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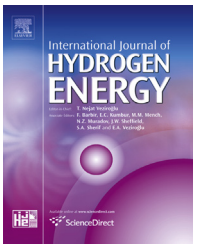

Short Communication

Titanium-substituted lanthanum strontium ferrite as a novel electrode material for symmetrical solid oxide fuel cell

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ABSTRACT

In this study, $La_{0.3}Sr_{0.7}Ti_{0.3}Fe_{0.7}O_{3-\delta}$ (LSTF) is evaluated as a novel symmetrical electrode on SDC($Sm_{0.2}Ce_{0.8}O_{1.9}$)-YSZ(yttria-stabilized zirconia)-SDC three-layer electrolyte. Impedance spectroscopy results indicate the polarization resistances of anode and cathode are 0.18 and 0.04 Ω cm^2 at 900 °C, respectively, suggesting that the micron-scale LSTF possesses high electrocatalytical activity for both oxygen reduction and hydrogen fuel oxidation reactions. A single cell consisting of LSTF symmetrical electrode and YSZ electrolyte support (~400 μm) shows a maximum power density (MPD) of 374 mW cm^{-2} at 900 °C using wet H_2 as fuel. Furthermore, the LSTF electrode shows good short-term stability in wet H_2 at 800 °C and reliable redox stability during the repeated redox cycles. The present results indicate that the $La_{0.3}Sr_{0.7}Ti_{0.3}Fe_{0.7}O_{3-\delta}$ is a promising electrode material for symmetrical SOFCs.

Introduction

Solid oxide fuel cells (SOFCs) have attracted extensive attention over the past few decades due to the distinctive advantages of high energy conversion efficiency, low emission of greenhouse gases and wide fuel flexibility [1–3]. The typical single cells of SOFCs consist of dense yttria-stabilized zirconia (YSZ) electrolytes, Ni-YSZ cermet anode and lanthanum strontium manganite (LSM) cathode [4]. Recently, a new concept of symmetrical SOFC (SSOFC) using the same redox-stable oxide material as both the anode and cathode has been proposed [5,6]. By employing this type of configuration, possible sulfur adsorption and carbon deposition on the active sites of the anode surface can be removed by briefly reversing the gas flow [7,8]. Practically, the development of symmetrical configuration can minimize the interfacial compatibility issues and simplify the fabrication process of the cell components.

The electrodes of SSOFC must be chemically and structurally stable in both reducing and oxidizing atmosphere; meanwhile, the electrodes should be highly sensitive for both

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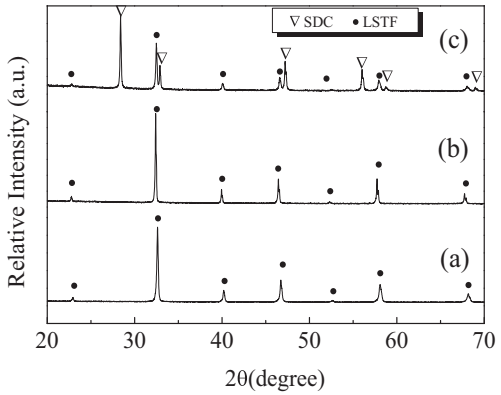

Fig. 1 – XRD patterns of (a) LSTF calcinated in air at 1400 °C for 5 h, (b) LSTF calcinated in humidified 20% H_2/Ar at 800 °C for 20 h, (c) LSTF-SDC mixture calcinated in air at 1300 °C for 10 h.

oxygen reduction and fuel oxidation. In the previous reports, only a few number of materials have been successfully demonstrated as possible electrodes for SSOFCs [7,9–12]. Initially, most of SSOFC electrode materials are derived from lanthanum chromite perovskite oxides that was ordinarily used as the interconnect materials in the SOFC stack [5,13,14]. Subsequently, the potential electrode materials for the symmetrical SOFCs sprang up all over the world including the Fe-based perovskite or double perovskite oxides such as $Sr_2Fe_{1.5}Mo_{0.5}O_{6-\delta}$ [15], $La_{0.4}Sr_{0.6}Co_{0.2}Fe_{0.7}Nb_{0.1}O_{3-\delta}$ [16], $La_{0.7}Sr_{0.3}Fe_{0.7}Ga_{0.3}O_{3-\delta}$ [17], $La_{0.6}Sr_{0.4}Co_{0.8}Fe_{0.2}O_3$ [18], CeO_2–$LaFeO_3$ [19], $SrFe_{0.75}M_{0.25}O_{3-\delta}$ (M = Ti, Zr, V, Nb, Cr, Mo, W) [20] and $LaSr_2Fe_2CrO_{9-\delta}$ [21]. Recently, Fe-based perovskite oxides $SrFe_{1-x}Ti_xO_{3-\delta}$ were developed as both the anode and cathode materials for intermediate-temperature solid oxide fuel cells and showed a relatively high power density performances at 700–800 °C [22,23]. It is reported that the content of rare earth Pr in $Pr_xSr_{0.6}Co_{0.2}Fe_{0.7}Nb_{0.1}O_{3-\delta}$ has a great effect on the SOFC performance and electrode microstructure [24]. Fagg et al. [25] reported that thermal expansion coefficient obviously decreases due to La doping for Fe-substituted Ti-based perovskite oxides. Chou et al. [26], Zhang et al. [27]and Li et al. [28] reported that the average grain size is remarkably reduced for the La doped $BaZr_{0.2}Ti_{0.8}O_{3-\delta}$ and $BiFeO_{3-\delta}$ ceramics. As the above studies mentioned, there have shown that La-doped Fe-based or Ti-based perovskites have several positive effect than $SrTi_{0.3}Fe_{0.7}O_{3-\delta}$ on the microstructure and thermal expansion coefficient, which inspired us via a high level of La substitution on the Sr site.

