Characterization of SDC Electrolyte-Supported SOFCs for the Direct Oxidation of Hydrocarbon Fuels

C. Lu[1], W. L. Worrell[1], J. M. Vohs[2] and R. J. Gorte[2]
Department of Materials Science and Engineering[1]
and Department of Chemical Engineering[2]
University of Pennsylvania, 3231 Walnut Street,
Philadelphia, PA 19104-6272

Introduction

Developing intermediate-temperature solid-oxide fuel cells (SOFCs) can increase cell performance, extend cell lifetimes and lower fabrication costs (1). However to achieve these goals, one must use an electrolyte whose oxygen-ion conductivity is significantly higher than yttria-stabilized zirconia (YSZ). One of the most promising electrolyte-candidate at temperatures below 700°C is samaria-doped ceria, (SDC) (2). With an SDC-electrolyte, cell-operating temperatures can be reduced as low as 400°C using hydrogen (H_2) fuel (3).

A new composite-anode (Cu-CeO_2-YSZ) has been successfully developed for direct oxidation of a variety of hydrocarbon fuels with YSZ electrolytes in the 700–800°C temperature range (4). However, there are no previous publications of intermediate-temperature SOFCs that have developed anodes for the direct oxidation of hydrocarbon fuels. Thus this study is the first electrolyte-supported intermediate-temperature SOFC using an SDC electrolyte, with a Cu-SDC composite-anode with H_2 and butene (C_4H_8) fuels.

Experimental

Sm0.15Ce0.85O1.925 electrolyte-powder (NexTech Materials Ltd.) was pressed and sintered at 1450oC for 4 hrs to obtain dense SDC wafers with a thickness of ~800μm. After attaching a porous SDC layer on one side of the wafer, the reference electrode and composite SDC-LSM (1:2 wt%) cathode were added to the other side. Then the porous SDC layer was impregnated with copper using an aqueous Cu(NO3)2 solutions. The composite-anode composition was Cu20%-SDC80% (wt%). Silver current collectors were attached on both cathode and anode with the aid of Pt and Au inks respectively. After the cell was mounted an alumina-support tube and sealed using a ceramic adhesive, it was slowly heated to 700oC in H2.

The undiluted H_2 or butene fuel was supplied to the anode at 1 atm, and the cathode was fed with air. The i-V and impedance measurements were carried out using a Solartron 1287 electrochemical interface, and a Solartron 1250 frequency response analyzer controlled by an HP computer. Cathode overpotential (η_c) were determined using the Solartron 1287, a Tektronic oscilloscope, and a rapid electronic switch.

Results

Our i-V curves and impedance measurements at 700°C are shown in Figs. 1 and 2. The open circuit voltages (OCVs) are 0.812 V and 0.734 V, with maximum power densities of ~86mW/cm^2 and ~68mW/cm^2, for H_2 and C_4H_8, respectively. The performance in C_4H_8 was stable with time, showing that coke formation with the Cu-based anodes is negligible. The electrochemical impedance results in Fig. 2 suggest that electrode-interface resistances are a major limitation for cell performance.

Fig. 3 shows that cathode overpotential (η_c) becomes more significant as the current density increases and may be the primary cause for the loss in cell-performance at 700°C. And the anode overpotential (η_a) is relatively small, indicating that the Cu-SDC composite-anode is an effective anode for the intermediate-temperature SOFC.

Conclusions

This research initiates our development of an intermediate-temperature SOFC for direct oxidation of hydrocarbon fuels. A Cu-SDC anode and an SDC-LSM cathode have been attached to a dense SDC wafer to form a single cell. Both hydrogen (H_2) and butene (C_4H_8) fuels are tested at 700°C in this cell. The cell performance is characterized using electrochemical impedance spectroscopy and current-interruption technique. Results indicate the effectiveness of the Cu-SDC composite-anode and the necessity to fabricate a thin-film SDC electrolyte and use active cathodes to improve cell performance.

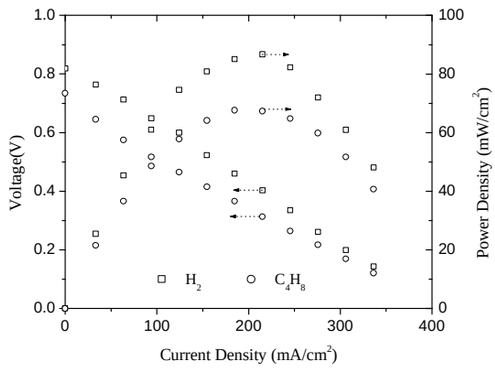

Fig. 1. i-V and power density curves of a $Cu_{20\%}$-$SDC_{80\%}$ /SDC/$SDC_{33\%}$-$LSM_{67\%}$ single cell in H_2 and C_4H_8 at 700°C

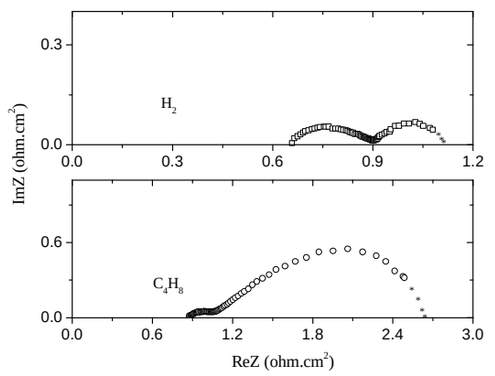

Fig. 2. Corresponding impedance spectra of the single cell in H_2 and C_4H_8 at 700°C

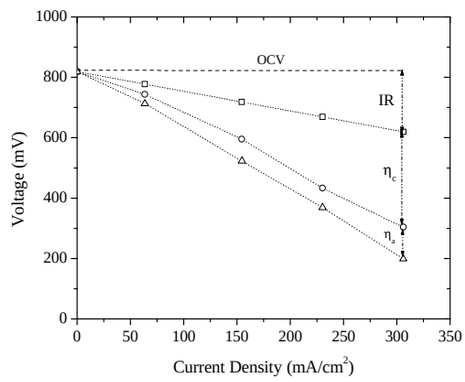

Fig. 3 The voltage drop of the single cell in H_2 at 700°C.

Acknowledgement

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