



## Influence of Post-Treatment on the Performances of Plasma Spraying $\text{La}_{0.8}\text{Sr}_{0.2}\text{CrO}_3$ Coating Layer on Ferritic Stainless Steel as Interconnects for Solid Oxide Fuel Cells†

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The  $\text{La}_{0.8}\text{Sr}_{0.2}\text{CrO}_3$  (LSC) coating layer prepared by plasma spraying is an effective means of providing oxidation resistance of ferrite stainless steel as interconnects for solid oxide fuel cells. The results show that a denser coating layer is acquired and the area specific resistances (ASRs) of the LSC coating layer and LSC coating layer modified by post-treatment are 0.18 and 0.015  $\Omega \text{ cm}^2$ , respectively, at 800 °C after oxidation at 1200 °C for 20 h, indicating the oxidation resistances of the modified LSC coating layer is significantly improved.

**Keywords:** Solid oxide fuel cells, Interconnect, Plasma spraying,  $\text{La}_{0.8}\text{Sr}_{0.2}\text{CrO}_3$ .

### INTRODUCTION

Solid oxide fuel cells (SOFCs) are becoming increasingly attractive because they are more efficient and produce fewer emissions than conventional energy-conversion systems<sup>1</sup>. An integral component of a SOFC system is the interconnect, which connects individual cells into a stack. Intermediate temperature SOFCs allow the use of low cost, commercially available ferritic stainless steels (18 % Cr) as interconnects because of their advantageous properties. Many studies have been concentrated on alloy or surface modifications and the application of protective conductive coatings to eliminate these problems<sup>2</sup>. Therefore, perovskite oxides, such as (La,Sr)CrO<sub>3</sub> and (La,Sr)MnO<sub>3</sub>, spinel oxides, have been extensively investigated as protective coatings for ferritic stainless steels interconnect due to their high electrical conductivity, thermal compatibility and stability in the oxidizing environments. Numerous techniques have been developed to deposit perovskite coatings on stainless steel substrate, such as sputtering, screen-printing, sol-gel and plasma spraying. Nevertheless the disadvantage of this method is that the rapid heating and quenching involved induces non-stoichiometry and residual strain, the post-treatment is applied<sup>3</sup>. In this study, the  $\text{La}_{0.8}\text{Sr}_{0.2}\text{CrO}_3$  (LSC) coating layer was prepared by plasma spraying method on ferrite stainless steel. The LSC coating layer was modified by dip coating and impregnating. The microstructure and performances of the coating layers were investigated.

### EXPERIMENTAL

The  $\text{La}_{0.8}\text{Sr}_{0.2}\text{CrO}_3$  (LSC) powders were prepared using the solid-liquid reaction method.

The coating layer was prepared by the air plasma spraying (Praxair3710) of granulated LSC powder onto the whole surfaces of a commercial ferritic stainless steel (SUS430) substrate (10 mm × 10 mm × 4.5 mm). The surfaces of the samples were sand blasted with alumina sand before plasma spraying.

The LSC coating layer was post-treated using dip-coating LSC slurry for two times and calcined at 850 °C for 2 h. Subsequently, the sample impregnated with a LSC sol, dried and then calcined at 600 °C for 2 h. The impregnation and calcination cycle was repeated for three times and then calcined at 1000 °C for 2 h. The sample put into the furnace again to further oxidize at different temperatures.

The LSC coating layer was characterized by an X-ray diffractometer (XRD) (D/max-rA, Rigaku). The samples were analyzed by scanning electron microscope (S-4800, Japan). The impedance was measured using an electrochemical station (IM6EX, Zahner) in the frequency range of 0.1-0<sup>6</sup> Hz with AC amplitude of 10 mV.

