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The Preparation and Characterization of LSCF and LCCF Perovskite Cathode Electrode for Solid Oxide Fuel Cell Applications

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Abstract

In this paper, LaSrCoFe and LaCaCoFe powders compositions were prepared with the solid state reaction. The crystal structure of powders perovskite possess hexagonal type crystal lattice according to the literature survey. Crystallographic and micro structural properties of the produced powder were characterized by XRD. Lattice parameter for LSCF a=5.471 Å,c=13.47 Å and for LCCF a=5.435 Å, c=13.23 Å. Cathode electrode which is small crystal particle was formed into a thin film. The conductivity of the thin film LSCF was measured by four probe conductive.

Keywords — Solid Oxide Fuel Cells, SOFC, Cathode Electrode, Thin Film, Spin Coating, Perovskite

1 Introduction

A solid oxide fuel cell is an electrochemical device that provides efficient and clean power generation. In solid oxide fuel cells, the electrode material must have mixed electronic and ionic conductivity [1]. In the solid oxide fuel cells, the cathode is the material where pure oxygen or oxygen from air is reduced through the following electrochemical reaction [2]. The electronic conductivity in the cathode is particularly important for cathode supported type cells, because of their electronic current path is very long [3]. There has been significant progress in reducing the operation temperature of SOFC from high temperature of 1000ºC to intermediate temperature range of 600 to 800 ºC [4].

Oxide phases with mixed oxygen ionic and electronic conductivity are of great interest for low temperature electrochemical applications, for example they can be used as electrodes of solid oxide fuel cells, oxygen separation and sensors [5,6]. Perovskite type oxides with oxygen ion and electron conductivity are well-known as the most commonly used cathode materials [6]. The perovskite structures ABO_3, in which A is a rare-earth element and B is a transition metal (A=La, Pr, Nd, and B= Mn, Co, Fe) [7].

In this paper, the LSCF and LCCF powders were prepared with the solid state reaction. Thin films of cathode materials which is small crystal particle were produced by the spin coating method. The electrical conductivities were measured with four probe d.c. method. Crystallographic and micro structural properties of the produced thin layers were characterized by XRD equipments.

2 Materials and Methods

LSCF and LCCF powders were synthesized classic solid state reaction method. Samples of $La_{0,6}Sr_{0,4}Co_{0,2}Fe_{0,8}$ and $La_{0,6}Ca_{0,4}Co_{0,2}Fe_{0,8}$ were prepared appropriate amounts of La_2O_3,Fe_2O_3, $SrCO_3$, Co_2O_3 and $CaCO_3$. Starting mixtures were ground in ethanol using a ball mill at 2 hours. The dried mixtures of LSCF and LCCF were ground in an agate mortar and preliminary heat treatments were applied in alumina crucible at 900 °C for 12 h. After heat treatment the powders were re-ground and calcined in air 1200°C for 12 h.

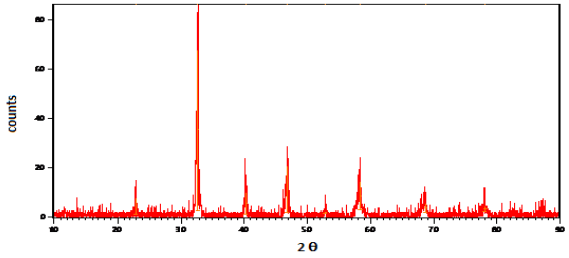
LSCF Cathode for SOFC were prepared by spin coating. The process started with dense slurry consisting of a mixture. The thin film electrolyte coating mix of organic binder system were prepared using solid electrolyte powder, ethanol, toluene, ethyl cellulose, DBF and α-terphinol using by solvent, binder, plasticizer, dispersant, respectively. The mixture was returned and homogenized at

jar mill for 12 hours. The coating mixture which homogenized mixture beherglass taken in magnetic stirrer was made from was dense suspension. That dense suspension was coated on a glass substrate by spin coater After each coating was expected layer to dry. From now on, coated layer were stripped from the glass surface. The coated layers of thin film were fired at 1200 ºC for 4 h to preliminary heat treatment. The raw layers sintered on alumina tray at 1200 ºC in air for 12 h and were fabricated ceramic thin films cathode.

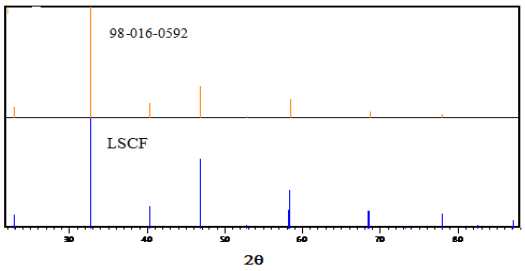
3 Results and Discussion

The powder X-ray diffraction patterns were recorded as PANalytical Empyrean with Cu Kα (λ=1.54 Å) at 45 kV voltage and 40 mA current. A scan rate, step size and 2θ range of the samples was 0.1deg/s, 0.013° and 10-90º, respectively.

