

# Modification of Composite Structure on Cobalt Free Cathode for Solid Oxide Fuel Cells

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**Abstract:** A novel cobalt-free cathode of composite  $\text{Sm}_{0.5}\text{Sr}_{0.15}\text{Ba}_{0.35}\text{Fe}_{3-\delta}$  for IT-SOFCs is developed using the solid-state reaction technique. Thermal gravimetric was carried out for monitoring the weight loss on the cathode system. In contrast, the X-ray diffraction was employed for the structure phase constructed on the model. Reduction of weight value during the calcination process was achieved to be 10.5%. Thus, a low temperature of the reduction reaction was obtained less than 920 °C. The decomposition reaction related to oxygen vacancy in the composite cathode-free cathode was begun at 410 °C. It takes the advantage in the device system for IT-SOFCs in application. The established structure of the composite cathode system was in the perovskite phase

## 1 INTRODUCTION

Intermediate temperature solid oxide fuel cells (IT-SOFCs) is an exciting device with high energy conversion efficiency (Zhang et al., 2017). In traditional SOFCs, its device operated approximately at 1000 °C, which limited to using the material (Shao & Haile, 2004). Today, IT-SOFCs offer an excellent device with a wide range of material uses due to a lower temperature application (Mahato et al., 2015). However, decreasing operating temperature led to an oxygen reduction reaction that suffers the mobility of its atom in the system (Kulkarni et al., 2016). The perovskite structure for cathode material was introduced to SOFCs due to its mixed ionic-electronic conducting (Zhou et al., 2016). It facilitates the oxygen reduction reaction on both the triple-phase boundary and along with the cathode bulk (Julián et al., 2020). So, developing the perovskite structure could also be interesting to reduce the area-specific resistance in the IT-SOFCs cathode system.

The perovskite structure containing cobalt have been studied, namely  $\text{SmBa}_{0.5}\text{Sr}_{0.5}\text{Co}_2\text{O}_{5+\delta}$ ,  $\text{Sm}_{0.5}\text{Sr}_{0.5}\text{CoO}_{3-\delta}$  (Subardi et al., 2017 and Li et al.

2012). Attending cobalt in the cathode system could demonstrate the high electro-catalyst activity. However, a higher thermal expansion coefficient (TEC) these cathodes than electrolyte such as  $\text{Sm}_{0.2}\text{Ce}_{0.8}\text{O}_{1.9}$  (SDC) restricted it for long term application (Li et al. 2012). It is caused by the damage structure in the interface between cathode layer and electrolyte. So, the reduction of TEC difference value for both cathode and electrolyte was considered to develop the IT-SOFCs system (Zhang et al., 2014 and Zhang et al., 2013). Thus, many TEC value differences can spoil the cathode/electrolyte layer, accelerating cell degradation initiated from the interface up to the surface of the layers (Susanto et al., 2019). So that, the attending of composite cathode-free with a novel oxide composition was in interesting study to be investigated.

In the report, the composite cathode  $\text{Sm}_{0.5}\text{Sr}_{0.15}\text{Ba}_{0.35}\text{Fe}_{3-\delta}$  was produced by the solid-state reaction method. The characterization will be employed to observe the decomposition step and the structure constructed on the model. The thermal gravimetric related to the analysis of weight loss and reduction reaction will be discussed in detail. While, the perovskite structure of the cathode model was

further identified comprehensively by XRD characterization and it be analysed in detail as well.

## 2 EXPERIMENTAL METHOD

The cathode material composition consists of  $\text{Sm}_2\text{O}_3$ ,  $\text{SrCO}_3$ ,  $\text{BaCO}_3$ , and  $\text{Fe}_2\text{O}_3$  powders (>99%) was calculated by the stoichiometry method. The synthetic of composites cathode was preparation via the solid-state reaction (Susanto, et al., 2020). The cathode powder was milled using alumina balls in liquid alcohol for 12 hours (to obtain an even mixture) and then dried at 65 °C for 24 hours. The cathode material was subsequently filtered using 200 mesh screening. The cathode material of 10 µg was heated using the thermal gravimetric machine from room temperature to 1200 °C, heating rate of 10 °C/minute. It cooled it(SBSF35) to room temperature in the air. Further, the 5 gr cathode powders put on the  $\text{Al}_2\text{O}_3$ -cup and calcined it up to 1000 °C with 3 °C/minute in a heating rate and it cooled to room temperature as well. The SBSF35 cathode structure was detected by Rigaku D/MAX-2500V of XRD using a scanning of 3 °/minute with a degree range of 20–80°. The total of The sample crystal structure was analyzed by applying the JADE 5 program to match the XRD pattern obtained from the XRD database at the International Center for Diffraction Data.

## 3 RESULT AND DISCUSSION

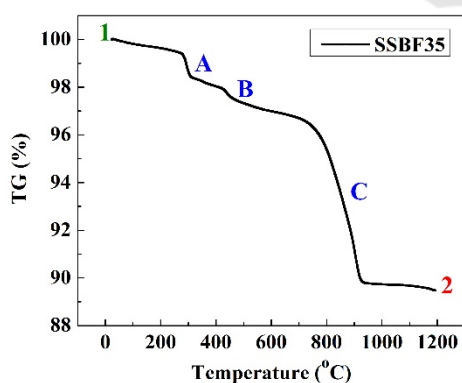


Figure 1. Thermal gravimetric of calcination process for SSBF35 cathode powders

Fig. 1 shows curve thermal gravimetric (TG) of SBSF35 oxide powders, which are calcined in the range of 1200 °C from the room temperature. There are three steep decreasing on the curve attended at 300 °C, 440 °C, and 760 °C for point A, B and C,

serially. At point A, the TG value reduction was 0.8%, and 0.4 % was in point B. In comparison, the decreasing in its value was 7 % at point C. The total TG % value was 10.5 % as long as 900 °C in range.

