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Reduction of Electrode Polarization in Anode-Supported Solid Oxide Fuel Cell

Malinee Meepho^a, Darunee Wattanasiriwech^a, Pavadee Aungkavattana^b,
Suthee Wattanasiriwech^{a*}

^aMae Fah Luang University, Chiangrai, 57100, Thailand

^bNational Metal and Materials Technology Centre, 12120, Thailand

Abstract

In this work, an attempt to reduce electrode polarization of an anode-supported solid oxide fuel cell with two approaches and the improvement of the cell electrochemical performance is reported. In fabrication of a conventional single solid oxide fuel cell, yttria stabilized zirconia (8YSZ), NiO-8YSZ, and lanthanum strontium cobalt fluorite (LSCF) were used as electrolyte, anode and cathode materials. On the pre-fired porous anode support, the electrolyte was deposited by electrophoresis deposition while the cathode layer was deposited using a screen-printing method. The first approach was performed by a deposition of samaria doped ceria (SDC) interlayer to prevent formation of an insulating phase between 8YSZ/LSCF interface, while the second approach involved adjustment of the anode microporous structure. The electrochemical performance of the fabricated cells was characterized using an impedance spectroscopy technique. The results showed that insertion of the interlayer between the LSCF cathode and YSZ electrolyte could prevent insulating phase formation, giving rise to a significantly decrease in polarization resistance and a much improved power density over the reference cell. In addition, the anode polarization was further reduced with pore enlargement in the anode substrate together with the fine microstructure of anode functional layer.

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1. Introduction

Solid oxide fuel cells (SOFCs) have been proposed to be one of the key energy resources for the future due to their promising efficiency, environmental friendliness, fuel flexibility and low chemical, particulate and noise emission as well as size compaction [1-2]. Operation of cells was based on

*Corresponding author. Tel.: +66-53-91-6263; fax: +66-53-91-6776.
E-mail address: suthee@mfu.ac.th

electrochemical reaction between a fuel and an oxidizing agent, principally oxygen resulting in water and electrical power. Conventionally SOFCs were operated at around 800-1000°C to obtain satisfactory ionic conductivity of the electrolyte layer. This high temperature operation could in turn cause undesirable effects such as high corrosion rate of the cell components and cost ineffectiveness. Lowering the operation temperatures to the intermediate range (600-800°C) by reducing the electrolyte thickness was one way forward to solve this problem.

SOFCs with a porous anode supported design were extensively studied as they showed lower ohmic resistance [3]. In this design configuration, a thin electrolyte film was deposited on the pre-fired porous anode, typically made of Ni/8YSZ composite and co-fired at the electrolyte sintering temperature. The challenge was to maintain porous anode feature while densifying only the electrolyte layer. This cell design was prone to electrolyte cracking during manufacturing due to high thermal expansion coefficient of the NiO compared to that of zirconia electrolyte [1]. Fabrication of this cells based on this design must therefore be done with great care. As the ohmic losses could be greatly reduced in anode supported design, the overall polarization was governed by electrode polarization, depending on the conductivities of anode, cathode and electrolyte/electrode interface. Interaction at 8YSZ-LSCF interface resulting dense insulating phase was reported to inhibit ion transportation across interface. Insertion of a ceria based electrolyte interlayer could prevent an undesirable interfacial reaction [4].

The anode supported design was based on thick anode layer which, however, could contribute greatly to electrode polarization. It was reported that the ideal microstructure of porous anode support was a continuously transitional structure with a thick porous layer of big pores and a thin porous layer of small pores [5]. From our previous results [6], the addition of anode functional layer which exhibited finer microstructure could increase activity at the electrolyte/anode interface. However, a significant electrode polarization resistance of the other components in the cells was still observed [6] due to the interaction between LSCF cathode and 8YSZ electrolyte, giving rise to formation of $\text{La}_2\text{Zr}_2\text{O}_7$ and SrZrO_3 phases at the cathode-electrolyte interface [7].

Electrophoresis deposition (EPD) is a technique widely used in fabrication of ceramic thin films [8]. It provides many advantages such as short formation time, little restriction in the shape of deposition substrate, suitability for mass production, and ease of thickness control [9]. In this study, the electrolyte layer with the thickness less than 10 μm was fabricated by EPD. Attempts to reduce electrode polarization of the cells by (i) insertion of the samaria doped ceria (SDC) interlayer and (ii) adjusting the anode microstructure were addressed.

2. Methodology

Three different cell designs were studied and were coded as follows;

- Cell-A: anode support, anode functional layer | | electrolyte | | LSCF cathode
- Cell-B: anode support, anode functional layer | | electrolyte | | SDC interlayer, LSCF cathode
- Cell-C: anode support, anode functional layer | | electrolyte | | SDC interlayer, LSCF cathode

The anode support was prepared by mixing NiO (Fuel Cell Materials, America) and 8YSZ powders (TOSOH, Japan) at a weight ratio of 50:50. Corn starch (15 wt% of the total solid) was used as the pore former. The anode mixture was milled for 24 h (Cell-A and Cell-B) and 1 h (Cell-C) to obtain two different microstructures. The anode support was subsequently pre-sintered at 900°C for 4 h. The anode functional layer was prepared by dispersion of mixed NiO and 8YSZ powders at the weight ratio of 60:40 in absolute ethanol. The suspension was prepared with powder loading of 10 g/L and ultrasonicated for 30 min before the EPD process at 30 V for 1 min, followed by sintering at 800°C for 2h. The electrolyte layer was then electrodeposited on the top of the functional layer at 30 V for 2 min. These layers were co-sintered at 1400°C for 2 h with a heating rate of 1°C/min. The SDC paste was prepared by mixing the

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