



SOFC APPLICATIONS BY INAUGURAL OF STRUTRAL STABILITY, ELECTRICAL CONDUCTIVITY AND WEIGHT LOSS CHARACTERISTICS OF PEROVSKITES

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Abstract

Growth of new practical materials with enhanced characteristics for solid oxide fuel cells (SOFCs) are one of the main criteria of modern science and materials science. Elevated electro catalytic behavior in oxygen reduction reaction cases, The most essential requirements for cathode materials used in SOFCs are chemical and thermo mechanical compatibility with solid electrolytes, as well as stability at elevated temperatures. The data available in the literature on crystal structure, temperature, electro transport-related, and other functional aspects of these materials are summarized in this review. The focus here is on cutting-edge ways to enhancing the functional properties of these complex oxides. Here we started synthesis with Sol-Gel method of the $\text{Sm}_{0.8}\text{Sr}_{0.2}\text{Fe}_{1-x}\text{Co}_x\text{O}_3$ (at $x = 0, 0.2, 0.4$) and the structural analysis are done with XRD, morphological approach was done with FESEM and TEM, the weight loss of the compositions was characterized with Thermo Gravimetric method and the electrical properties are carried out using four-probe technique of temperature to nearly 600°C and the conductivity calculated as nearly 125.87 S/cm to 881 S/cm which are highly useful for the fabrication of SOFCs as a cathode materials which are exhibits O-type ($a < c/\sqrt{2} < b$) structural character.

Keywords: SOFCs, layered perovskite, oxygen reduction, cathode materials, electrical transport.

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1. Introduction

SOFCs are all solid-state devices that can change chemical energy to electrical energy by the chemical reactions between anodic and cathodic materials with the help of electrolyte of ion exchange process. SOFC has solid advantages comparatively conventional power source technologies also the different types of fuel cells, i) less cost due to the utilization of

low-cost materials, ii) minimal sensitivity to poisonous contaminants in fuels, iii) excellent conversion property. Many significant research reports have been made in recent years to promote industrial applications of SOFCs, including optimal material expansion, despicable hydrocarbon gas consumption, and acceptable stack design ^[1-4]. In the United States, Japan, and Europe, several distinct



versions of SOFC are already in the regular market. Despite recent major breakthroughs in reducing cost and improving strength, SOFC systems must still overcome their high expenditure and assure great performance resilience to compete with conventional or traditional combustion systems^[5-7]. Extracted or considerable deprivation issues are mechanical unsteadiness^[8], interfacial chemical reactions causes the Ohmic slaughter around the interfaces of the compositions^[9-12]. Phase changes of the YSZ type of electrolytes are most important to the conductivity deprivation^[13-16] and poisoning changes of impurities present in anode materials^[17-18] and cathode materials^[19-21].

Generally the perovskite oxides are having formula ABO_3 , where A is the rare earth element and B is the transition element. In this work we discussed $Sm_{0.8} Sr_{0.2} Fe_{1-x} Co_x O_3$ (SSFCO) (at $x = 0, 0.2, 0.4$) and this is belongs to the perovskite ceramics. These are having excellent semi conductive nature at the operational temperatures like $25^\circ C$ to $35^\circ C$ or above. Due to the semi conductivity in nature are useful in fabrication of the SOFCs as for the larger scale applications in the society. The conductivity of these materials is not discussed earlier research. The present work depicts the nature of the materials, structure along with conductivity discussed. So, this work will be useful in the fabrication of the SOFCs at operational or moderate temperatures, especially for cathode materials.

2. Experimental

Polycrystalline powdered samples of SSFCO were prepared by the sol-gel technique. Stoichiometric amounts of $Fe(NO_2)_3 \cdot 9H_2O$ and Sm_2O_3 with cobalt oxide (Co_3O_4) are considered for the sample preparation. Sm_2O_3 is converted to nitrate form by adding ammonia, then this

will evaporated to dehydration. The nitrates are dissolved in the distilled water and then added Citric acid in the ratio of 1:2 then using magnetic stirrer for stirring process with temperature up to $85^\circ C$ until the gel is formed, there after the fuel is ethylene glycol added. The resulting gel was calcined at nearly $320^\circ C$, the collected material further grinded and sintered to $550^\circ C$ for 3 hours. The pellets (circular) were hard-pressed at 450 kg/cm^2 in a disc. Further the pellets again sintered to $1120^\circ C$ for 8 hours in air.

The X-Ray diffraction (XRD) peaks of the present work samples were acquired in Philips diffractometer using $CuK\alpha$ irradiated with wavelength of $\lambda = 0.15418 \text{ nm}$. The acquired data were comparable with the reference data to identify the crystal structure. The microstructures of the compositions are investigated using the field-emission scanning electron microscopy (SEM, 460, ZEISS Gemini) with elemental composition taken using energy-dispersive X-ray spectroscopy. The size and morphology of SSFCO nano powders were investigated by transmission electron microscopy (TEM, JEM-2100, Joel Ltd. Tokyo, Japan). The calcined nano powders are decided to analyze the thermo-gravimetric analysis-differential scanning calorimetry TGA-DSC. The DC electrical conductivity was calculated, the conductivity values of the present samples using uniaxial disc with four probe method. On the disc, the four probes are connected to the pellet surface, as the function of the temperature the conductivity values were obtained. Single phase perovskite ceramics and cathodic materials with SSFCO were used for electrochemical investigations with suitable techniques are used. They are annealed at $1100^\circ C - 1120^\circ C$ in sequence to variety of a porous electrode formation for well enclosed to electrolyte.

