21e Direct Oxidation of Hydrocarbon Fuels in Solid Oxide Fuel Cells

Valentin K. Medvedev, Laura M. Roen, and Eric M. Stuve

Solid oxide fuel cells (SOFC) provide an opportunity for fuel-flexible fuel cells that operate at higher efficiencies than other types of fuel cells. These advantages arise from the high temperature of SOFC operation, 800–1000 °C, which facilitates direct oxidation and reforming of hydrocarbon fuels and a source of high quality waste heat. Some of the issues faced in direct hydrocarbon oxidation are (1) avoiding carbon formation on the anode and (2) understanding the role of oxide ions in the reaction mechanism. To address these issues we have developed a SOFC mounted in a vacuum system with facilities for accurate control of fuel and oxygen partial pressures and measurement of reaction products by a calibrated mass spectrometer. The measurements highlight the interplay of fuel oxidation kinetics, carbon deposition on the anode, and transport of oxide ions through the electrolyte. The SOFC consisted of a Gd-doped ceria electrolyte ($Gd_{0.1}Ce_{0.9}O_x$) with platinum anode and cathode. Fuels of study included methanol, ethanol, methane, ethylene, carbon monoxide, and hydrogen. The reactions were studied over the temperature range of 800–1000 °C with fuel and oxygen partial pressures of 0–10 Torr and 0–70 Torr, respectively. Hydrogen, CO, methanol, and ethanol show similar reaction characteristics, with high open circuit voltages of 0.6 V and above and maximum current densities of approximately 2 mA/cm^2. By contrast, ethylene and methane show much slower reaction rates, with open circuit voltages of approximately 0.1 V and maximum current densities of approximately 0.01 mA/cm^2. Post-reaction titration of the anode surface with oxygen showed evidence of extensive carbon formation under the low reaction conditions. The dynamic response of the system under changing fuel and oxygen partial pressures provided further evidence of carbon formation. These experiments help establish the mechanism of direct fuel oxidation in solid oxide fuel cells and the conditions for avoiding carbon deposition on the anodes. This work was supported by the Office of Naval Research.