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Characterization of IT-SOFC non-symmetrical anode sintered through conventional furnace and microwave

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Abstract

This work investigated the mechanical and electrical properties of NiO–SDC/SDC anode sintered by two different methods: in a microwave at about 1200 °C for 1 h and in a conventional furnace at 1200 °C with a holding time of 1 h (total sintering time of 21 h). Nano-powders $Sm_{0.2}Ce_{0.8}O_{1.9}$ (SDC) and NiO were mixed using a high-energy ball mill, followed by the co-pressing technique at a compaction pressure of 400 MPa. No binder was used between the layers. The electrical behaviors of all sintered samples were studied using electrochemical impedance spectra in the frequency range of 0.01–10^5 Hz under 97% H_2–3% H_2O, an amplitude of 10 mV, and at high temperature range of 600–800 °C. Results indicate that the non-symmetrical NiO–SDC/SDC anode achieved through microwave sintering has finer grain size and higher electrochemical performance. However, hardness and Young's modulus increased in the samples sintered through a conventional furnace.

Keywords: A. Microwave processing; A. Sintering; C. Electrical conductivity; E. Fuel cells

1. Introduction

Solid oxide fuel cells (SOFCs), the most important types of energy sources, present several advantages in electrical power generation through direct conversion of chemical energy into electrical energy [1–3]. SOFCs have attracted significant attention because of their extensive applications in high-temperature environments, flexibility in various types of fuels, and environmental safety [4–6]. Among different materials used for SOFCs, samaria-doped ceria (SDC) is one of the most promising. SDC has been extensively used because of its Sm cation and oxygen vacancies that cause transmission to be more active during operation [1,5]. Meanwhile, NiO is commonly used as an anode material in intermediate-temperature solid oxide fuel cells (IT-SOFCs) because of its low cost and excellent catalytic activity toward hydrogen oxidation [5,7].

The fabrication process significantly affects the performance of the cell; that is, reducing the particle size of the anode powder decreases the boundaries between the anode and the electrolyte [1]. All the methods commonly used for fabrication of anode-supported cells are accompanied by certain disadvantages. For example, the screen printing method has difficulty in maintaining control over ink viscosity [8]. The dry ball milling technique appears to be the most feasible method for reducing these disadvantages and increasing the boundaries between the elements because it results in greater surface area of the particles, changes in the morphology of the elements, and decrease in particle size [9,10]. Heat treatment is applied on the co-pressed pellets to produce pellets with well-defined atomic combination between NiO–SDC and SDC powders [11].

In recent years, microwave-assisted heating has been considered superior to conventional furnace heating because of its greater energy capacity, rapid heating rate, improved microstructure, and less shrinkage [12,13]. The use of conventional furnace is a more time- and energy-consuming compared with the use of a

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microwave. Microwave has higher heating speed and lower thermal stress than conventional furnace [14,15]. Microwave heating is an extremely fast method for ceramics, so the grain size is smaller than the grain size of the samples heated in a conventional furnace [16–18]. Likewise, the mechanical behaviors of the SOFC materials are primarily influenced by the coarse and fine structures of SOFCs [19,20]. The electrical resistance of the pellets is typically measured using electrochemical impedance spectroscopy (EIS) and Nyquist plot to determine the responses of the material to the current density passage and the voltage drop [21,22]. Several researchers have recently investigated the anode conductivity of air and hydrogen gas to study the effect of the fabrication process and the material properties of SOFC cells [8,23].

This work focuses on heat treatment and characterization of SOFC samples fabricated through two methods, namely, conventional and microwave furnace. This work aims to understand the effect of manufacturing strategies on the mechanical properties and electrical conductivities of the SOFC samples.

2. Experimental procedures

NiO and $Ce_{0.8}Sm_{0.2}O_{1.9}$ powders (Sigma Aldrich, USA) with grain size below 50 and 60 nm, respectively, and weight ratio of 70:30 wt% were mixed and then ball milled (Fritsch Pulverisette 6, Germany) at a speed of 200 rpm for 20 h under ball-to-powder mass ratio of 10:1 [24].

