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Determination of Rice Husk Silica Effect on SOFC SDC'S Electrolyte Through Material Properties Characterization

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Abstract

This thesis delves into the comprehensive characterization of Solid Oxide Fuel Cell (SOFC) electrolytes, incorporating Rice Husk Silica (RHS SiO2) and Samarium Doped Ceria (SDC). SOFCs present an enticing prospect for electricity generation with exceptional efficiency and minimal environmental impact. However, the high operational and fabrication costs, notably during the sintering process for SOFC components, pose substantial economic challenges for large-scale industries. The primary objectives are to produce SOFC electrolytes with RHS SiO2 as an additive and to determine the properties of the resulting SDC/RHS composite. The experimental methodology involves meticulous combinations of rice husk silica with SDC, utilizing predetermined parameters. This encompasses the calcination of rice husk, sintering of RHS-filled SDC, and conducting chemical and physical tests for electrolyte characterization. Results from elemental phase analysis reveal dominant cerium (Ce) composition, with oxygen (O), samarium (Sm), and silica (Si) following. Fourier Transform Infrared (FTIR) analysis, despite noise interference, indicates the incorporation of new bonding elements with silica addition and varying sintering temperatures. In conclusion, the correlation between sintering temperature, phase, and elemental composition showcases a significant influence on silica purity and porosity. Higher silica purity at increased sintering temperatures reduces porosity, providing crucial insights for optimizing SOFC performance.

1. Introduction

SOFCs are a promising technology with the potential to generate electricity with minimal emissions and high efficiency. By means of an electrochemical process, they directly transform the chemical energy of a fuel into electricity, thereby avoiding the need for combustion. Commercialization of solid oxide fuel cell (SOFC) technology is hampered by the prohibitively expensive fabrication of SOFC components. The sintering procedure is a critical step in the fabrication and production of SOFC components[1]–[3]. It is necessary to regulate the sintering process to guarantee that ceramics products are adequately densified at the macroscopic level, thereby producing items with exceptional properties. Functional advanced ceramics' densification frequently influences microstructure, mechanical, and electrical conductivity, among other properties[4]. The main challenge is the densification of the high-performance electrolyte such as samarium doped ceria (SDC) at low temperature (400-700C). The high sintering temperature is often unfavorable as this will incur high fabrication cost [5]. Additionally, Samarium Doped Cerium (SDC) is a commonly used electrode material and catalyst in SOFCs, offering enhanced conductivity, lower operating temperatures, and increased carbon tolerance. The electrolyte plays a crucial role in the effective energy conversion of SOFCs, making them a highly promising fuel cell system for energy conversion. Rice Husk Ash (RHA), known for its high silica content of 86% - 93%, has gained value as a supplementary cementitious material due to its silica enrichment [6]. The high operating temperature of solid oxide fuel cells (SOFCs), which typically ranges from 500 to 1000°C, is one of the most major barriers to their common use [7].

This high temperature requirement presents difficulties in terms of material selection, system design, and thermal management. The high temperature also raises the chance of thermal stresses, which can lead to mechanical failure. The long-term stability of solid oxide fuel cell (SOFC) systems and system components is a major concern in the field of SOFC development. The sintering process is one of the important steps in creating and producing SOFC components. Controlling the sintering process is necessary to produce ceramic products that are well densified at the macro levels and have great characteristics. Densification of functional advanced ceramics frequently influences electrical conductivity, mechanical characteristics, and microstructure[8]–[10]. The objective of this study is too produce SOFC Electrolyte with Rice Husk Silica as additive, to characterize the properties of RHA/SDC electrolyte and to determine the contribution of RHA as additive in SDC based electrolyte

2. Methodology

Rice Husk Silica (RHA SiO2) will be burn at 700'C for 4 hours by calcination process using furnace. Both pure silica are mixed with SDC powder that used for this experiment from Kceracell electrolyte. Name for this product is SDC-20-N. Samarium doped ceria will be mix with RHA SiO2 using puverisette ball mill. The speed and duration for this process are 200RPM and 3 hours. There are two different weight percentage for this electrolyte. The first wt% are 99.5 % SDC and 0.5 % RHA SiO2. The next is 99% SDC and 0.1 RHA SiO2. After palletizing for 2 Ton and 3 minute, the sample will be sinter at 900'C to 1200'C and the characterization is determine by FTIR,EDX,XRD, TGA and SEM.

