UNDERSTANDING THE CORROSION BEHAVIOR OF CHROMIA-FORMING 316L STAINLESS STEEL IN A DUAL OXIDIZING-REDUCING ENVIRONMENT REPRESENTATIVE OF SOFC INTERCONNECT

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A and B site doped $LaCrO_3$ – based electronically conducting Perovskite ceramic materials have been extensively used as interconnects in solid oxide fuel cells (SOFC) operating at 800° to 1000°C as the perovskites offer good electrical conductivity, chemical compatibility with the adjacent components of the fuel cell, chemical stability in reducing and oxidizing atmospheres, and thermal expansion coefficients that match other cell components. However, requirements for good mechanical properties, electrical and thermal conductivities, and low cost make metallic interconnects more promising. Significant progress in reducing the operating temperature of SOFC from ~1000°C to ~750°C is expected to permit the use of metallic materials with substantial cost reduction.

Among the commercially available metallic materials, Cr_2O_3 (chromia) scale-forming iron base alloys appear to be the most promising candidates since they can fulfill the technical and economical requirements. These alloys, however, remain prone to reactions with oxygen and water vapor at fuel cell operating conditions and formation of gaseous chromium oxides and oxyhydroxides. To study the degradation processes and corrosion mechanisms of commercial chromia scale – forming alloys under SOFC interconnect exposure conditions, 316L was selected for this research because of the availability of the material. The dual environment to which the interconnect material was exposed consisted of dry air (simulates the cathode side environment) and a mixture of H_2 and 3% H_2O (simulates the anode side environment). Post - corrosion surface evaluation involved the use of optical and scanning electron microscopy, as well as energy dispersive X-ray analyses.

Introduction

Cost effective fuel cell manufacturing is largely dependent on the choice of materials used and stack design [1]. A lower temperature SOFC is of interest because it would allow the use of less expensive metallic materials as the interconnect. There is, hence, a need to understand corrosion processes under SOFC interconnect exposure conditions and develop low cost corrosion resistant alloys for use as interconnects For these applications, interconnect materials have to be simultaneously exposed to fuel and oxidant, also known as a dual environment, at temperatures up to 800°C. 316L was selected as the first step in understanding the role of dual atmosphere on the corrosion behavior. It should be noted that this is the first step towards developing the Albany Research Center's research capabilities to study the corrosion behavior of materials for their applications in complex dual environments.

Experimental

In corrosion experiments, a tubular specimen made of 316L was simultaneously exposed to an oxidizing/reducing dual environment with reducing gas on one side and air on the other side for 96 h at 907 K. The fuel environment consisted of H_2 + 3% by volume H_2O vapor. The second specimen, called a control, was simultaneously exposed to air on one side and air on the other side. The experimental setup used for the tubular specimens is

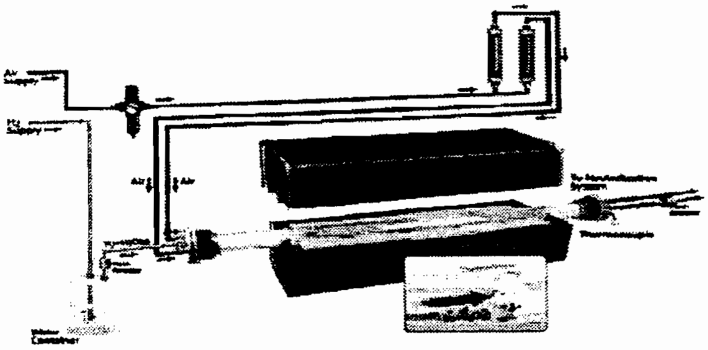

Fig. 1 Schematic of the experimental setup using tubular corrosion specimens.

After the experiment, the topography of the specimen surfaces was observed under an optical microscope. Transverse cross-sections of the specimens were observed under a scanning electron microscope (SEM). The SEM, equipped with an energy dispersive X-ray analyzer (EDX), was used to determine the morphology and chemical distribution of iron and chromium.