Table1. Sample's Abbreviations

Chemical Composition	Abbreviations
$\text{Sm}_{0.8} \text{Sr}_{0.2} \text{Fe} \text{O}_3$	SSFO
$\text{Sm}_{0.8} \text{Sr}_{0.2} \text{Fe}_{0.8} \text{Co}_{0.2} \text{O}_3$	SSFCO82
$\text{Sm}_{0.8} \text{Sr}_{0.2} \text{Fe}_{0.6} \text{Co}_{0.4} \text{O}_3$	SSFCO64

3. Results and Discussion

XRD results of $\text{Sm}_{0.8} \text{Sr}_{0.2} \text{Fe} \text{O}_3$ (SSFO), $\text{Sm}_{0.8} \text{Sr}_{0.2} \text{Fe}_{0.8} \text{Co}_{0.2} \text{O}_3$ (SSFCO82) and $\text{Sm}_{0.8} \text{Sr}_{0.2} \text{Fe}_{0.6} \text{Co}_{0.4} \text{O}_3$ (SSFCO64) are shown in the figure .1. Single phase samples are indentified in each composition. Though the use of dissimilar compositions of iron and cobalt in the B-Site where the Sm and Sr are kept constant in A-site of ABO_3 general SOFC formula, B-site results are different XRD behavior. When iron content is increasing the peaks from 20° to 90° (2 Theta degree) are split in individual sample.

The arrangement of iron mixed and cobalt mixed compounds are with different-sized rare earth samples can exist in orthorhombic structure ^[22]. When considered intermediate size cation Sm the SSFO is identified as orthorhombic structure with

'Pbnm' Space Group, similarly those SSFCO82 and SSFCO64 are also identified same. To examine the reactivity of the present samples mixture of iron and cobalt were sintered for 4 hours at temperature range from 1100 to 1120°C the phase composition was done by XRD data. Figure .1. Shows the present work compositions are unsuitable direct-contact 8 YSZ electrolytes ^[25-26] where heating process or operating heating exceeds above 1000°C . The sensitivity of SSFO and the mixture compositions SSFCO82 and SSFCO64 was evaluated and found no noticeable secondary or unidentified peaks are observed it was shown in figure.2 for the high sintered temperature of 1120°C . These phases materialize on the two lattices, mainly the relocation of Sr and CO from the SSFCO82 and SSFCO64 to the grain boundaries. This result can be used in the fabrication of the cathode materials in the SOFCs applications.



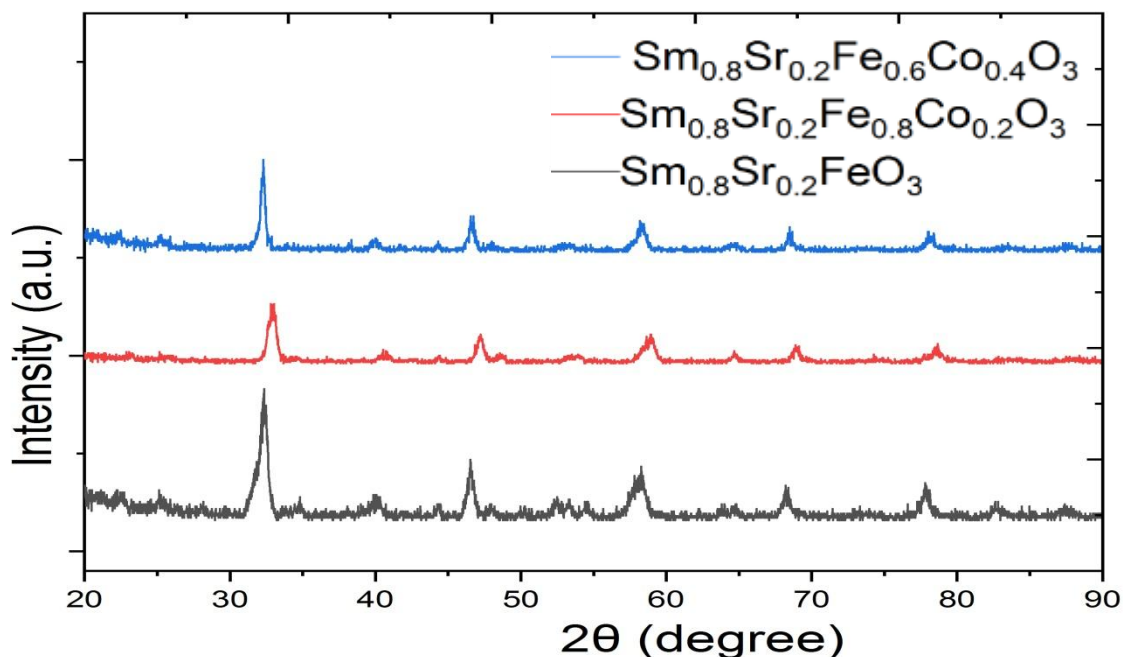


Figure.1 XRD results of $\text{Sm}_{0.8}\text{Sr}_{0.2}\text{FeO}_3$ (SSFO), $\text{Sm}_{0.8}\text{Sr}_{0.2}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$ (SSFC082) and $\text{Sm}_{0.8}\text{Sr}_{0.2}\text{Fe}_{0.6}\text{Co}_{0.4}\text{O}_3$ (SSFC064).

