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Effect of strontium content on microstructure in $(La_xSr_{1-x})FeO_3$ ceramics

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Abstract

The effect of strontium content on microstructure in $(La_xSr_{1-x})FeO_3$ (LSFO) ceramics was investigated. It was observed that grain size increased as strontium content increased: mean grain sizes of 2.4 μm for 60% strontium content and 6.1 μm for 80% strontium content were observed in LSFO ceramics after 1250 °C/4 h sintering.

Keywords: B. Microstructure; D. Perovskite; (La,Sr)FeO_3; Solid oxide fuel cell

1. Introduction

Research and development of solid oxide fuel cells (SOFCs) has received much attention recently [1–4]. SOFCs are energy-conversion devices that produce electric power via the electrochemical combustion of fuel. There are three parts in a SOFC, including the electrolyte, the anode, and the cathode. A dense electrolyte is needed to prevent gas mixing, whereas the anode and cathode must be porous to allow gas transport to the reaction sites. The electronic and ionic conductors $(La_xSr_{1-x})CoO_3$ (LSCO) and $(La_xSr_{1-x})MnO_3$ (LSMO) are receiving great attention as cathode and interconnection materials for SOFCs [5–9]. Increased porosity in such a cathode increases gas transport to the reaction sites in the electrolyte. In this study, the effect of strontium content on microstructure in $(La_xSr_{1-x})FeO_3$ ceramics has been investigated.

2. Experimental procedure

$(La_xSr_{1-x})FeO_3$ with $x = 0.2$, 0.25, 0.35, and 0.4 were prepared by solid state reaction from oxides and carbonates. The powder mixtures were milled in distilled water with alumina balls for 24 h. After drying, the powder was calcined at 900 °C for 4 h with a heating rate of 10 °C/min. The calcined powder was then milled and pressed to pellets 12 mm in diameter and 2 mm thick. The pellets were sintered at 1150 and 1250 °C for 4 h with a heating rate of 10 °C/min in air atmosphere. The pellets were cooled at a rate of 10 °C/min after sintering soak time. Microstructures were analyzed by scanning electron microscopy (SEM).

3. Results and discussion

SEM photographs of the as-fired LSFO ceramics after 1150 °C/4 h sintering are shown in Fig. 1. Porous pellets with sub-micron grains were formed in these LSFO ceramics. This means that 1150 °C/4 h sintering is not high enough for grain growth and densification in LSFO ceramics. Some regions of blurry grains (RBG) without clear grain boundaries formed in LSFO at $x = 0.25$, 0.35, and 0.4. The size of RBG decreased as strontium content decreased. SEM photographs of the as-fired LSFO ceramics after 1250 °C/4 h sintering are illustrated in Fig. 2. Pores were found in LSFO ceramics with $x = 0.2$ and 0.25. Increased porosity is needed in a cathode of SOFC to increase the gas transported to the reaction sites in the electrolyte. Pores were not found in LSFO ceramics with $x = 0.35$ and 0.4. The mean grain sizes of LSFO ceramics are listed in Table 1. Mean grain size of 6.1 μm for 80% strontium content and 2.4 μm for 60% strontium content were observed

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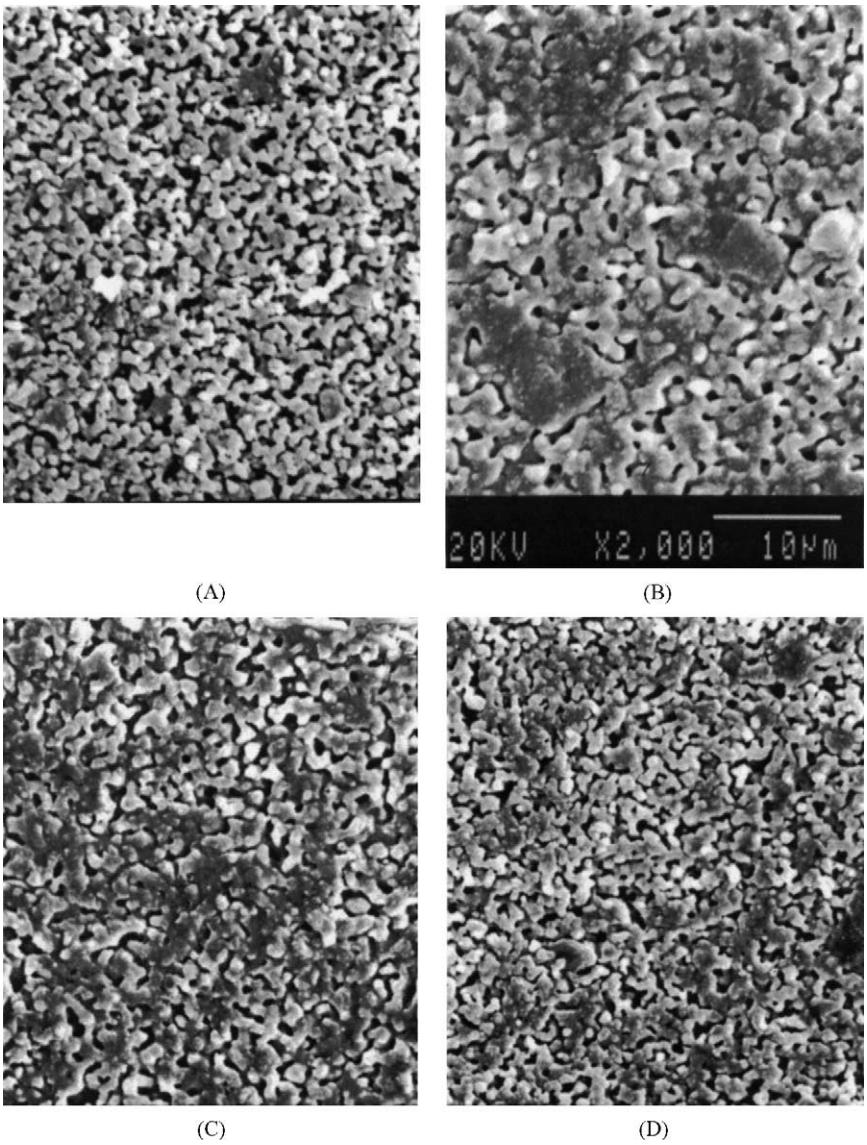