Results and Discussion

In the air exposure, oxidation products uniformly covered the surface, as it can be seen in Figure 2. The EDX X-ray maps of Cr and Fe generated for the corrosion products formed show the presence of chromium in the scale, Figure 3. These results are in good agreement with the results generated on 304 stainless steel by Singh et al. [2].

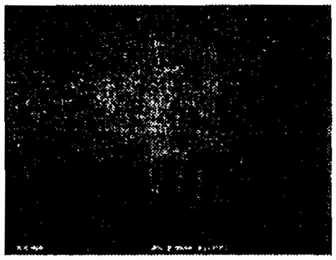

Fig. 2. Optical image of the Control tubular specimen exposed to air.

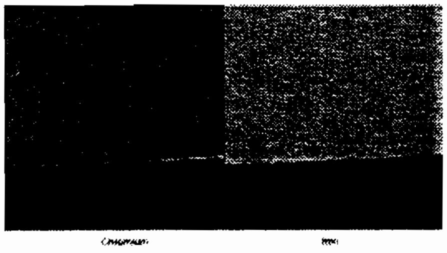

Fig. 3. EDX maps of chromium and iron for the control tubular specimen exposed to air environment.

The scale formed on the air side of the tubular specimen exposed to the oxidizing/reducing dual environment was flaky and susceptible to spallation, as shown in Figure 4.

Fig. 4. Optical image of the air-side of the tubular specimen exposed to the oxidizing/reducing dual environment at 907 K.

Singh and Yang [2] observed a scale on 304L in a similar environment. They proposed the following mechanism of degradation:

$MO + 2(H) \rightarrow M + H_2O$
$M + 0.5O_2 \rightarrow MO$

If M is chromium, this could explain the presence of chromium in the scale in addition to iron, as in the EDX X-ray maps of chromium and iron in Figure 5. Also, an extensive wall thinning is observed.

Iron Chromium

Fig. 5. EDX maps of iron and chromium for the air side of the tubular specimen exposed to the oxidizing/ reducing dual environment at 907 K.

The SEM image of the transverse cross section of the specimen exposed to $H_2 + 3\% H_2O$ shows the presence of Cr and Fe in the scale, Figure 6.

Future Research

Plans are in progress to study the corrosion behavior of materials simultaneously exposed to oxidizing and reducing environments for SOFC and balance of plant (BOP) applications using flat specimens. A scheme of the experimental setup for the flat specimens is shown in Figure 7.

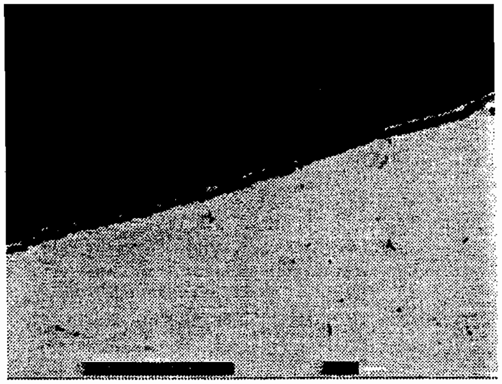

Fig. 6. SEM image of the H_2 + 3% H_2O side (inner surface) of the tubular specimen exposed to the oxidizing/reducing dual environmental at 907 K.

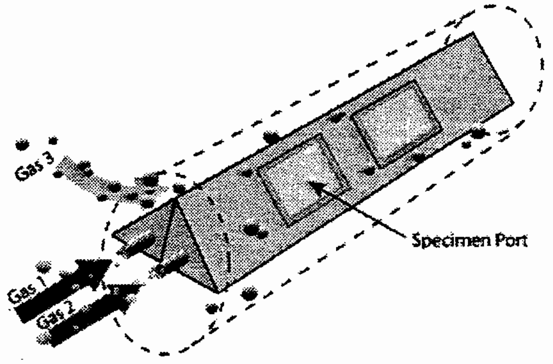

Fig. 7. Schematic of the experimental setup for flat specimens.

The fixture is divided into two compartments. Inside one compartment, reducing gases will be present; inside the second compartment oxidizing gas will be present. Either oxidizing or reducing gas will surround the outside surface of the fixture. Multiple flat specimens could be mounted on two sides of the fixture. This will provide the means for determining experimental reproducibility.

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References

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