The measured x-ray diffraction patterns of LSCF and LCCF type perovskites are shown in Figure 1 and Figure 2. These measurements indicated that single phase. All of XRD peaks of this material were indexed in hexagonal crystal lattice and cell parameters were calculated and showed Table 1. These calculated constants were correct with the literature values ICSD 98-016-0592 and 98-024-7306, respectively.

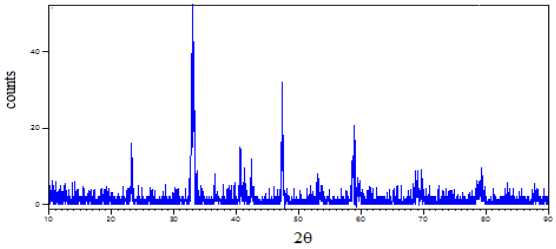


(a)

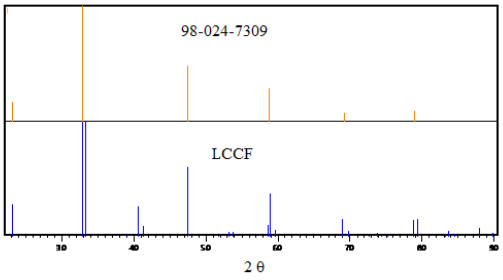


(b)

Figure 1. (a) and (b)XRD patterns of LSCF.



(a)



(b)

Figure 2 (a) and (b) XRD patterns of LCCF.

The calculated lattice parameters of LSCF and LCCF samples are shown in Table 1. The crystallite size and lattice strain were estimated from using Scherrer equation of X'Pert High Score Plus software;

$$D = \frac{0.89\,\lambda}{\beta\,cos\theta} \qquad \beta = \beta_{obs} - \beta_{std} \tag{3.1}$$

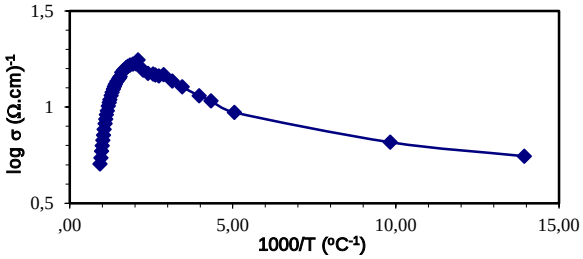
$$\varepsilon = \frac{\beta}{4\tan\theta} \qquad \beta = \sqrt{(\beta_{obs}^2 - \beta_{std}^2)} \tag{3.2}$$

where D crystalline size, ε is the lattice strain, λ is the X-ray wave lengt hangularline, β full width at half maximum (FWHM) and θ the Bragg'sangle. The silicon standard is using the instrumental correction with FWHM value. The calculated crystalline size of LSCF and LCCF are 48.4 and 74.3 nm, respectively. The calculated strain of LSCF and LCCF are 0.32 and 0.64 %, respectively. This result summarized at Table 1.

Table 1. Crystalline properties for LSCF and LCCF

Samples	Crystal System	Lattice parameters (Å)		Space Group	Volume (Å)3	Crystalline size (nm)	Micro strain (%)
		a	c				
LSCF	Hexagonal Primitive	5.471	13.47	P 6	349.22	48.4	0.32
LCCF	Hexagonal Primitive	5.435	13.23	P 63/mmc	339.74	74.3	0.64

Because LSCF crystal size smaller than LCCF, LSCF 's thin film was made. Electrical conductivity plots versus temperature of thin film LSCF is given in Fig. 3. As seen in figures, the conductivity of thin films increases with increasing temperature. It is expeced that this is related to the interstitial oxygen ionic mobility rises with the temperature. The



maximum electrical conductivity was seen 600°C range for 800°C.

Figure 3. Total conductivity of thin film LSCF

Table 2. $LaSrCoFeO_3$ thin film mixing rations

Powder cathode	Toluen (mL)	Ethanol (mL)	Ethyl cellulose (g)	α-terpinole (g)	DBF (µL)	Cathode amount (g)
LaSrCoFeO3	16	4.95	0.4050	0.04500	250	4.5000

4 Conclusion

This study useful and applicable cathode electrode was developed for SOFC fabrications. The observed micro structural properties, crystallographic features of LSCF and LCCF. The thin film was produced of LSCF because the particle size smaller than LCCF. Thin film of LSCF cathode powders was prepared by using an organic binder system on the spin coater system. Than, the electrical conductivity degree of produced LSCF thin layer was observed as the positive properties for the performance of SOFC system. Therefore, LSCF system can be an alternative cathode electrode for the ordinary used electrodes. Because the improvement electrode has many advantages and it can be used as a cathode electrode in SOFC systems which have a high efficiency of electrochemical energy production.

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