Microstructural Characterization of $Y\text{-}ZrO_2/La_{1-x}Sr_xMnO_3$ Ceramic Material

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Introduction

Studies in ceramic material for functional purposes are steadily progressing and have become significant in technological advancement. Ceramics are highly admired for their strength, smooth texture, stiffness, oil/gas, Yttria Stabilized Zirconia ($Y\text{-}ZrO_2$) / Lanthanum Strontium Maganite ($La_{1-x}Sr_xMnO_3$) ceramic material has been selected for production of fuel cell cathodes. YSZ/LSM is a composite ceramic; it displays a macroscopic combination between two or more distinct materials with recognizable interfaces between them. The combination between YSZ/LSM ceramic material is highly electronically conductive and has proven long-term stability. YSZ also serves as an electrolyte in fuel cells and has a great affinity for oxygen. These characteristics are of great importance to the performance of the fuel cell cathode, but it is at the microstructural level where YSZ/LSM ceramic material can be properly and effectively characterized.

Like fuel cells, YSZ/LSM ceramic material has three phases: Yttria Stabilized Zirconia, Lanthanum Strontium Maganite, and Pores. The point at which all of these phases meet is called a Triple Phase Boundary (TPB). The length of TPB's is of extreme importance in applications of YSZ/LSM ceramic material to fuel cell cathodes because TPB's display the most reactivity. In addition to Length of TPB, Volume Fraction and Surface/Interface Area per Unit Volume are essential because they too govern the properties and performance of YSZ/LSM ceramic material. The objective of this research was to characterize $Y\text{-}ZrO_2/La_{1-x}Sr_xMnO_3$ ceramic material by estimating its volume fraction, surface/interface area per unit volume, length of triple phase boundaries, porosity, and confirming its property of isotropy (analysis of surface/interface area per unit volume).

Procedure

The material studied in this research project was Yttria Stabilized Zirconia/Lanthanum Strontium Maganite ceramic material. YSZ/LSM microstructure was fabricated by mixing quantitative amounts of YSZ and LSM powder, pressing, and then sintering at 1250˚C. The material was then mounted, polished, and solution etched with HCl. The process was repeated at 1200˚C.

Digital images of the specimen were captured via SEM. The YSZ/LSM microstructure was then characterized by a point-counting method with applications of stereological equations to estimate volume fraction, surface/interface area per unit volume, and length of triple phase boundaries.

Results and Discussion

After estimating the volume fraction, surface/interface area per unit volume, and length of triple phase boundaries of YSZ/LSM fabricated at both temperatures, an average of the samples was calculated to produce Table 1, which also features the sampling error.

Table 1 YSZ/LSM Characterization Results

YSZ/LSM Microstructure (1250˚C)								
Sample	Volume Fraction			Surface/Interface Area (μm^{-1})				Length of Triple Phase Boundary (μm^{-2})
				Horizontal		Vertical		
	Zirconia	Maganite	Pores	YSZ/LSM	LSM/AIR	YSZ/LSM	LSM/AIR	
Average	0.472222	0.446825	0.080952	0.263542	0.059348	0.229167	0.052083	0.013671875
Error	0.109069	0.104115	0.104115	0.107535	0.057513	0.115232	0.062198	0.007487021
YSZ/LSM Microstructure (1200˚C)								
Average	0.496032	0.349206	0.154762	1.927052	0.705167	2.012158	0.869301	1.32266568
Error	0.185847	0.207121	0.066332	0.472262	0.550503	0.280132	0.495208	0.471139419

Analysis of volume fraction in Table 1 shows that sintering YSZ/LSM ceramic material at 1250˚C and 1200˚C resulted in comparable amounts YSZ and LSM. Surface/interface area per unit volume revealed that there is a larger area of YSZ/LSM vs. LSM/AIR. Horizontal and vertical surface/interface area per unit volumes displayed similar values. Additionally, microstructural characterization at both temperatures shows presence of triple phase boundaries.

Although characterizations of YSZ/LSM at 1250˚C and 1200˚C present similar results, there is a significant contrast between the two. Average length of triple phase boundaries present in 1200˚C sample is almost 100 times greater than that featured in 1250˚C sample. At 1200˚C, porosity surface/interface area per unit volume of YSZ/LSM ceramic material is also present in great amounts in comparison to those related values displayed in 1250˚C sample.

The sampling error represents that 95% of the samples characterized represent these true values.

Conclusions

Since horizontal and vertical surface/interface area per unit volumes are similar, isotropic assumption of $Y\text{-}ZrO_2/La_{1-x}Sr_xMnO_3$ ceramic material can be confirmed. YSZ/LSM ceramic material has greater volume fractions, surface/interface area per unit volume, and length of triple phase boundaries per unit volume at lower temperatures. Therefore, YSZ/LSM ceramic material processed at lower temperatures may possibly provide greater efficiency and performance in fuel cell cathodes.

References

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