Fig. 1. SEM photographs of the as-fired $(La_xSr_{1-x})FeO_3$ ceramics after 1150 °C/4 h sintering with x = (A) 0.2, (B) 0.25, (C) 0.35 and (D) 0.4. (with a magnification value of 2000).

in LSFO ceramics after 1250 °C/4 h sintering. Grain size increased as strontium content increased. This is the same as in our other studies of $(La_xSr_{1-x})CoO_3$, $(La_xSr_{1-x})MnO_3$ ceramics, and in Chou's study [10] of $La_{1-x}Sr_xCo_{0.2}Fe_{0.8}O_3$ ceramics. In $(La_xSr_{1-x})CoO_3$ ceramics, 6–10 μm RBG size for 60% and 15–25 μm for 80% strontium content formed after 1250 °C/4 h sintering. While in $(La_xSr_{1-x})MnO_3$ ceramics, mean grain size did not exceed 2 μm with a strontium content between 60 and 75% after 1400 °C/4 h sintering. This means lower temperature is needed for grains to grow in $(La_xSr_{1-x})CoO_3$ ceramics. Higher temperature is needed in $(La_xSr_{1-x})MnO_3$ ceramics. In Chou's study of $La_{1-x}Sr_xCo_{0.2}Fe_{0.8}O_3$ ceramics, mean grain size increased about 12 times from 1.8 μm for 20% strontium content to 21.9 μm for 80% strontium content after 1250 °C/4 h sintering. All of these studies show that more strontium content makes grain growth easier at the same sintering temperature.

Table 1
Mean grain size of $(La_xSr_{1-x})FeO_3$ ceramics sintered at 1250 °C for 4 h (in μm)

Lanthanum content	0.2	0.25	0.35	0.4
Grain size	6.1	4.7	3.6	2.4

4. Conclusion

Mean grain size of 6.1 μm for 80% strontium content and 2.4 μm for 60% strontium content were observed in LSFO ceramics after 1250 °C/4 h sintering. Grain size in-