3. Result and Discussion

3.1 Elemental Composition Analysis

The component (Ce) comprises the largest proportion of the SDC/RHS composite electrolyte granules, followed by (O), (Sm), and (Si). Due to the reduced quantity of RHS added, the composite contains less detectable silica. By comparing the result with previous study, atomic % of Ce is from 30.33 to 33.56 and O is from 62.21 to 68.44 [6], [7]. Because of this sample must coating with Ag, the value of Ag are neglected.

Table 1 *Result Elemental composition 99.5% SDC/RHA*

Temperature °C	Elemental Composition SDC 99.5%		
	Compound	Atomic (%)	Weight (%)
900	Ce-L	27.98	68.69
	Sm-L	4.72	12.45
	O-K	67.3	18.87
1000	Ce-L	27.89	69.53
	Sm-L	4.16	11.13
	O-K	67.95	19.34
1100	Ce-L	28.03	69.01
	Sm-L	4.56	12.02
	Si-K	0.6	0.13
	O-K	67.41	18.85
1200	Ce-L	26.02	66.9
	Sm-L	4.62	12.64
	Si-K	0.8	0.16
	O-K	69.36	20.30

Table 2 *Result Elemental composition 99% SDC/RHA*

Temperature °C	Elemental Composition SDC 99%		
	Compound	Atomic (%)	Weight (%)
900	Ce-L	27.26	68.01
	Sm-L	4.68	12.44
	Si-K	0.18	0.15
	O-K	68.06	19.4
1000	Ce-L	23	67.21
	Sm-L	5.04	13.45
	Si-K	0.17	0.14
	O-K	67.96	19.20
1100	Ce-L	27.51	68.52
	Sm-L	4.53	12.11
	Si-K	0.20	0.17
	O-K	67.97	19.20
1200	Ce-L	27.88	69.0
	Sm-L	4.17	11.05
	Si-K	0.22	0.18
	O-K	67.96	19.05

3.2 Chemical bonding analysis

Fourier Transform Infrared (FTIR) analysis is performed over the wavelength range of 600 to 4000 cm^{-1}.A portion of the wavelength presence at that wavelength point is attributable to noise interference during scanning FTIR, which causes the graph to vacillate.

For SDC were Sm-O, O-H, C-H, N-O, Ce-O-C, and Ce-O.[6], [11]. Based on table 3 and 4, it is indisputable that the incorporation of additional elements into the composite, as is the case with the silica addition, and that the sintering temperature will likely increase the number of new bonding elements in the SDC/RHS composite electrolyte granules, will result in the addition of new elements. The new band assignment such as Si-OH, Si-O-Si

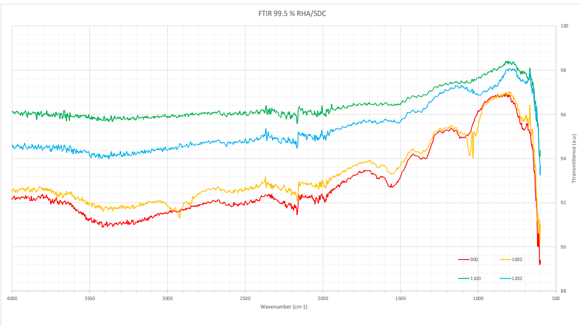


Figure 1 *Result FTIR 99 % SDC/RHA*

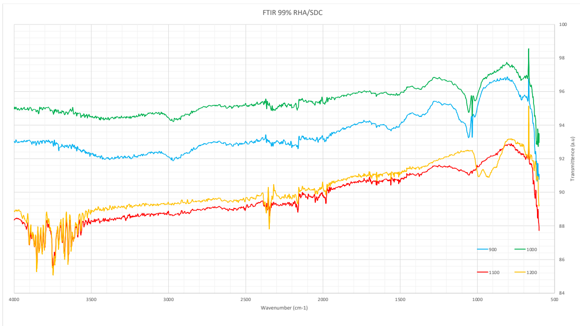


Figure 2 *Result FTIR 99 % SDC/RHA*

Table3 *Result FTIR 99.5 % SDC/RHA*

Temp.	Wavelength (cm^{-1})	Bond	Band Assignment	Paper
	Chemical Bonding 99.5% RHA/SDC			
900°C	648	Si-OH	Bending	[12]–[14]
	1465	Si-O-Si	Asymmetrical Stretching	
	2050,2165	OH	Hydroxyl group stretching vibration	
	3314	OH	OH Stretching	
1000°C	612,674	Si-OH	Bending	
	2145	Ce-O	Stretching vibration	
	3213	OH	OH Stretching	
1100°C	674	Si-OH	Bending	
	2009	Ce-O	Stretching vibration	
	2266	OH	Hydroxyl group stretching vibration	
	3278	OH	OH Stretching	
1200°C	629,695	Si-OH	Bending	
	2167	Ce-O	Stretching vibration	
	3378	OH	OH Stretching	

