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Effects of dual porosity honeycomb structure in SSC–SDC composite cathode for SOFCs

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ABSTRACT

This study proposed an effective structure for the cathode of SOFC to reduce resistance, the honeycomb structure with dual porosity (micro and macro pores). A $Sm_{0.5}Sr_{0.5}CoO_{3-\delta}$ (SSC) $-Sm_{0.2}Ce_{0.8}O_{2-\delta}$ (SDC) composite cathode for solid oxide fuel cells, with a noble honeycomb structure comprising of nano and micro-sized pores, was fabricated by electrostatic slurry spray deposition (ESSD). The macro-pores distribute in the whole film with size range of 5 –20 μm and micro-pores were formed throughout the skeleton with the size under 1 μm. This dual porosity composite cathode from interface to surface of the electrode was deposited by electrostatic slurry spray deposition (ESSD). Its electrochemical property was evaluated using electrochemical impedance spectroscopy and turned out to be enhanced compared to a conventional porous structure of cathode. The polarization resistances were significantly decreased with increasing measurement temperature.

Introduction

In spite of significant advantages such as fuel flexibility, fuel efficiency, inexpensive catalysts and environmental compatibility [1,2], solid oxide fuel cell (SOFC) still has limitations in commercialization due to the lack of price competency. High operation temperature of SOFC renders the disadvantages hampering commercialization as well as the abovementioned benefits. Peripheral components require high durability for high temperatures, which means the price of components are obliged to increase. Therefore, various efforts for reducing manufacturing costs have been examined by many researchers. One of the representative approaches is reducing operation temperatures of the SOFC from the range of 800–1000 °C to 600–800 °C or even below [3–5]. Reducing operating temperature offers several benefits such as the reduction of harmful reactions between the components, thermal degradation, or mechanical failure by thermal expansion mismatch [6,7]. If the temperature is lower, the materials for the cell components and peripheral materials such as cell interconnection and sealing materials could be selected with mitigated standards. Therefore, intensive investigations have been carried out to reduce the operating temperature. Unfortunately, this is not an easy solution because severe problems such as increased electrode and electrolyte resistance are encountered as the temperature

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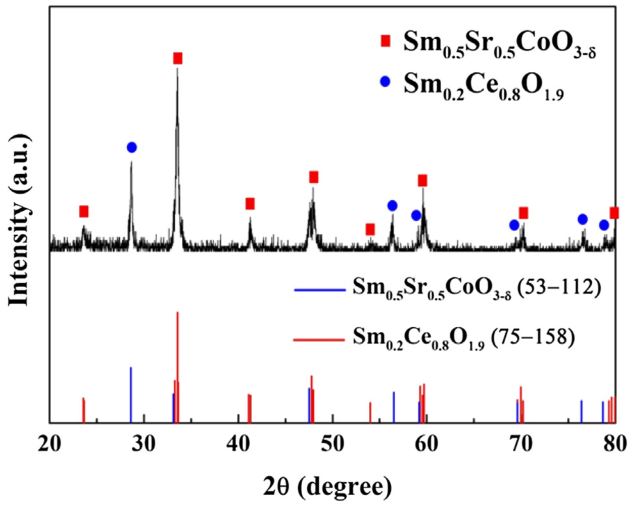

Fig. 1 – X-ray diffraction patterns of the fabricated SSC–SDC composite cathode; square-type indexed peak is SSC and circle-type indexed peak is SDC.

becomes lower [3,8,9]. The polarization resistance in the cathode side, in particular, is dominantly increased with the decrease of the operating temperature. In recent years, structural modification of the cathode, e.g. bi-layer cathode [3,5,8,10], functionally gradient [11–13] and nano-scaled cathode [14,15] has been examined by many research groups. We have also reported that the electrochemical performance of the SOFC is appreciably improved when a double layer cathode [3], nano-porous at the interface between electrolyte and electrode and micro-porous near to the surface, and particle embedded fiber cathodes [9] are employed.