The electrode and electrolyte powders were subjected to the co-pressing process to evaluate the anode performance [25–27]. Polyethylene glycol binder was applied to the mold prior to exposure to high compaction pressure at room temperature [28,29]. To prepare the thin film of SDC electrolyte on top of the anode side, SDC powder was added to the metal die, which was then uniaxially co-pressed (100 kN; Zwick-Roell, Germany) at 400 MPa to generate green pellets of NiO–SDC/SDC of the anode substrate (diameter: 13 mm; thickness: 2 mm). The process is shown schematically in Fig. 1e. The samples (five samples for each method) were heated using two methods, namely, microwave furnace heating using a 6 kW, 2.45 GHz, multimode cavity microwave for 1 h at about 1200 °C and a

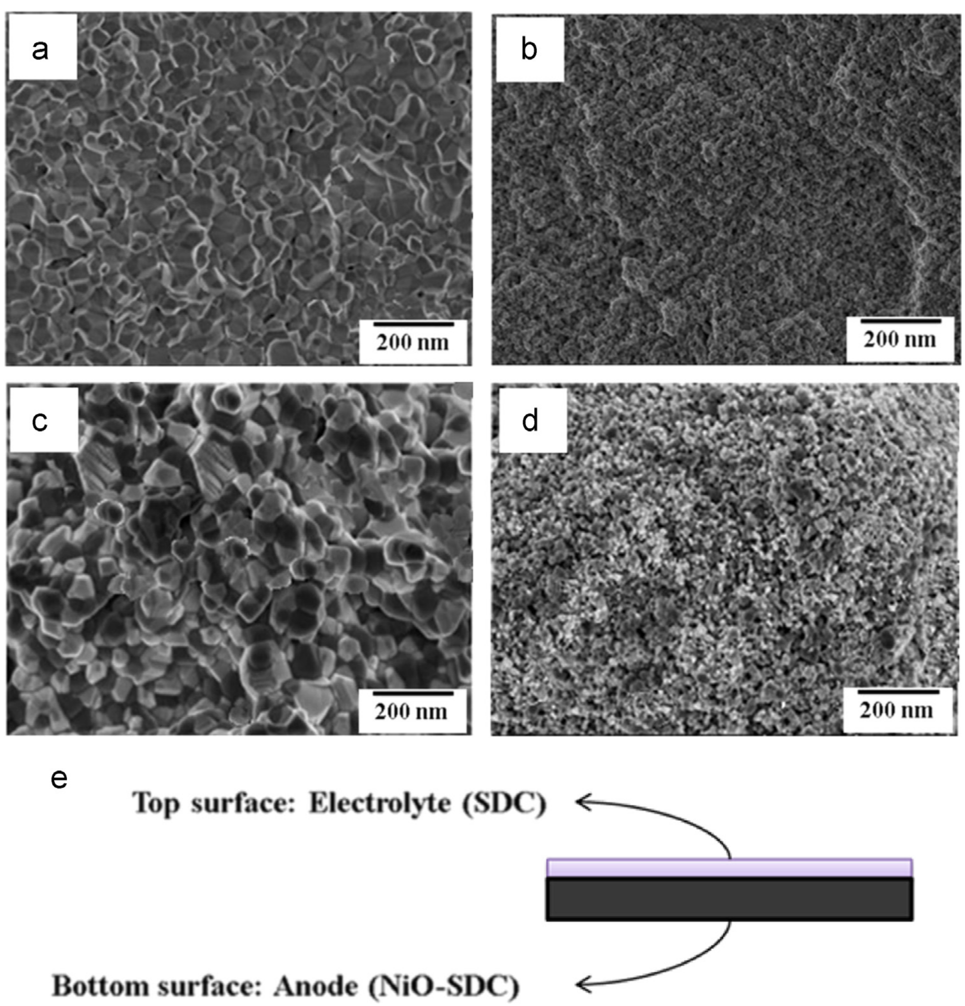

Fig. 1. FE-SEM morphology of the pellets: electrolyte surface (a) in the conventional furnace and (b) in the microwave furnace; anode surface (c) in the conventional furnace and (d) in the microwave furnace and (e) the schematic of the co-pressed sample.