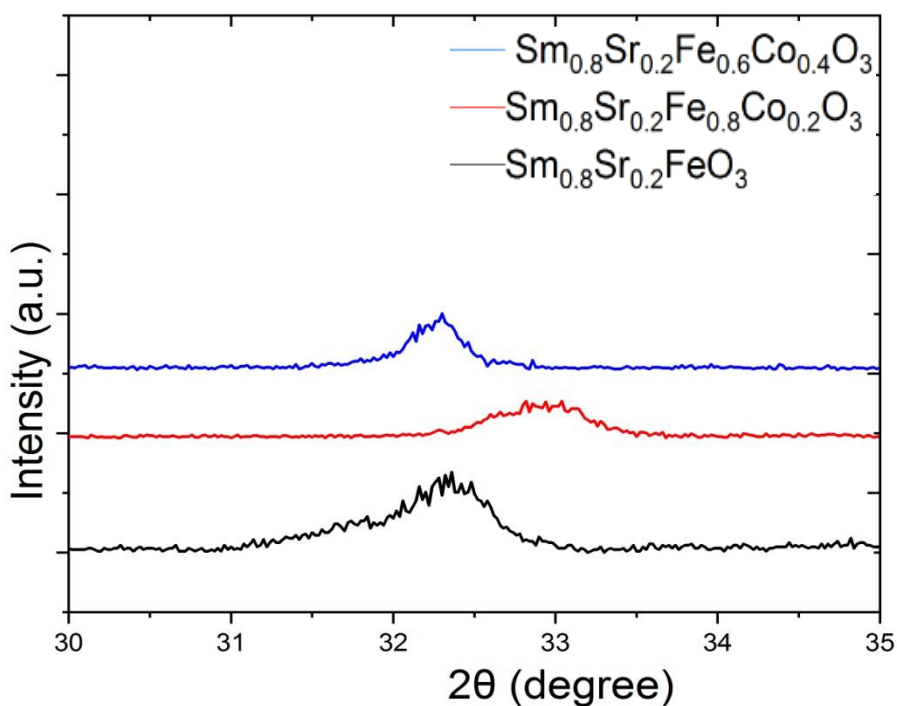


Figure.2 results of $\text{Sm}_{0.8}\text{Sr}_{0.2}\text{FeO}_3$ (SSFO), $\text{Sm}_{0.8}\text{Sr}_{0.2}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$ (SSFC082) and $\text{Sm}_{0.8}\text{Sr}_{0.2}\text{Fe}_{0.6}\text{Co}_{0.4}\text{O}_3$ (SSFC064). XRD peak

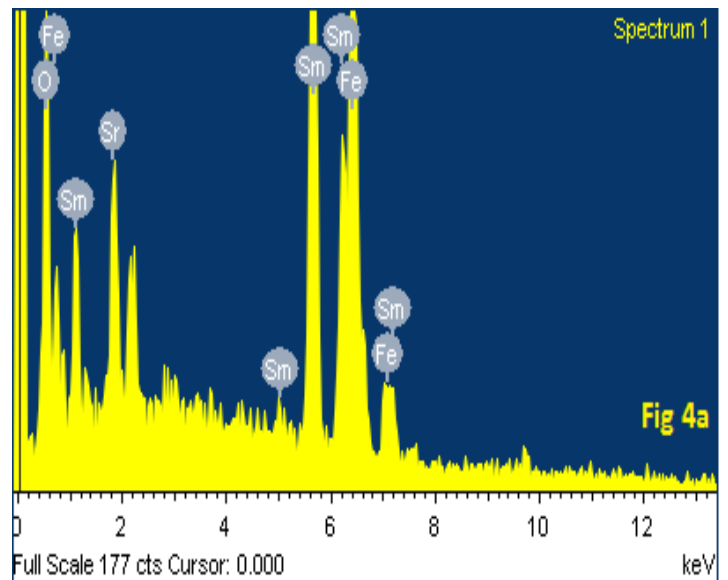
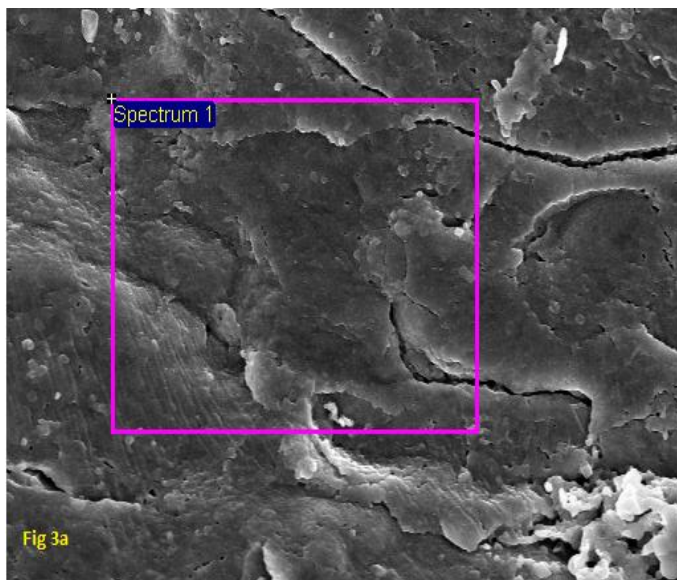
Table 2: Structural data of $\text{Sm}_{0.8}\text{Sr}_{0.2}\text{Fe}_{1-x}\text{Co}_x\text{O}_3$ ($x=0, 0.2, 0.4$)

Composition	Crystal Structure	a(A ⁰)	b(A ⁰)	c(A ⁰)	Volume(A ⁰) ³
0	Orthorhombic	5.47	5.59	7.63	233.3
0.2	Orthorhombic	5.44	5.57	7.59	229.98
0.4	Orthorhombic	5.41	5.52	7.58	226.36

Table 3: Crystallite size of Sm_{0.8}Sr_{0.2}Fe_{1-x}Co_xO₃ (x=0, 0.2, 0.4)

x	Crystallite size (nm)
0	404nm
0.2	438nm
0.4	466nm

The structural values and crystallite size of the present samples also investigated secured in Table2 and 3. Figure 3 (a, b, c) , Figure 4(a, b, c) and Figure 5 are show that the nano particles are uniform with reference to grains with a diameter of nearly 30 to 35 nm of the crystalline of all the samples were investigated in this paper. A chemical composition of each sample was determined using EDAX spectra shown in the Figure 4(a, b, c). The EDAX spectra mapping outcome show the percentages of Sm, Sr, Fe, Co and O without any unwanted contamination. The mass percentages are the samples likely different from those who obtained theoretically that is $m_{exp}/m_{calc} = 98\%$.