The thermal gravimetric was monitored the stability of SBSF35 related to a reduction of the weight on temperature. The calcination process of composite powders was carried out to generate the reaction of solid-state in the system. It decreasing the TG curve from point 1 to 2 corresponded to the reduction of weight loss of composite powders. For the calcination process, the curve's reduction at the first phase occurred at room temperature to 400 °C. In point A, reduction of TG related to the release of water content from the materials. The water content could evaporate due to the system's heat energy in the composite powders (Zhang and Zhao, 2020). Furthermore, in the point B, The decreasing of TG value suspected with purity of the materials. The evaporating was demonstrated by the samarium powder, which was performed by the lost weight in the range temperature (Susanto, et al., 2020). It also is proven by the endothermic process at the same temperature due to the dehydration of materials. Furthermore, in point C, the rate of subsequent weight loss occurs that is caused by the decomposition of strontium carbonate, forming the oxide materials of SBSF35. The solid-state reaction was generated on which held from this temperature up to 920 °C [31]. The endothermic could be constructed the formation of the perovskite structure, confirmed by XRD in Fig.3.

Moreover, the TG curve of SSBF35 after calcination was displayed in Fig 2. The heating process was given to 1000 °C. Three regions on the curve related to lost weight on the materials during calcination. The decreasing curve gradually in the range of point one to point two, about 0.36 TG %, was created from room temperature to 410 °C. It demonstrated the lost weight influenced by the water content that evaporated in the air. Furthermore, the degradation of a curve from point 2 to 3 was simultaneous to be 1% at 755 °C. Finally, the reduction curve trend was only 0.2% which was relatively stable up to 1000 °C. The total reduction in the curve value was about 1.2 % which is smaller than the lost weight during the calcination process. The decreasing of weight corresponded with heat energy encourage the oxygen atom to loose from the bonding system. Decomposition process correlated with the release of oxygen atoms in the structure system at higher temperature, which was generating oxygen vacancy. It could also facilitate the transport of mobility oxygen in the cathode to be easier when

applied in the IT-SOFC system. So, based on the thermal gravimetric characterization, the transport mobility of oxygen ion make it possible to be started at 410 °C.

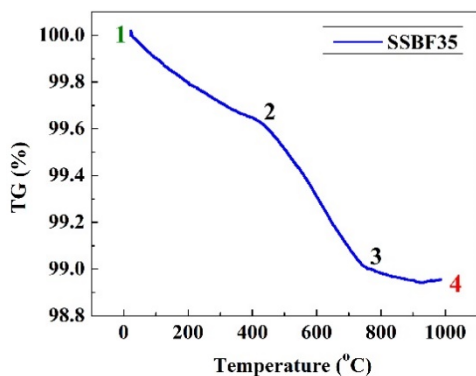


Figure 2. Thermal gravimetric of SSBF35 cathode powders after calcination

Fig 3 displays the XRD pattern of a composite system of SSBF35 cathode (B) and the LaFeO<sub>3</sub> (A) as a reference. The observation was carried out from 20 to 80° of 2θ with a scan rate of 3°/minute. There are nine peaks namely 22.88°, 32.64°, 40.46°, 46.68°, 52.32°, 57.68°, 67.42°, 72.48°, and 77.14° closed with reference, respectively. The structure of the cathode model system has a mixture phase of rhombohedral with PDF number of 20-0130 and the structure of cubic phase with PDF number of 14-0180 (Liu. et al., 2018). It indicates that the structure of the cathode system was the perovskite phase. Based on the XRD result, the composite cathode structure related to design in the beginning for creating the perovskite structure. Its structure could be facilitated the oxygen ions to be easier for movement in the cathode element. At the device system, it takes the advantages for IT-SOFCs system in application.

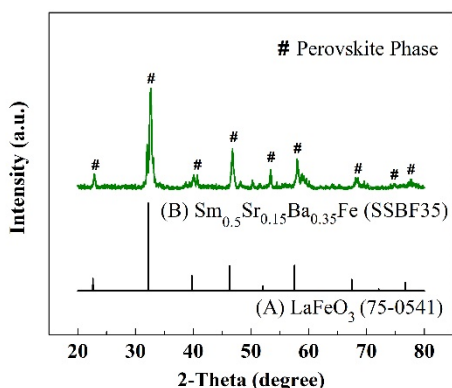


Figure 3. The XRD pattern of composite SSBF35 cathode

## 4 CONCLUSIONS

In this research, the composite cathode was successfully modified using the solid-state reaction. Thermal gravimetric confirmed that weight loss was created during the heated process up to 1000 °C. The decomposition reaction influenced the weight loss of model SSBF35 in the range of 410 to 755 °C drastically. The calcination temperature for generating the perovskite structure was obtained less than 920 °C, which can be used to references for the calcination process. The perovskite phase related to the structure modified was successfully constructed on the composite cathode related to XRD result.

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