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TITLE:
Fabrication and testing of Cu/GDC-based IT-SOFC

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Abstract
Planar solid oxide fuel cells (SOFC) with CuO/gadolinium-doped ceria (GDC) supporting anode were produced and tested in H_2 and in CH_4/CO_2 mixture at 650°C. The electrolyte densification at 900°C was promoted by compressive strains induced by larger anodic thickness. The reduction behaviour of CuO/GDC anodic powders was preliminarily evaluated. The electrochemical measurements showed an increasing power density with the anode thickness (from ≈500 μm to ≈1.4mm) reaching a maximum value of 227 $mWcm^{-2}$ at 650°C in pure H_2. Power density of 29 mW cm^{-2} was measured in wet CH_4/CO_2 biogas mixture at 650°C. Catalytic activity measurements toward methane dry reforming showed limited conversion at all investigated temperatures, this suggesting that the actual anodic reaction is the methane combustion. Scanning electron microscope observations and energy dispersive X-ray analyses of the cell tested in CH_4/CO_2 mixture did not show any carbon deposit, thus pointing out that the Cu/GDC cermet can be considered a stable and reliable anodic substrate for IT-SOFC fed by CH_4/CO_2 mixture.

Keywords: Copper-based anode; Gadolinia-doped Ceria; planar intermediate temperature solid oxide fuel cell; co-sintering; electrochemical impedance spectroscopy

1 Introduction

Solid oxide fuel cells represent one of the most suitable and versatile stationary devices for power applications due to their fuel flexibility and high efficiency [1]. Nevertheless, their commercialisation has been limited due to the high operative temperatures that can cause interdiffusion of the electrode materials to the electrolyte, which weakens the performances and reduces the lifetime [2]. Another parameter that must be taken into account is the reduction of the polarisation resistance that mainly depends on the cell design. A very typical SOFC configuration is the so-called anode-supported cell, which allows to reduce the ohmic resistance and activation polarization associated with thick electrolytes and the consequent reduction of operating temperature even below 800°C.

In order to reduce the operating temperature further, some innovative electrolytic materials have been proposed in the last years. Lanthanum gallate perovskite (like (La, Sr)(Ga, Mg)O_3 or LSGM) is one of the widely used material in the low or intermediate-temperature SOFC [3-6]. Gadolinium-doped ceria (GDC) compounds have also been intensively investigated for their high ionic conductivity in the intermediate temperature (IT) range, i.e. between 600 and 800°C [7-10]. GDC densification, which is usually carried out at temperature in excess to 1500°C, can be achieved at reduced temperature either by using sintering aids (like Cu, Co, Fe, Mn, Li and Zn oxides) [11] or by using nanosized GDC powders [12-14] or by very recently proposed field assisted and flash sintering

4 Conclusions

Planar CuO-containing GDC anode and Li-doped GDC-based electrolyte were produced by tape casting and co-sintering.
Larger anode/electrolyte thickness ratio was shown to have a positive influence on SOFC performance because of the better electrolyte densification promoted by compressive stresses generated upon sintering because of the differential anode/electrolyte shrinkage.
The electrochemical characterization revealed in fact that the power density in H_2 increases with the anode thickness, reaching 227 mW cm^{-2} at 650 °C for 1.4 mm thick anode.
The anodic powder catalytic activity determination pointed out that GDC promotes complete methane combustion and Cu is unable to activate the C-H bond of methane, this being advantageous for limiting the presence of carbon deposits. The cell with better microstructure (i.e., denser electrolyte) was tested by using wet CH_4/CO_2 biogas mixture at 650°C and power density of 29 mW cm^{-2} was measured. The low power outputs in biogas suggest the need of further anodic composition optimisations in order to produce more acceptable performances.
The results obtained in the present work point out that Cu/GDC cermet can be considered as reliable anodic substrate for IT-SOFC fed by H_2 and/ or biogas.

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