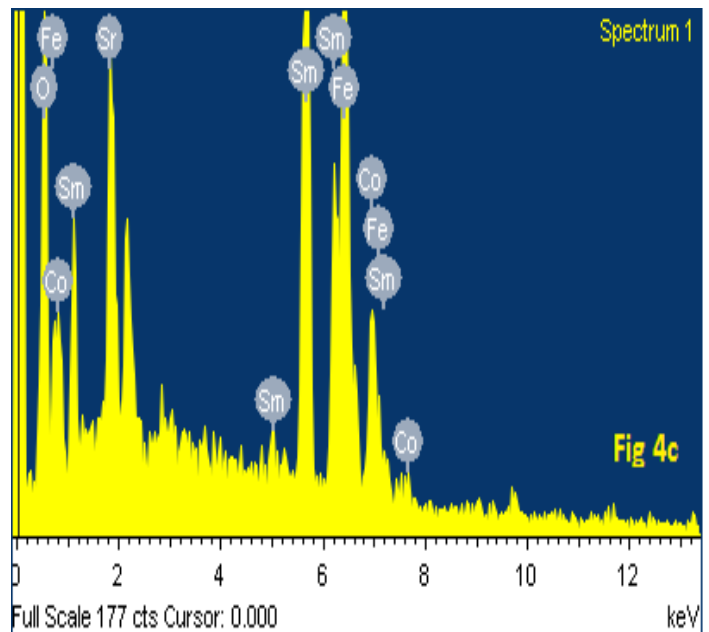
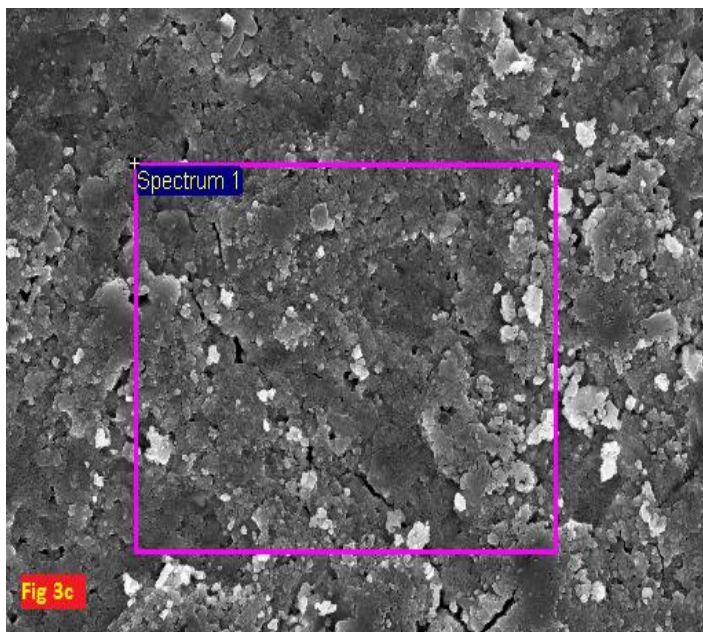
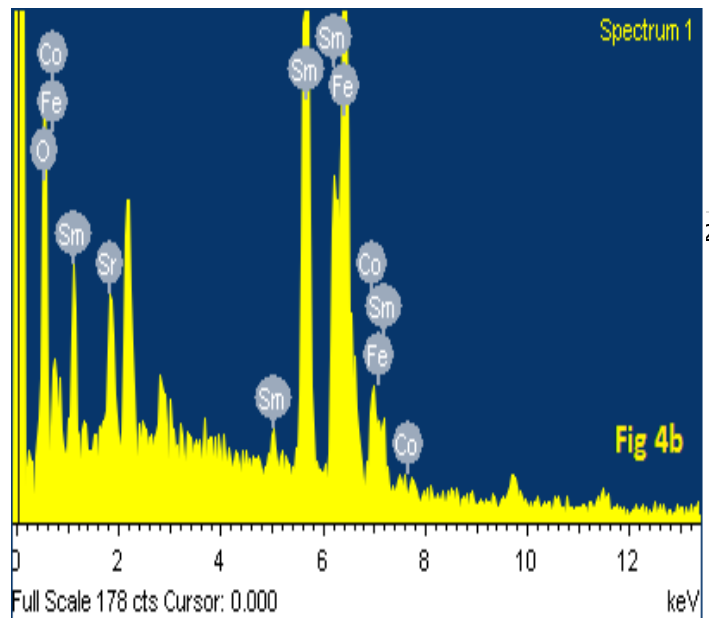
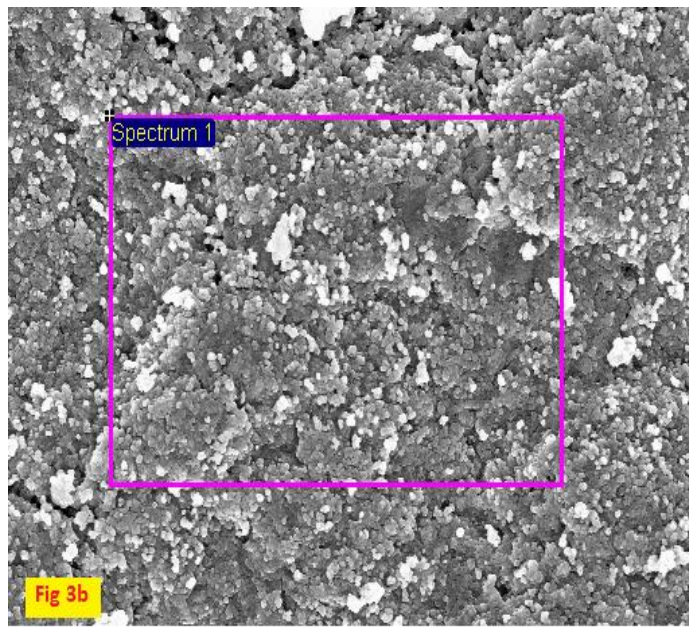
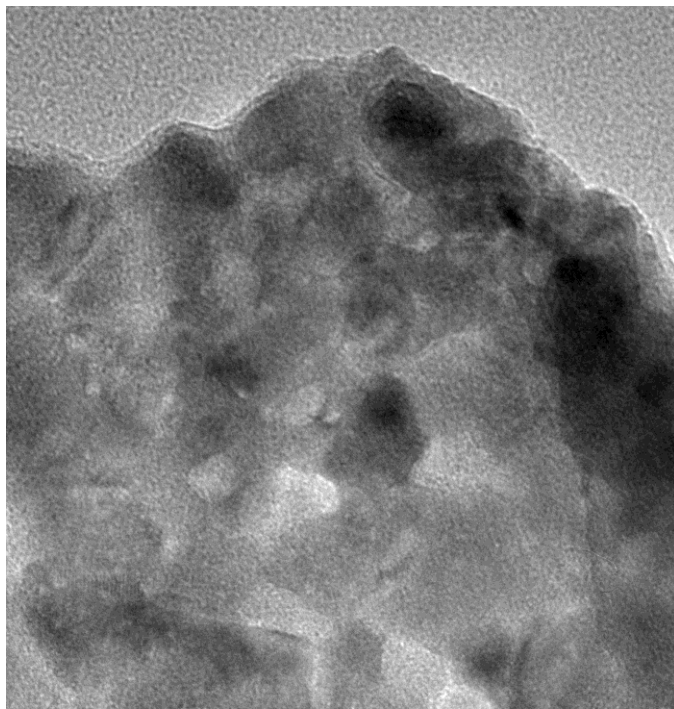
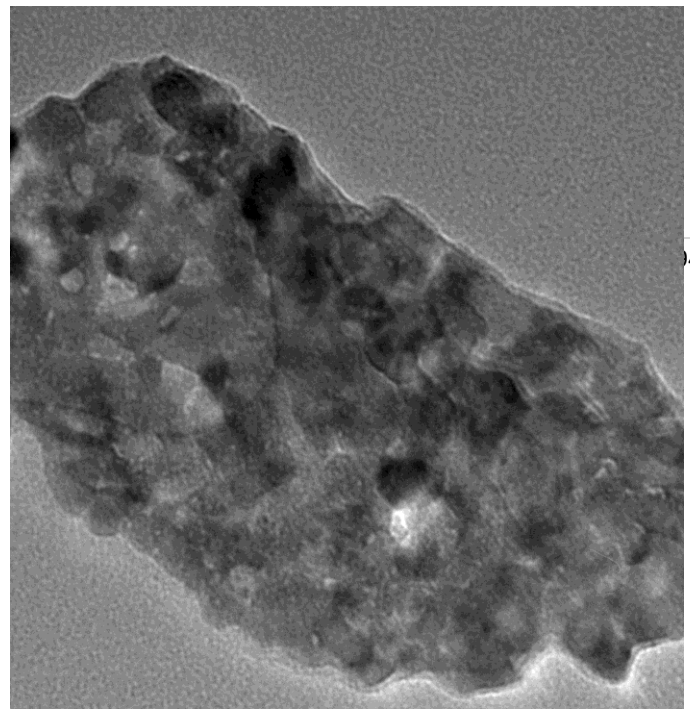


