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Preparation of NiO-YSZ Substrate for Electrophoretic Deposition of thin YSZ Film

Malinee Meepho[a]*, Darunee Wattanasiriwech[a], Suthee Wattanasiriwech[a], Pavadee Aungkavattana[b]

[1]*School of Science, Mae Fah Luang University, Chiangrai 57100, Thailand*
[2]*National Metal and Materials Technology Center, Pathumthani 12120, Thailand*

Abstract

In this report, a strategic approach for preparation of dense 8YSZ electrolyte layer on porous NiO-YSZ substrate was proposed. Porosity in the substrate was introduced by mixing corn starch with the starting NiO-YSZ powder. By varying the content of corn starch, porosity and sintering shrinkage of the sintered substrates were studied. The porous substrates were deposited with an electrolyte layer using the Electrophoretic Deposition (EPD) technique. The difference in total sintering shrinkage between the substrate and that of YSZ electrolyte layer was found to be the major cause of cracks and pores in the electrolyte films. Finally, by optimizing the preparation conditions of the porous NiO-YSZ substrates, a dense YSZ film as thin as 2 μm was successfully fabricated.

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1. Introduction

Solid oxide fuel cells (SOFCs) are regarded as a promising power generation technology for the future. The attractiveness of SOFC is its efficient and clean production of electricity from a variety of fuels. 8 mol% yttria stabilized zirconia ceramics (8YSZ) are the most common electrolyte in SOFCs owing to its high oxygen ion conductivity and chemical stability over a wide range of temperatures and oxygen partial pressures [1]. However, it requires sufficiently high operating temperature around 1000^{o}C to achieve the required ionic conductivity of 0.1 S/cm [2]. Current development of SOFCs is focused on lowering the operating temperatures to 600–800°C, since the advantages of a reduced-temperature

* Corresponding author. Tel.: +6-684-177-8008.
E-mail address: mmeepho@yahoo.com.

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operation for SOFCs include wider material selection, better long-term performance, system compactness and potentially reduced fuel cell costs [3]. In order to reduce the operating temperature, one needs either to use materials with higher ionic conductivity, or to reduce the thickness of the electrolyte. The second approach is a favorite way for practical applications, because cheap, reliable and mature electrolyte materials can be used. An anode supported electrolyte thin film configuration has been widely studied. It was claimed that a thinner electrolyte film resulted in lower ohmic losses during cell operation, preferably to below 10 μm [4]. NiO-YSZ is usually used as the anode substrate with YSZ thin film.

Electrophoretic deposition (EPD) process is one of the promising candidates for forming thin film of electrolyte on a porous support. EPD is described as a colloidal processing method in which charged particles dispersed in a liquid medium are attracted and deposited onto an oppositely charged conductive electrode on application of a dc electric field [5]. It has the advantages of short formation time, little restriction in the shape of deposition substrate, suitability for mass production, suitability for deposition of laminates. In addition, EPD offers easy control of the thickness and morphology of the deposited films through simple adjustment of the deposition time and applied potential.

Prerequisite of substrate for a successful EPD are: (1) the substrate should be electrically conductive. However, non-conducting substrate such as NiO-YSZ can be provided electrical conductivity by graphite-coated before EPD process; (2) in case of non-conducting substrate, it must show enough porosity to provide conductive path during deposition process [6]; (3) sintering shrinkage of the substrate should be close to that of electrolyte film. It has to be noted that matching in the sintering shrinkage between an anode substrate and electrolyte is very important for producing a dense electrolyte film. To comply with these requirements, preparation conditions of the NiO-YSZ substrate must be optimized.

This report studied preparation of the porous NiO-YSZ anode for using as a substrate for EPD. Effective parameters on pore shape, porosity, and sintering shrinkage have been investigated. The preparation conditions were studied first using commercial NiO-YSZ powder and then these results were used as the starting point for tuning the sintering shrinkage of the substrate.

2. Experimental

2.1. Preparation of NiO-YSZ substrate

In order to investigate the effect of processing parameters, preliminary experiments were carried out on the commercial powder of NiO-YSZ (NiO:YSZ, wt. ratio = 50:50, American Elements). Corn starch (Sigma-Aldrich) was used as a pore former. Various weight percent values of corn starch (15%, 20%, and 25%, abbreviated as Anode-Ax, x = wt% of corn strach) were prepared to observe the variation of the porosity. Corn starch was mixed with NiO-YSZ powder by ball-milling for 24 h in ethanol medium. Then the mixed powders were dried at 80^{o}C. Porous NiO–YSZ anode substrates were fabricated by pressing the mixed powders at 100 MPa in a 1.5 cm diameter stainless steel die. Finally, the pressed composites were pre-sintered at 900-1100^{o}C for 4 h to remove pore former and provide strength for handling. The dimensions of the green and sintered samples were measured to determine the shrinkage. Porosity of the sintered substrates (1400^{o}C, 2h) was measured by Archimedes method.

For tuning sintering shrinkage between electrolyte and anode substrate, 3 compositions of substrate were varied in order to determine condition that accurately matched the shrinkage profile of the electrolyte layer. Their composition details were shown in Table 1.