

Development and performance of perovskites as a cathode with application towards gas cleaning.

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Abstract— *The solid oxide fuel cell (SOFCs) is a new alternative energy and environmentally friendly. There are three major elements in SOFC which are anode, cathode and electrolyte. As perovskite is one of the major materials in SOFC where used as a cathode. However, the development of high-quality performance SOFC might be facing a difficulty because of its development quite costly. This study is to determine the electrical conductivity of cathode achieved and to fabricate SOFC cathode using combination of polyvinyl alcohol as a binder and starch. During this study, three different weight percentage of starch is used to determine the electrical conductivity. The result showed all the samples are classified as crystallite thus can use Scherrer equation to calculate the average crystallite size. The average crystallite sizes are decreasing as the starch weight percentage increase. For conductivity test, there is unavoidable error during the test. The conductivity of LSCF pellet should be increase as the weight percentage of starch increase. The result showed fluctuation resulting from the catalytic activity for oxygen reduction of LSCF cathode reaction. Thus, the objectives of this study not fully achieved due the unavoidable error lead to fluctuation result.*

Keywords— *Perovskites, Solid oxide fuel cells (SOFCs), Cathode, Lanthanum strontium cobalt ferrite, cathode*

I. INTRODUCTION

An electrochemical device that can convert chemical energy to electricity with high efficiency is called a fuel cell. The one of the usual fuel cell type which is solid oxide fuel cell have a few advantages than other types of fuel cell. Most of the fuels from hydrocarbon to hydrogen can be used to generate SOFC with minimum fuel processing [1]. It was quite convenient because this type fuel cells can be operated using variety of fuels and used minimum fuel consumption.

SOFC has basic structures consist of electrolyte, anode and cathode. The layer of electrolyte must be from a dense ceramic and the usual materials used is yttria stabilized zirconia (YSZ) or gadolinium doped ceria (CGO). For the electrode, it must be

porous. The usual materials for constructing anode are Ni-YSZ and Ni-CGO and for cathode the materials are LSM-YSZ and LSCF [2]. Most of the research suggested these materials used for electrode and cathode as they are mainly used in the construction.

The operating temperature for SOFC range from low to high. As the development of high-performance electrolyte and electrode is very important in reducing the operating temperature to the low and intermediate temperature range between 500 °C to 700 °C. The result from the reducing temperature lead to the cell parts can be easily and less expensive produced [3]. For the optimum result, it is advisable to use intermediate temperature to fabricate the cathode because the cathode structure may be degraded due to high temperature.

For example, YSZ electrolyte must be heated up to 900 °C to 1000 °C to provide enough oxygen ion conductivity and the costly material used to interconnect the fuel cell. All of this cost can be decrease by reduced the operating temperature to between 600 °C to 800 °C [4]. The increase of system efficiency can be achieved by reducing operating temperature which resulting the system can be used for a longer time. Fabrication cost can be reduced if the agreed operating temperature lowered to 500 °C- 800 °C [5].

Nowadays, the YSZ and CGO widely used as electrolyte for intermediate SOFC (IT-SOFC) [5.] The optimum operating temperature for electrolyte depends on the material used during the development of SOFC. The temperature of 700 °C used for yttria stabilized zirconia (YSZ) and 500 °C for gadolinium doped ceria (CGO) [6].

The mechanism of SOFC started when the oxygen ionic conducting oxide acted as electrolyte then diffuse through the anode lead by the differences in oxygen chemical potential between air and fuel of the cell, which oxidize chemically of the fuel such as hydrocarbon and oxygen. Next, the electron flow through the circuit to the cathode to complete the circuit [3].

The crucial component of SOFC is cathode where the oxygen reduction reaction occurs (ORR) in order to determine the power output and cell stability [7,8]. Cathode also have a few promising properties such as rapid surface electrochemical reaction, very stable at high temperature in oxidizing surrounding, and fast ionic transportation [9].

LSM and LSCF known to be used to fabricate cathode in SOFC. From the research, LSM showed lower ionic conductivity and lower oxygen surface energy kinetic than LSCF [10]. Meanwhile, the LSCF have high ionic and electrical conductivity [11]. In this study, the only focus will be on LSCF only to investigate the how LSCF act as cathode.