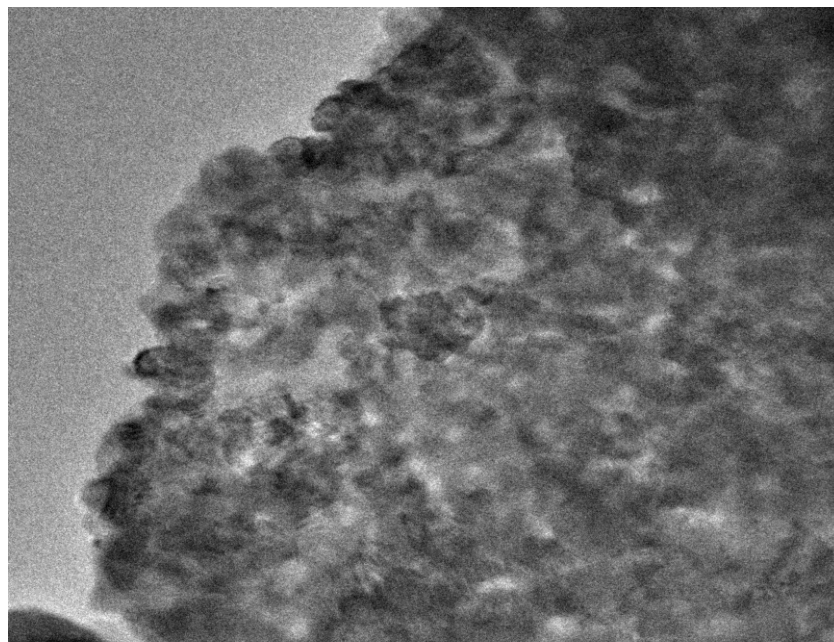
Figure.3,4 FESEM and EDAX images of $\text{Sm}_{0.8}\text{Sr}_{0.2}\text{FeO}_3$ (SSFO), $\text{Sm}_{0.8}\text{Sr}_{0.2}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$ (SSFCO82) and $\text{Sm}_{0.8}\text{Sr}_{0.2}\text{Fe}_{0.6}\text{Co}_{0.4}\text{O}_3$ (SSFCO64).