Table 4 Result FTIR 99 % SDC/RHA

Temp.	Wavelength (cm^{-1})	Bond	Band Assignment	Paper
	Chemical Bonding 99% SDC/RHA			
900°C	663	Si-OH	Bending	[12]–[14]
	1087	Si-O-Si	Asymmetrical Stretching	
	1458	OH	Bending	
	3212	OH	OH Stretching	
1000°C	718	Si-OH	Bending	
	1156	Ce-O	Stretching vibration	
	2324	OH	Hydroxyl group stretching vibration	
	2968	OH	OH Stretching	
1100°C	610,668	Si-OH	Bending	
	1055,1981	Ce-O	Stretching vibration	
	2162,2345	OH	Hydroxyl group stretching vibration	
	3568,3745	OH	OH Stretching	
1200°C	672,932	Si-OH	Bending	
	1651	Si-O-Si	Asymmetrical Stretching	
	2367	OH	Hydroxyl group stretching vibration	
	3650,3854	OH	OH Stretching	

3.3 Surface Morphology analysis RHA/SDC

Based on Table 5 & Table 6, The surface microstructure of RHA/SDC exhibits close alignment, as evidenced by observations made at 10000X and 7000X magnifications. From image, it shows that the visual of pore and the distance

Table 5 *Result SEM for 99% SDC/RHA*

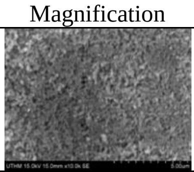
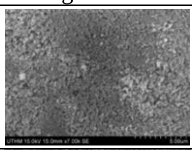
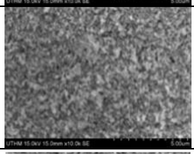
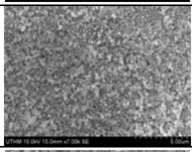
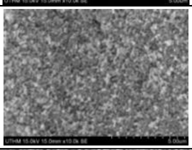
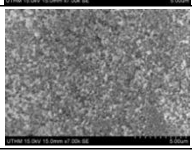
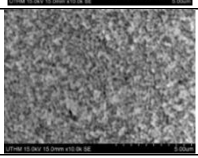
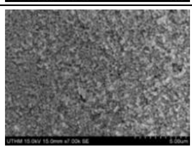
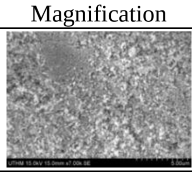
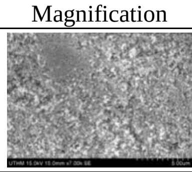
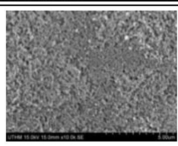
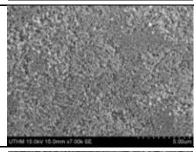
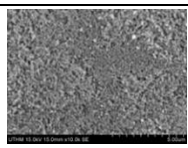
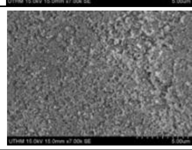
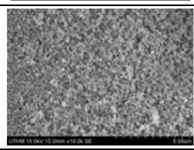
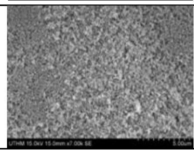
Temp.	10000X Magnification	7000X Magnification	Description
	SEM Conducted SDC 99.5%		
900°C			The pores are discernible, with most of them arranged in a cantered configuration.
1000°C			
1100°C			
1200°C			

Table 6 *Result SEM for 99.5% SSDC/RHA*

Temp.	10000X Magnification	7000X Magnification	Description
	SEM Conducted SDC 99.5%		
900°C			Pores are visible, and their inter-pore distance is greater.
1000°C			
1100°C			
1200°C			

3.4 Phase analysis of RHA/SDC

The intensity peak of sintered RHA/SDC as determined by XRD with a Bruker machine. The angle of interest is between 22° and 82°, as this range contains a significant peak representing the crystal phase of RHA/SDC. The introduction of novel phases, including quartz, cristobalite, and tridymite, during an increase in sintering temperature, provides confirmation that SiO2 was present in the composite, as detailed in Tables 6 and 7[11], [15].