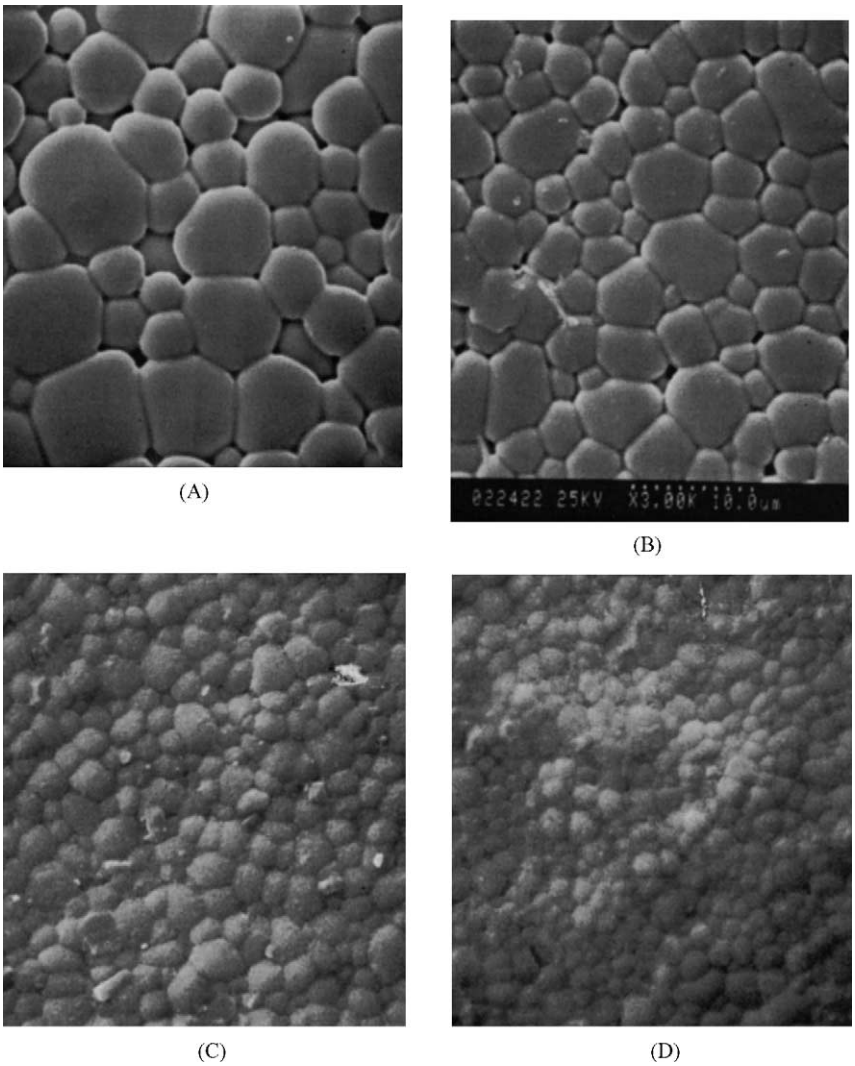

Fig. 2. SEM photographs of the as-fired $(La_xSr_{1-x})FeO_3$ ceramics after 1250 °C/4 h sintering with $x =$ (A) 0.2, (B) 0.25, (C) 0.35 and (D) 0.4. (with a magnification value of 3000).

creased as strontium content increased. This is the same as in $(La_xSr_{1-x})CoO_3$ and $(La_xSr_{1-x})MnO_3$ ceramics.

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References

[1] N.Q. Minh, High-temperature fuel cells. Part 2. The solid oxide cell, CHEMTECH 21 (1991) 120–126.
[2] T. Yoshida, T. Hoshina, I. Mukaizawa, S. Sakurada, Properties of partially stabilized zirconia fuel cell, J. Electrochem. Soc. 136 (1989) 2604–2606.
[3] A.V. Virkar, Theoretical analysis of solid oxide fuel cells with two-layer composite electrolyte: electrolyte stability, J. Electrochem. Soc. 138 (1991) 1481–1487.
[4] N.Q. Minh, Ceramic fuel cells, J. Am. Ceram. Soc. 76 (1993) 563.
[5] P. Holtappels, C. Bagger, Fabrication and performance of advanced multi-layer SOFC cathodes, J. Eur. Ceram. Soc. 22 (2002) 41–48.
[6] Y. Teraoka, H.M. Zhang, K. Okamoto, N. Yamazoe, Mixed ionic-electronic conductivity of $La_{1-x}Sr_xCo_{1-y}Fe_yO_{3-\delta}$ perovskite-type oxides, Mater. Res. Bull. 23 (1988) 51–58.
[7] K. Huang, M. Feng, J.B. Goodenough, M. Schmerling, Characterization of Sr-doped $LaMnO_3$ and $LaCoO_3$ as cathode materials for a doped $LaGaO_3$ ceramic fuel cells, J. Electrochem. Soc. 143 (1996) 3630.
[8] C.Y. Tsai, A.G. Dixon, Y.H. Ma, W.R. Moser, M.R. Pascucci, Dense perovskite, $La_{1-x}A_x'Fe_{1-y}Co_yO_{3-\delta}$ (A′ = Ba, Sr, Ca), membrane synthesis, applications, and characterization, J. Am. Ceram. Soc. 81 (6) (1998) 1437–1444.
[9] C.C. Chen, M.M. Nasralla, H.U. Anderson, M.A. Alim, Immittance response of $La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_3$ based electrochemical cells, J. Electrochem. Soc. 142 (2) (1995) 491–496.
[10] Y.S. Chou, J.W. Stevenson, T.R. Armstrong, L.R. Pederson, Mechanical properties of $La_{1-x}Sr_xCo_{0.2}Fe_{0.8}O_3$ mixed-conducting perovskites made by the combustion synthesis technique, J. Am. Ceram. Soc. 83 (6) (2000) 1457–1464.