Magnification	Camera Length	Microscope	Sample	
200000 x	-	JEM-2100	6	—20 nm—



Magnification	Camera Length	Microscope	Sample	
100000 x	-	JEM-2100	6	—50 nm—



Magnification	Camera Length	Microscope	Sample	
50000 x	-	JEM-2100	6	—100 nm—

Figure .5 TEM Images of SSFO (at 20nm and 50nm)

The thermal examination of the calcined powders shown in Figure.6 and observed perfect weight loss in the compositions during heating of the compositions in the range of 50 – 950°C was investigated. The most significant or slight rapid weight loss was observed in the range of 650-750°C this was the slight different change in the weight loss. As a whole all of the $\text{Sm}_{0.8}\text{Sr}_{0.2}\text{FeO}_3$ (SSFO), $\text{Sm}_{0.8}\text{Sr}_{0.2}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$ (SSFCO82) and $\text{Sm}_{0.8}\text{Sr}_{0.2}\text{Fe}_{0.6}\text{Co}_{0.4}\text{O}_3$ (SSFCO64) sample's clear weight loss observed significantly. The procedure occurring through heating of the precipitate were go along with endothermic effects at 650-750°C range, attribute for water evaporation, disintegration Iron (III) and Cobalt(III) was observed consequent to the structure of the perovskites.

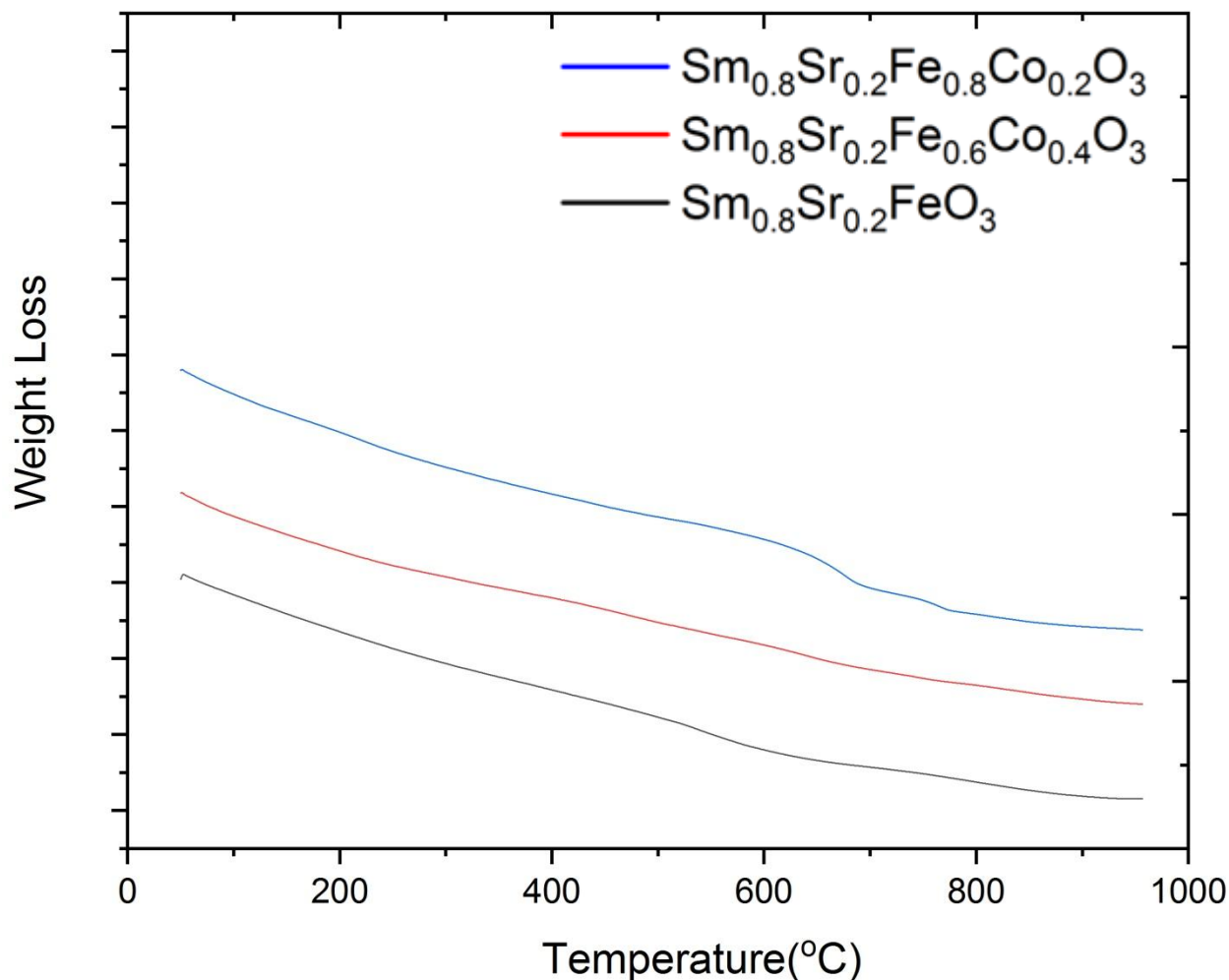
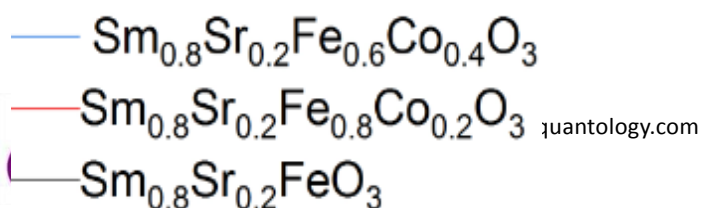