II. METHODOLOGY

A. Fabrication of cathode

Three different starch concentration of 2 wt%, 10 wt% and 15 wt% were mixed with the LSCF using polyvinyl alcohol as a binder and were pressed as pellets. Then the pellets were sintered

for 2 hours at 1000 °C. The stainless steel with grade of SS430 was used to come in contact with the pellets. The pellets and stainless steel contacted without pressure and sintered again at 700 °C for 2 hours. The pellets will be tested by the impedance spectrometer for electrical conductivity test.

B. Structure and crystallite size

The physical properties of the samples depending on the crystallite size. The equipment used to measure the crystallite is X-ray powder diffraction (XRD) [12]. XRD known as the non-destructive procedure to characterize crystallite and give information about structural parameter such as average crystallite size [13].

C. Electrochemical impedance characterization

The electrochemical impedance spectroscopy (EIS) experiments were performed by using an Hioki 3532-50 LCR HiTester to test the electrochemical impedance of the samples. The EIS used to characterize the electrochemical systems. The electrochemical impedance measurement is tested by applying an AC potential to an electrochemical cell [14].

III. RESULTS AND DISCUSSION

A. The flowchart of cathode fabrication

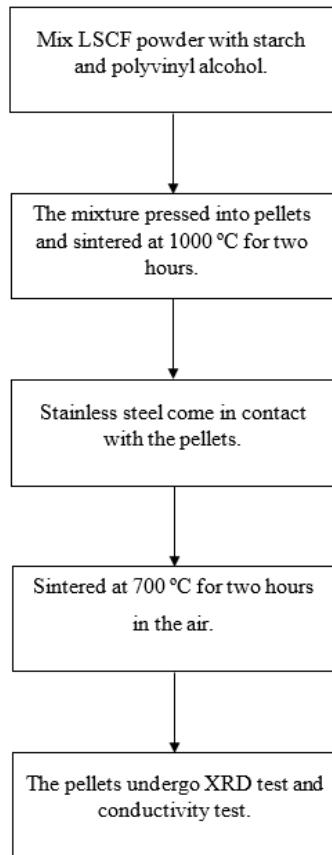
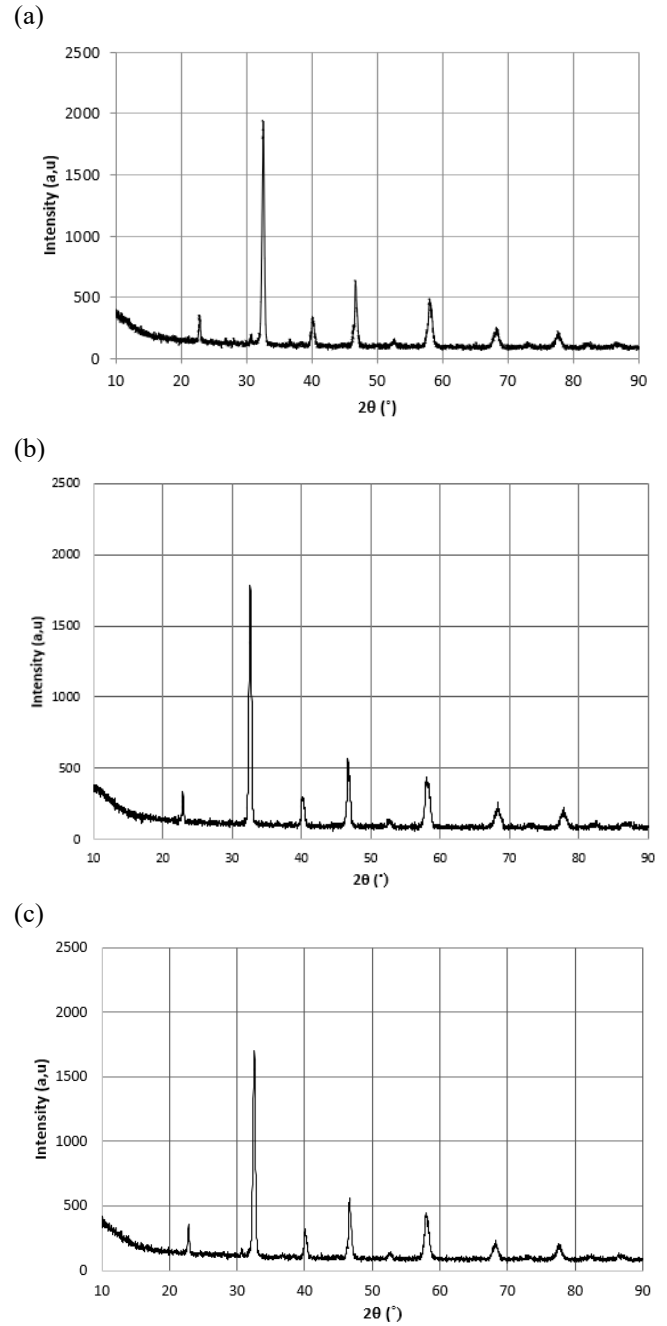