In this paper, we report the Fe-based perovskite $La_{0.3}Sr_{0.7}Ti_{0.3}Fe_{0.7}O_{3-\delta}$ (LSTF) as a novel SSOFC electrode material. The LSTF shows a good redox stability and excellent electrocatalytic activity in both anode and cathode conditions. The single cells with micro-scale LSTF symmetrical electrodes provide a peak power density of 374 mW cm^{-2} using a 400-μm-thick electrolyte support at 900 °C.

Experimental

$La_{0.3}Sr_{0.7}Ti_{0.3}Fe_{0.7}O_3$ (LSTF) powders were synthesized by a conventional solid–state reaction method. Stoichiometric amounts of La_2O_3 (99.99%, Shanghai Yuelong New Materials Co.Ltd., China), TiO_2 (A.R., Sinopharm Chemical Reagent Co.Ltd., China), $SrCO_3$ (A.R., Sinopharm Chemical Reagent Co.Ltd., China) and Fe_2O_3 (A.R., Sinopharm Chemical Reagent Co.Ltd., China) were weighted and ball-milled for 24 h and then subsequently calcined at 1100 °C for 10 h and 1400 °C for 5 h in air. The 8YSZ (TZ-8Y, Tosoh Corporation, Japan) powder was pressed into pellets under a pressure of ~250 MPa and then sintered at 1400 °C for 6 h to obtain dense YSZ electrolyte (13 mm in diameter and ~400 μm in thickness). In order to eliminate possible harmful solid reaction between YSZ electrolyte and the LSTF anode, SDC ($Ce_{0.8}Sm_{0.2}O_{1.9}$ calcined at 1000 °C for 2 h) barrier layer was coated onto the anode side of the sintered YSZ pellets by slurry spin coating technique and then sintered at 1300 °C for 4 h. Ethyl cellulose (A. R.) in terpineol (A. R.) was used as binder for preparation of electrode slurry. The LSTF electrode slurry was coated on both sides of the YSZ pellets, then co-sintered at 1200 °C for 2 h. The effective area of both anode and cathode was 0.12 cm^2. The commercial powder $(La_{0.75}Sr_{0.25})_{0.95}MnO_{3-\delta}$ (LSM, Ningbo

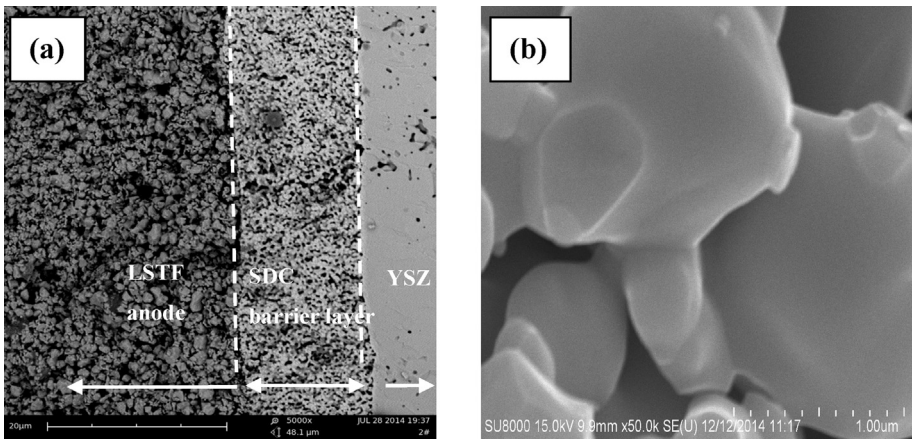

Fig. 2 – SEM image of (a) the anode|barrier layer|YSZ electrolyte portion in electrolyte supported symmetrical cell and (b) as-prepared LSTF electrodes.

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