### RESULTS AND DISCUSSION

XRD pattern of the LSC coating layer prepared by plasma spraying on ferritic stainless steel is shown in Fig. 1. The crystal

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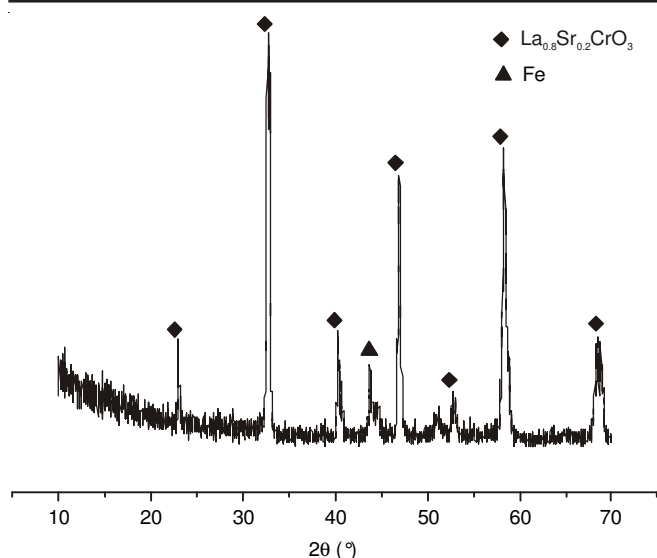


Fig. 1. X-Ray diffraction pattern of LSC coating layer prepared by plasma spraying on ferritic stainless steel

phase is  $\text{La}_{0.2}\text{Sr}_{0.8}\text{CrO}_3$  perovskite structure. No  $\text{La}_2\text{O}_3$  and  $\text{La}_2\text{SrO}_x$  phases are found in the as-sprayed coating layer. The surface microstructure of the LSC coating layer is shown in Fig. 2. From Fig. 2, there are no micro cracks in the coating layer. Obviously, the LSC particles are loosely packed and a porous layer is produced, which can probably be attributed to the inclusion of some unmelted particles.

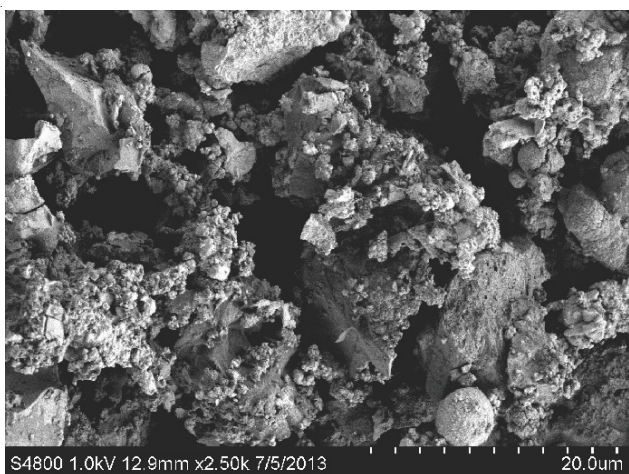


Fig. 2. SEM surface microstructure of LSC coating layer prepared by plasma spraying on ferritic stainless steel

The early experimental result showed the maximum weight gain of the LSC coating layer is more than  $10 \text{ mg/cm}^2$  after oxidizing in air at  $1000^\circ\text{C}$  for 100 h. At the same time, we find that the density and roughness of the LSC coating layer directly affects the performances of cell stack. The surface and cross-section microstructure are shown in Fig. 3. From Fig. 3, the porosity decreases after modification. These initial pores are filled by the fine and high active LSC particles from the LSC sol decomposing. In contrast with the LSC coating layer, the modified layer shows denser.

The area specific resistances (ASRs) of two coating layers are shown in Fig. 4. From Fig. 4, the area specific resistance of the coating layer in air increase with oxidizing temperature