Fig 1: The flowchart of LSCF cathode fabrication.

The Fig 1 showed the flow of the experiment before undergo test to measure physical properties of the samples and the conductivity of the samples.

B. The effects of different starch concentration to the physical properties



(d)

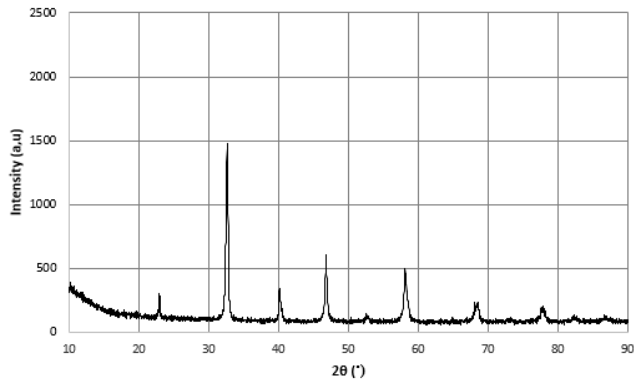


Fig 2: The structure of LSCF cathode for different weight percentage of starch (a) 2% (b) 10% , (c) 15% and standard LSCF powder.

The structure from Fig 2 showed the similarity of the elements in the LSCF cathode. Each of the peak represent elements exists in the cathode which are mainly lanthanum, strontium, cobalt and ferrite. Based on the Fig 2, the position of each peak quite similar to each other even though the cathode fabricate from the different starch weight percentage. The different starch weight percentage still maintained the main element in LSCF without changing its structure too much.

Before calculating the average size, it already confirmed that all the samples are crystallite. From all the graphs plotted in Fig 2, the average crystallite size can be calculated using Scherrer's formula below:

$$FWHM = \frac{k \lambda}{D \cos \theta} \quad (1)$$

FWHM is the full width at half-maximum of the diffraction peak, k is the constant [15] , D is the crystallite size and θ is the Bragg angle. Some research argues this equation only valid for crystallite size up to 200 nm [16]. The calculated average crystallite size using Scherrer equation shown in the Table 1 below with value of $k = 0.94$

Table 1: Average crystallite size at different starch weight percentage.

Starch weight percentage, wt %	Average crystallite size, D_{xrd} , nm
2	50.45
10	49.83
15	48.91

The average crystallite size for LSCF cathode was decreasing from 50.45 nm to 48.91 nm with the increasing of starch weight percentage. This happened may due to the degradation of samples during the heating process. With the decreasing of average size, the texture of samples also become finest by obseravtion for the 15wt% of starch.

The Scherrer equation in this study because this equation have more accuracy than dynamic theory of XRD. The acceptable range of validity for crystallite size up to 600 nm with an acceptable error [17].

