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Low temperature anode-supported solid oxide fuel cells based on gadolinium doped ceria electrolytes☆

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Abstract

The utilization of anode-supported electrolytes is a useful strategy to increase the electrical properties of the solid oxide fuel cells, because it is possible to decrease considerably the thickness of the electrolytes. We have successfully prepared single-chamber fuel cells of gadolinium doped ceria electrolytes $Ce_{1-x}Gd_xO_{2-y}$ (CGO) supported on an anode formed by a cermet of NiO/CGO. Mixtures of precursor powders of NiO and gadolinium doped ceria with different particle sizes and compositions were analysed to obtain optimal bulk porous anodes to be used as anode-supported fuel cells. Doped ceria electrolytes were prepared by sol–gel related techniques. Then, ceria-based electrolytes were deposited by dip coating at different thicknesses (15–30 μm) using an ink prepared with nanometric powders of electrolytes dispersed in a liquid polymer. Cathodes of $La_{1-x}Sr_xCoO_3$ (LSCO) were also prepared by sol–gel related techniques and were deposited on the electrolyte thick films. Finally, electrical properties were determined in a single-chamber reactor where propane, as fuel, was mixed with synthetic air below the direct combustion limit. Stable density currents were obtained in these experimental conditions. Flux rate values of the carrier gas and propane partial pressure were determinants for the optimization of the electrical properties of the fuel cells.

Keywords: SOFC; Single-chamber; Ceria; Cobaltite

1. Introduction

In recent years, a new type of SOFC, the single-chamber fuel cell, which shows very high current density at low temperatures (450–630 °C), has been developed by different research groups [1–10]. The main difference between the one-chamber fuel cells and the conventional two-chamber fuel cells is that, in the former, both electrodes are simultaneously in contact with both the fuel and the air. The advantages of such SOFCs are that they do not need expensive materials, they are very simple to fabricate, and it is very easy to assemble them into multiple stacks. These SOFCs can work directly with hydrocarbons (internal reforming) because the temperature at which they operate is adequate for hydrocarbon reforming in the anode. Moreover, the poisoning of the Ni by carbon or sulphur is not possible due to the presence of air on the anode electrode.

Solid oxide electrolytes based on ceria doped materials are considered to be one of the most promising candidate materials for use in single-chamber, low temperature solid oxide fuel cells, because they offer considerably higher ionic conductivity than YSZ in the range of 450–700 °C. The substitution of Ce^{4+} by suitable trivalent cations such as Gd^{3+}, Sm^{3+}, Y^{3+} or La^{3+} enhances the chemical stability, increases the ionic conductivity and suppresses the reducibility of ceria-based materials. The most effective substitutes are Gd_2O_3 and Sm_2O_3 possibly due to the fact that they minimize the changes in lattice parameter.

Both, electrolyte- and anode-supported fuel cells have been reported for these doped ceria fuel cells based in one chamber reactor. However, there is some difficulty to find stable cathodes in one-chamber fuel cells under the proposed reducing conditions. Hibino et al. [8] reported a relatively high peak power density at 500 °C for an electrolyte-supported fuel cell using $Sm_{0.5}Sr_{0.5}CoO_{3-\delta}$ mixed with $Ce_{0.8}Sm_{0.2}O_{1.9}$ (SSC + CSO) as the cathode and ethane as the fuel. However, they found that this cathode was incompatible with propane at temperatures higher than 450 °C. It should be noted that, because of the heat release during partial exothermic oxidation at the anode, the actual temperature of the fuel cell is higher than the furnace temperature,

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