Available online at www.sciencedirect.com

SciVerse ScienceDirect

Energy Procedia 34 (2013) 471 – 478

Energy Procedia

10th Eco-Energy and Materials Science and Engineering

(EMSES2012)

Fabrication of samarium doped ceria electrolyte on rough glass substrate with high electrical conductivity by electrostatic spray deposition for intermediate temperature solid oxide fuel cells

Tanapol Chalermkiti[a], Manop Panapoy[a,b], Nattawut Chaiyut[a] and Bussarin Ksapabutr[a,b,*]

[a]*Department of Materials Science and Engineering, Faculty of Engineering and Industrial Technology, Silpakorn University, Nakhon Pathom 73000, Thailand*

[b]*High Performance and Smart Materials, Center of Excellence for Petrochemical and Materials Technology, Chulalongkorn University, Bangkok 10330, Thailand*

Abstract

Samarium-doped ceria (SDC) thin films have been fabricated on unetched and etched glass substrates by an electrostatic spray deposition (ESD) technique for intermediate-temperature solid oxide fuel cells (SOFCs). The influence of substrate surface was studied to prepare a dense and crack-free SDC thin film with high electrical conductivity. With a heat treatment temperature of 400 °C, dense and crack-free SDC thin films were obtained on both unetched and etched glass substrates. The SDC films were nanocrystalline with cubic fluorite structure at the heat treatment temperature of 400 °C. The results revealed that the SDC film deposited on the etched glass substrate was smaller in thickness and higher in electrical conductivity than that on the unetched glass substrate. The maximum in electrical conductivity of the SDC film deposited on the etched substrate was approximately 1.34×10^{-1} S/cm at a low operating temperature of 600 °C.

Selection and peer-review under responsibility of COE of Sustainalble Energy System, Rajamangala University of Technology Thanyaburi (RMUTT)

Keywords: Electrostatic spray deposition; samarium doped ceria; solid oxide fuel cell; thin films

* Corresponding author. Tel.: +66-219-363; fax: +66-219-363.
E-mail address: kbussarin@yahoo.com.

Selection and peer-review under responsibility of COE of Sustainalble Energy System, Rajamangala University of Technology Thanyaburi (RMUTT)
doi:10.1016/j.egypro.2013.06.775

1. Introduction

Solid oxide fuel cells (SOFCs) have attracted much attention as a promising source of electrical power generation due to their high efficiency of converting chemical energy into electrical energy by electrochemical reactions. In recent years, lowering the operating temperature of SOFCs to the intermediate range (500–800 ºC) has become one of the main goals in current SOFCs researches [1–3]. There are typically two effective approaches to reduce the operating temperature: the decrease in electrolyte thickness and the use of alternative electrolyte materials with higher ionic conductivity. Samarium-doped ceria (SDC) is considered to be one of the most promising electrolytes for SOFCs operating at intermediate temperature since it has high ionic conductivity and reduction of the ohmic losses through the cell resulting in higher power outputs [4–5].

Although many studies have reported on the fabrication of ceria based thin films by different processes, attempts are being made to improve their electrical conductivity at lower operating temperature. Compared with other techniques, electrostatic spray deposition (ESD) is a simple setup, with relatively high film growth rate, non-vacuum deposition condition, and a well-controlled structure and composition [6–9]. In our previous studies, dense SDC thin films could successfully be fabricated by ESD technique [10–11]. In this work, the dense SDC thin films are further investigated for the application in the fabrication of thin electrolyte for intermediate temperature SOFCs. The aim of the present study is to investigate the effect of substrate roughness on the morphological features of SDC electrolyte to obtain dense and crack-free thin films with high electrical conductivity at low operating temperatures.

2. Experimental

2.1 Film preparation

$Sm_{0.1}Ce_{0.9}O_{1.95}$ (SDC) films were deposited on unetched and etched glass substrates using a vertical ESD setup described in our previous works [8–11]. The rough glass substrate was prepared by etching glass slide (Sail Brand, China) with laser engraver machine (JCUT-4060, China). Surface roughnesses of both substrates were measured using a Mitutoyo SJ-201 surface roughness tester. The process used to prepare the SDC films on the unetched and etched glass substrates is schematically shown in Fig. 1. The molar ratio of Sm/Ce in the precursor solution is equal to 0.1:0.9. Samarium nitrate hexahydrate ($Sm(NO_3)_3 \cdot 6H_2O$, 99.9% purity, Acros Organics) and cerium nitrate hexahydrate ($Ce(NO_3)_3 \cdot 6H_2O$, 99.5% purity, Acros Organics) were first dissolved in a butyl carbitol-ethanol mixture at ratio of 80:20 v/v.

The above-prepared 0.025 M precursor solution was pumped through the nozzle at a flow rate of 1 ml/h. The suitable deposition temperature for the SDC films was determined by thermogravimetric analysis (Perkin Elmer, TGA7) under an air atmosphere. The TGA result of precursor solution showed major weight losses below 350 °C, which corresponded to the vaporization of solvents and water, and the decomposition of organic components and nitrates in the precursor solution. The deposition temperature in this observation was therefore controlled at 400 °C. The applied voltage, the deposition time, and the nozzle-to-substrate distance were controlled at 19 kV, 2 h, and 7 cm, respectively. The as-deposited films were thereafter heat-treated at 400 °C in an oxygen atmosphere for 4 h to remove any residual carbon.