C. The effects of different starch concentration to the electrical conductivity

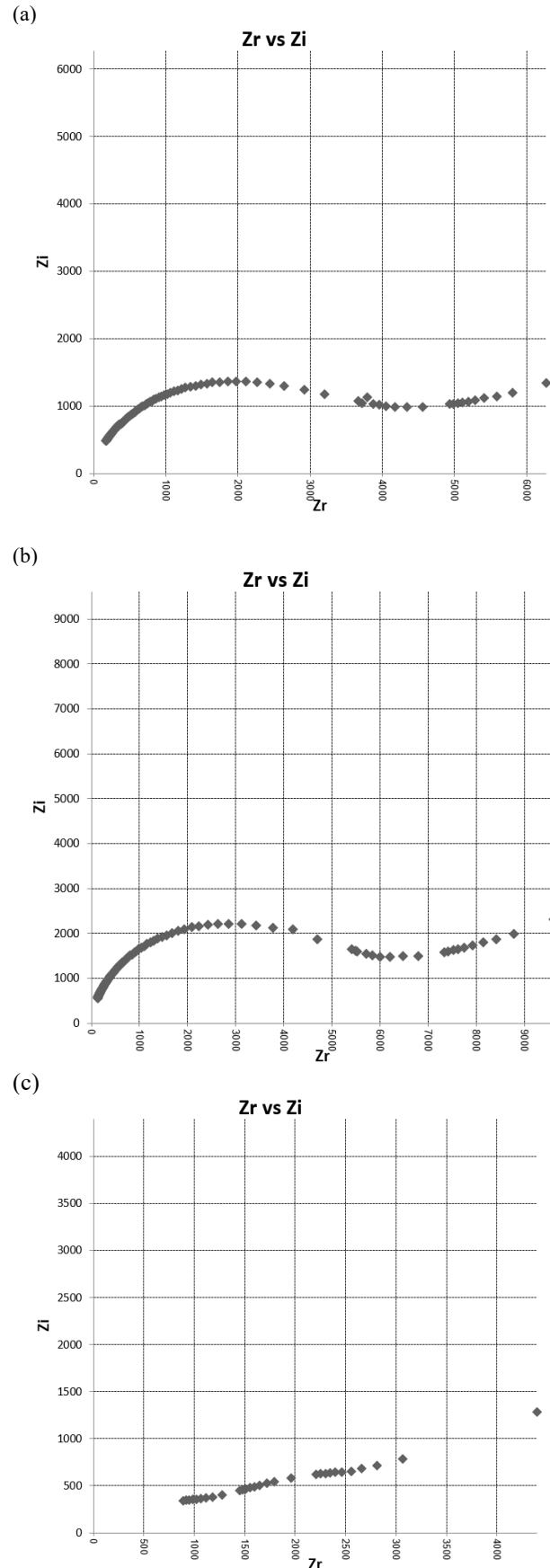


Fig 3 : The graph of real impedance versus imaginary impedance for (a) 2% (b) 10% , and (c) 15% .

The Fig 3 showed the graph of real impedance versus imaginary impedance resulting from the EIS reading. The electrical conductivity calculated from this equation:

$$R = \rho \frac{L}{A} \quad (2)$$

Where R is bulk resistance ($\Omega \cdot \text{cm}^2$), L is thickness of sample (cm), A is area (cm^2) and ρ is the conductivity (Ω/cm). In order to find conductivity, the equation was rearranged into this equation:

$$\rho = \frac{L}{A \times R} \quad (3)$$

The calculated conductivity shown in the Table 2 below for each different starch weight percentage.

Table 2: Electrical conductivity at different starch weight percentage.

Starch weight percentage, wt %	Electrical conductivity, Ω/cm
2	9.54×10^{-6}
10	6.57×10^{-6}
15	2.20×10^{-5}

The conductivity for 2 wt% of starch is $9.54 \times 10^{-6} \Omega/\text{cm}$, 10 wt % of starch is $6.57 \times 10^{-6} \Omega/\text{cm}$ and 15 wt% of starch is $2.20 \times 10^{-5} \Omega/\text{cm}$. There is slightly decrease trend from 2wt% to 10 wt% but there is rapid increase to the 15 wt% of starch. The difference in result might be happened because of Chromium poisoning that cause by contacting the pellet to stainless steel [18].

Apart from chromium poisoning, lower resistance happened because LSCF material itself has better catalytic activity for oxygen reduction during cathode reaction [19].

IV. CONCLUSION

In this study, the LSCF cathode pellets for SOFCs were successfully made using different starch weight percentage. The result showed all the samples are classified as crystallite after undergoing the experiment. The calculated average crystallize size showed decreasing result as the starch weight percentage is increasing. The powder itself become finest with the increasing of starch weight percentage. For conductivity test, the objective only half achieved because error made by the impurity or the EIS can only read a part of the pellet. The result should decrease as the starch weight percentage increase.

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