Figure.6 TGA images of weight loss of $\text{Sm}_{0.8}\text{Sr}_{0.2}\text{FeO}_3$ (SSFO), $\text{Sm}_{0.8}\text{Sr}_{0.2}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$ (SSFCO82) and $\text{Sm}_{0.8}\text{Sr}_{0.2}\text{Fe}_{0.6}\text{Co}_{0.4}\text{O}_3$ (SSFCO64).

Figure.7 is the temperature dependent relative of the whole electrical conductivity for SSFO and SSFCO. The conductivity properties of undoped SSFCO64 are consistent with the literature reports ^[23-24].



SSFO indicated and performed the maximum electrical conductivity amongst the others at entire temperature range below investigation. For samples with $x = 0.2$ or $x = 0.2$, the electrical conductivities are increased as the Cobalt content is increased. In the Fig. 7 heating dependant of the electrical conductivity of SSFO and other are shown in air. In addition to the electrical conductivities of Co-doped SSFCO64 are all higher than 881 S cm^{-1} , which is suitable in the fabrication of SOFC cathode materials.

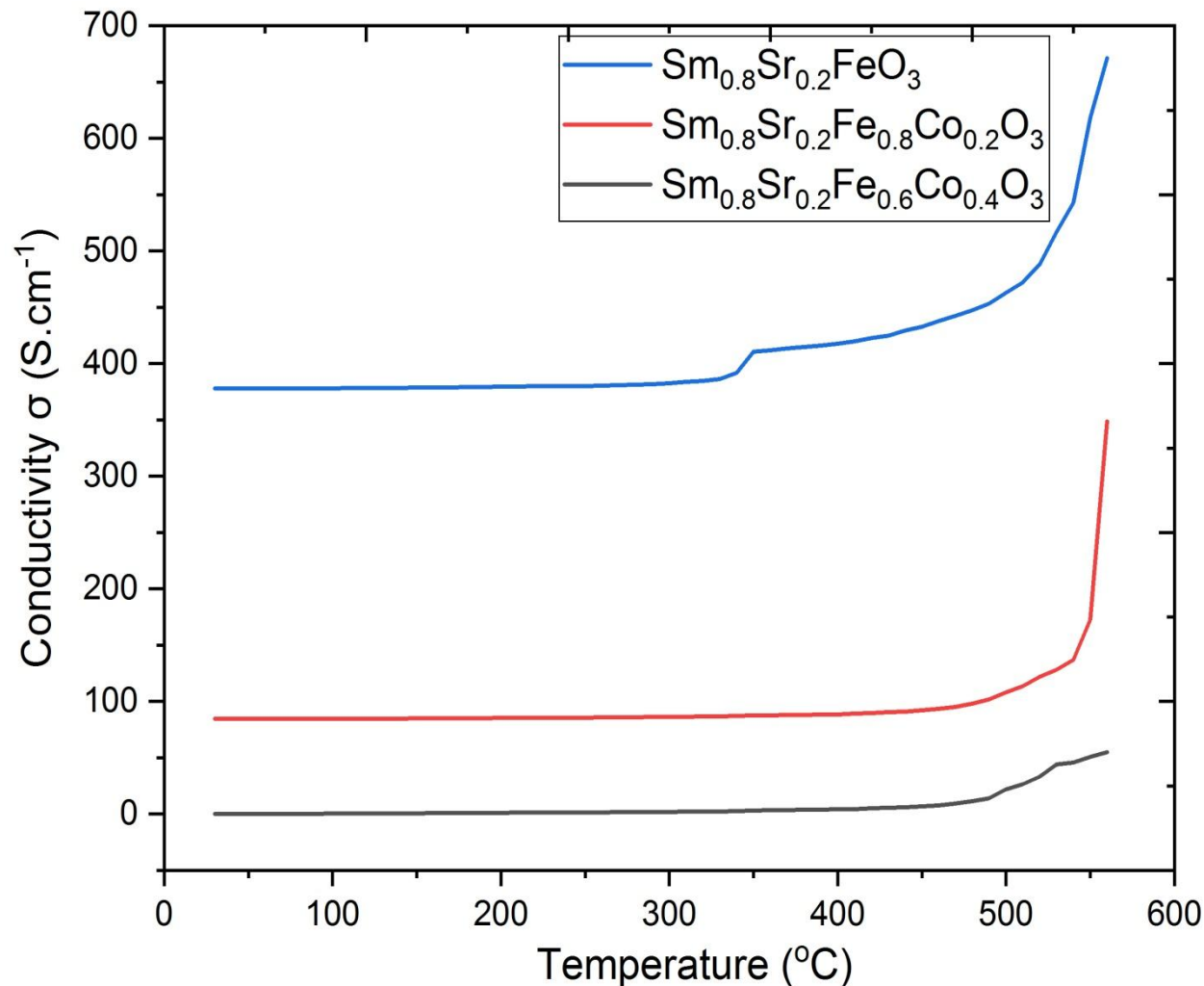
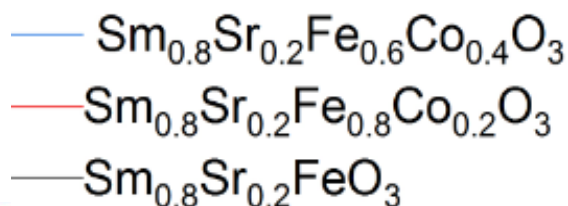


Figure 7. Temperature dependence of electrical conductivity of the SSFO, SSFCO82 and SSFCO64.