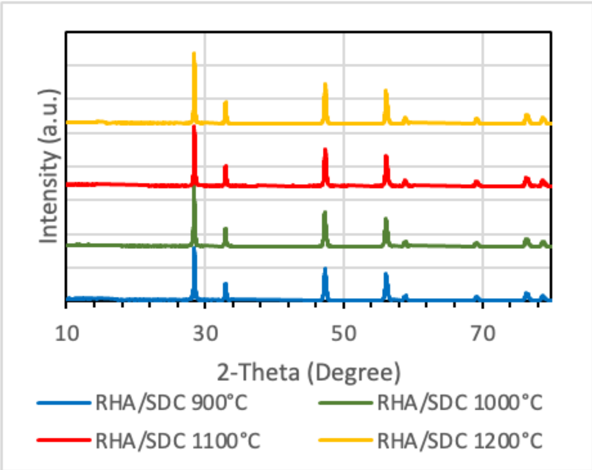


Figure 3 *XRD SDC 99.5%*

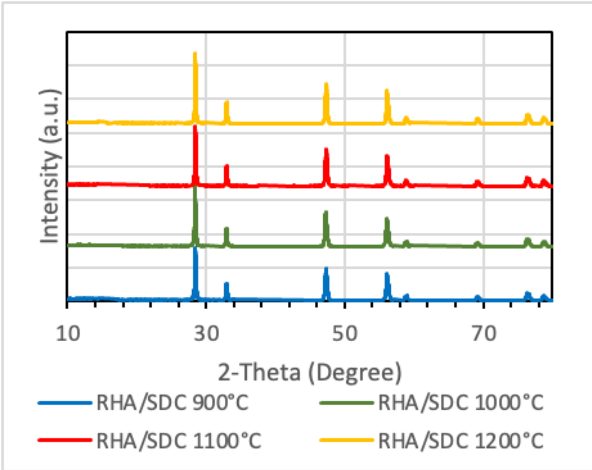


Figure 4 *XRD SDC 99%*

Table 6 *XRD SDC 99%*

99.5% RHA/SDC					Paper
Temperature	Sample	Silica nature	Phase	Intense peak	
900	SiO2	Armorphoes	Quart	23,31	(Mohammad et al., 2019)
	Ceria	Crystalline	Cubic Flourite	53,57,68,76	
1000	SiO2	Armorphoes	Tridymite	24,31	
	Ceria	Crystalline	Cubic Flourite	51,57,67,76	(Azmi et al.,2016c)
1100	SiO2	Armorphoes	Cristobalite	22,,32	
	Ceria	Crystalline	Cubic Flourite	51,57,67,76	
1200	SiO2	Crystalline	Cristobalite	25,31	
	Ceria	Crystalline	Cubic Flourite	50,56,67,75	

Table 7 *XRD SDC 99%*

99% RHA/SDC					Paper
Temperature	Sample	Silica nature	Phase	Intense peak	
900	SiO2	Armorphoes	Quart	23,34	(Azmi et al.,2016c)
	Ceria	Crystalline	Cubic Flourite	53,56,66,76	
1000	SiO2	Armorphoes	Tridymite	24,33	
	Ceria	Crystalline	Cubic Flourite	51,55,69,73	
1100	SiO2	Armorphoes	Cristobalite	22,,33	(Mohammad et al., 2019)
	Ceria	Crystalline	Cubic Flourite	51,57,67,76	
1200	SiO2	Crystalline	Cristobalite	25,31	
	Ceria	Crystalline	Cubic Flourite	50,56,67,75	

4. Conclusion

In conclusion, the combination of Rice Husk Silica (RHA) and Samarium Doped Ceria (SDC) in our study has successfully produced a promising solid oxide fuel cell (SOFC) electrolyte. Through varying weight percentages of RHA, we achieved favorable physical and molecular qualities in the SDC-RHA composite. Further tests on elemental composition, phase, density, porosity, and surface morphology confirmed its potential as an economically viable electrolyte for SOFCs. Notably, RHA played a positive role by increasing density and contributing to an amorphous phase. The correlation between sintering temperature and material properties revealed that higher silica purity at elevated temperatures reduced porosity. Overall, our findings highlight the viability of SDC-RHA as a solid electrolyte, influenced significantly by the weight percentage of RHA and sintering temperature.

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