbon fuels on the fuel electrode internally in a SOFC module. The power generation characteristics of SOFCs with internal steam reforming of methane were investigated. Steam reforming over a Ni-YSZ (yttria-stabilized zirconia) cermet catalyst attained almost the equilibrium conversion and selectivity in a fixed bed reactor at 1000°C. Internal reforming of hydrocarbons was incomplete because of the limited contact time with the thick layer of the Ni cermet electrode. Therefore, the fuel cell supplied with pre-reformed gas to the anode always produced a lower terminal voltage due to insufficient conversion of the fuel compared with that supplied with post-reformed gas at a given current density. Methane internal reforming proceeded without deterioration with time, whereas power generation with ethane and ethylene was deteriorated by carbon deposition even at high steam-to-carbon ratio. The carbon deposition region and equilibrium partial pressure of oxygen in the C-H-O diagram were estimated from thermodynamic data. The characteristics of CH_4 steam reforming, carbon deposition, and power generation with Ni-YSZ cermet anodes modified by MgO, CaO, SrO, CeO_2, and precious metals were examined. CaO addition was effective for suppressing carbon deposition and promoting CH_4 steam reforming, although the anode electrochemical activity was slightly deteriorated.

Ru and Pt addition enhanced steam reforming and suppressed carbon deposition without deteriorating the anode electrochemical activity. The impedance related to gas diffusion was significantly reduced by precious metal additions, indicating that the stability of the anode catalyst was considerably improved since no carbon was deposited.

Keywords: Solid oxide fuel cell, Fuel flexibility, Shift reaction, Steam reforming, Carbon deposition