Figure.8 explains the Arrhenius plots of the SSFO, SSFCO82 and SSFCO64 samples. These Arrhenius plots are helpful to investigate the cause of temperature on the charge of chemical reactions. Almost all in the present work all samples are shown same Arrhenius behavior.



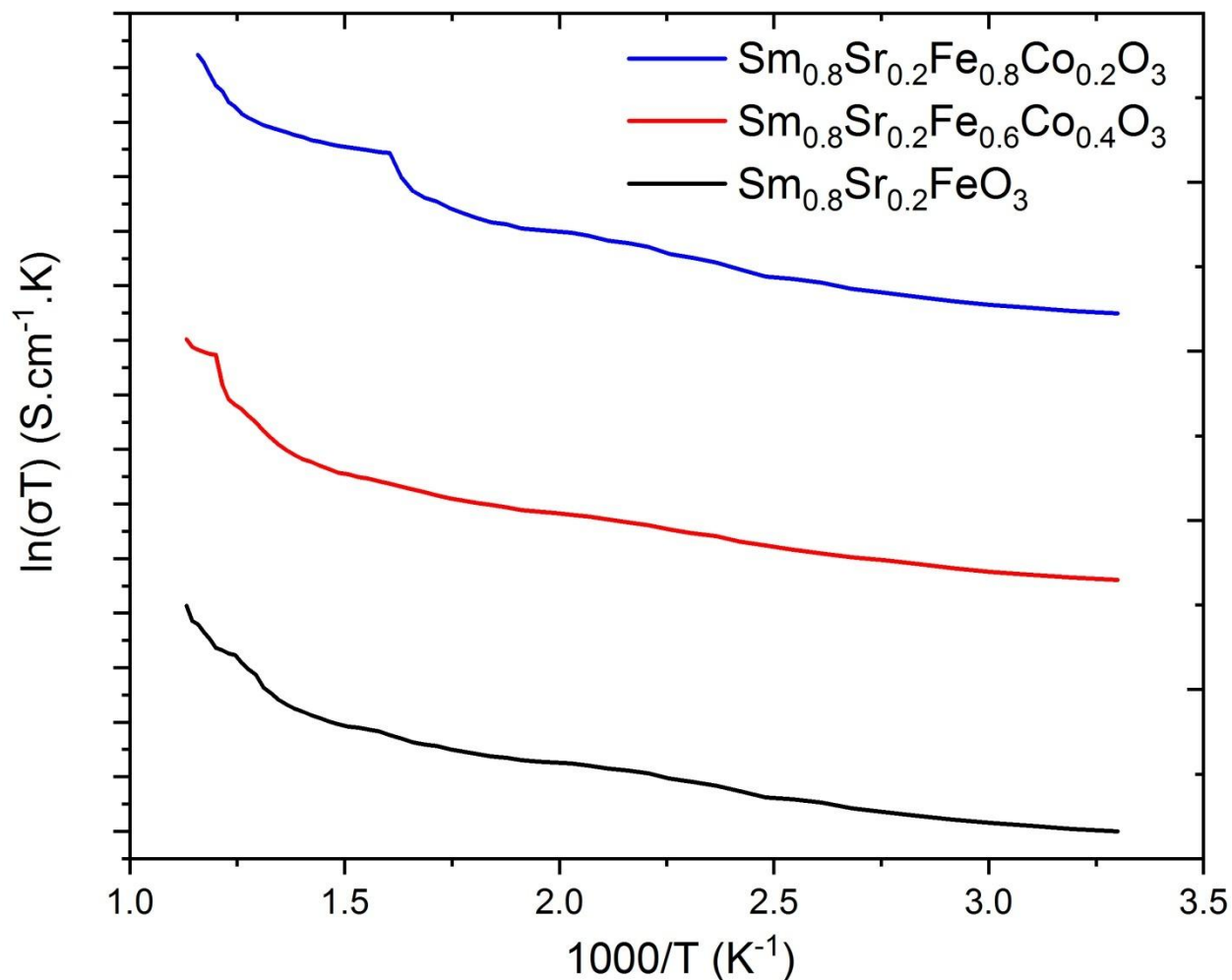


Figure 8. Arrhenius plots for the SSFO, SSFCO82 and SSFCO64.

4. Conclusion

In the present work investigated, Sm_{0.8}Sr_{0.2}Fe_{1-x}Co_xO₃ (x=0, 0.2, 0.4) of all samples are produced at a single-phase perovskites, for the SOFCs applications. For the structural analysis XRD was used and confirmed the orthorhombic crystal structure in nature, in the present samples

SSFCO64 chemically constant for cathode material for operating at high temperatures. No other contamination is occurred and confirmed with EDAX spectra. The electrical conductivity point of view SSFCO64 had shown very high conductivity at moderate temperatures that are above 550°C. The conductive behavior observed is very high of 881 S/Cm in the heating treating up to 580°C-600°C, which is

excellent for cathode material operating at moderate and high temperatures in view of SOFCs applications. Especially all the samples are shown above 96% density, Remarkable weight loss was observed with TGA analysis.

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