In this study, we propose an effective structure for the cathode of SOFC to reduce resistance, the honeycomb structure with dual porosity (micro and macro pores). This novel composite cathode was fabricated by electrostatic slurry spray deposition (ESSD) method and its electrochemical property was evaluated through electrochemical impedance spectra.

Experimental and procedures

To prepare a $Sm_{0.5}Sr_{0.5}CoO_{3-\delta}$(SSC)-$Sm_{0.2}CeO_{3-\delta}$(SDC) composite cathode, the SDC precursor solution was firstly prepared. Samarium chloride hexahydrate ($SmCl_3 \cdot 6H_2O$, >99.9%, Sigma–Aldrich Co.), Cerium nitrate hexahydrate ($Ce(NO_3)_2 \cdot 6H_2O$, >99.9%, Sigma–Aldrich Co.) were dissolved in a solvent consisted of isopropyl alcohol (IPA) and toluene, then small amount (3 wt.%) of polyvinyl butyral (PVB) was added in the solution. After entire dissolution of the PVB, the SSC (Winner Tech., Korea) nanopowder was added in the prepared SDC solution. Finally, the SSC-SDC composite slurry was stirred with the ultra-sonication method for 1 h to enhance the dispersion stabilization of the slurry.

The ESSD system was applied to fabricate the SSC-SDC composite cathode with dual porosity honeycomb structure. The schematic diagram was described in elsewhere [16]. A whole deposition process for the composite cathode was conducted in an ambient atmosphere. The SSC-SDC composite slurry was sprayed and deposited onto a SDC pellet which was heated at 200 °C, then, the as-deposited composite film was subsequently sintered at 900 °C for 5 min in a microwave furnace (2.45 GH, 2 kW).

The microstructure and crystallinity of the prepared SSC-SDC composite cathode were examined with scanning electron microscopy (SEM, JEOL JCM-5700) and X-ray

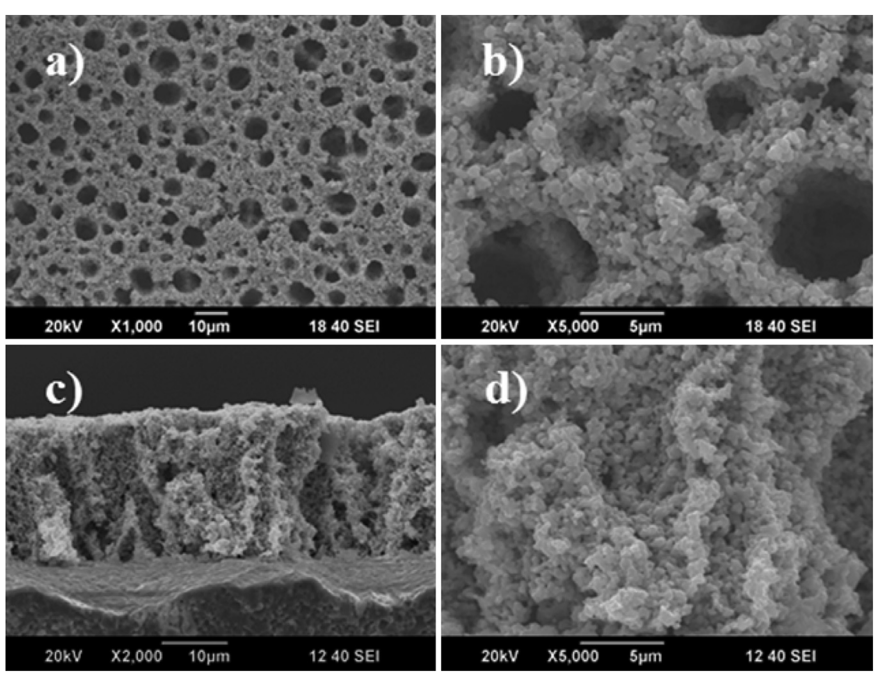

Fig. 2 – Surface and cross-sectional morphologies of the dual pore honeycomb composite cathode; (a-low mag, b-high mag) surface and (c-low mag, d-high-mag) cross-sectional.

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