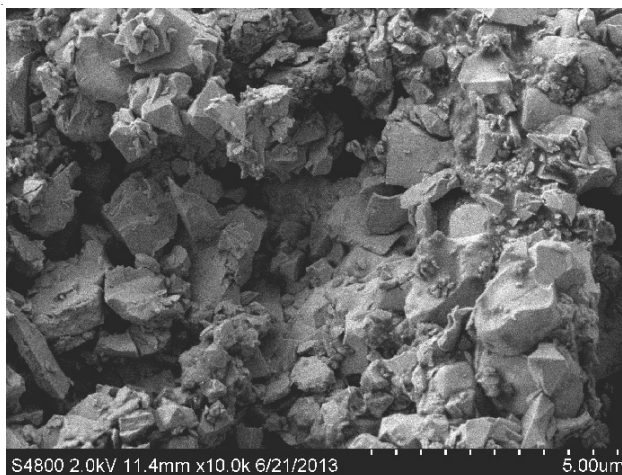


Fig. 3. SEM surface microstructure of the LSC coating layer modified by dip coating LSC slurry and then calcined in air at  $850^\circ\text{C}$  for 2 h

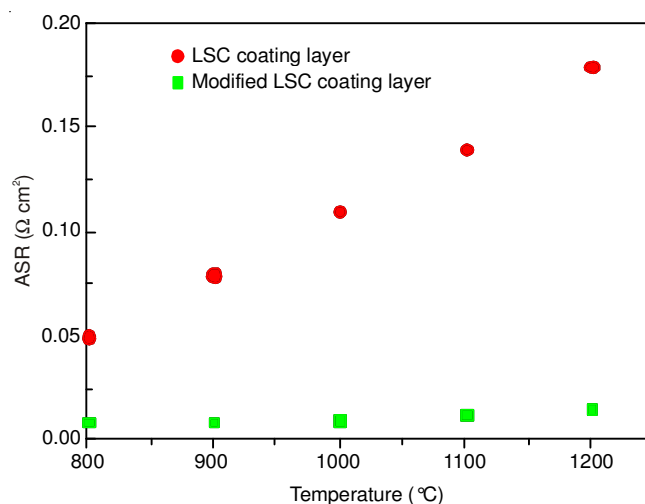


Fig. 4. Area specific resistances for LSC coating layer and modified LSC coating layer after oxidation at different temperatures in air for 20 h, measured at  $800^\circ\text{C}$

increasing. For the LSC coating layer, oxidizing in air at  $1000^\circ\text{C}$  for 20 h, the area specific resistance value is  $0.11 \Omega \text{ cm}^2$ , which is more than  $0.1 \Omega \text{ cm}^2$ . The generally accepted upper limit of area specific resistance for SOFC interconnects is  $0.1 \Omega \text{ cm}^2$ . As oxidizing in more temperature, such as  $1100^\circ\text{C}$  for 20 h, the area specific resistance value is  $0.14 \Omega \text{ cm}^2$ , indicating the oxidation resistance of the coating layer obviously decrease. But, for modified LSC coating layer, oxidizing in air at  $1200^\circ\text{C}$  for 20 h, the area specific resistance value is  $0.015 \Omega \text{ cm}^2$ , which is significantly lower than  $0.1 \Omega \text{ cm}^2$ . The area specific resistance of a metallic interconnect is very much influenced by the growth kinetics of the oxide layer upon its long-term exposure to oxidizing atmospheres, which is the product of electrical resistivity of the studied layer and its thickness<sup>5</sup>. Therefore, an effective, dense LSC coating layer is produced after post-treating on ferritic stainless steel, which has the result of excellent oxidizing resistance at elevated temperature.

## Conclusion

The LSC coating layer prepared by the plasma spraying was modified by dip coating and impregnating method. The

crystal phase of the LSC coating layer prepared by plasma spraying is  $\text{La}_{0.8}\text{Sr}_{0.2}\text{CrO}_3$  perovskite structure. The coating layer with a loose and rough microstructure was modified by dip coating and repeatedly impregnating. A denser coating layer was acquired and the surface microstructure was improved. After oxidation in air at 1200 °C for 20 h, the area specific resistance values are 0.18 and 0.015  $\Omega \text{ cm}^2$  at 800 °C for the LSC coating layer and modified LSC coating layer, respectively. The LSC coating layer modified seems to provide the most appropriate solution in that the problems of high area specific resistance increase rate of the interconnect long-term exposing to oxidizing atmospheres can be eliminated.

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