Intermediate temperature (750 - 800°C) operation of solid oxide fuel cells allows the use of metallic interconnects. Ferritic stainless steels have attracted considerable attention because of their close thermal expansion match with zirconia electrolyte. Continued growth of resistive oxide scale and the loss of Cr via vapor phase transport that potentially could poison the cathode are the two immediate challenges that must be addressed to provide the long-term performance stability of stacks using metal interconnects. In order to provide mechanical compliance and to employ atmosphere-appropriate materials, a multi-component interconnect design was selected. In the present work, ferritic stainless steel was evaluated for high temperature oxidation properties. Controlled pre-oxidation was found to provide an adherent oxide scale. Low interfacial resistances of 10 to 20 milliohm.cm² were measured in air at 850°C.

INTRODUCTION

The SOFC interconnect must simultaneously satisfy several functional requirements. These functions require materials with high electronic conductivity for the series electrical connection of individual cells, gas impermeability to separate fuel and oxidant gases, chemical stability and conductivity over a large oxygen concentration range. In addition, thermal expansion match with the rest of the cell elements is desired. A metallic interconnect is very suitable in terms of achieving high electrical conductivity and gas impermeability. It also lends itself to ease of fabrication of gas channels by corrugation or by forming dimples on a planar structure. The use of a flexible metallic interconnect eliminates problems associated with the non-conformity of planar components. Greater control over dimensions helps improve the conformity as well as provides uniform reactant distribution required to ensure uniform current density and high fuel efficiency. High thermal conductivity of metal interconnects helps distribute the heat generated during the operation of the cell, thereby lowering the cooling air requirement and reducing thermal stresses in adjoining ceramic components.

The use of metal interconnects, while well known, has posed considerable challenges. Typical austenitic or ferritic materials undergo rapid corrosion at the temperatures of SOFC operation, leading to large and unacceptable increases in resistance. While high Cr alloys match the thermal expansion coefficient of zirconia (1), the evaporation of Cr species was found to result in degradation in SOFC performance (2). To mitigate this
problem, the metal interconnect was coated with a perovskite such as lantanum manganite or chromite, which imparts oxide scale conductivity and suppresses the Cr evaporation. While recent work in the development of metal interconnect has focused on the use of inexpensive ferritic stainless steels (3), the flatness requirement for good electrical contact is likely to add to the overall fabrication cost. Additionally, some level of compliance in interconnect is advantageous to improve the structural reliability of stacks. We have evaluated a modified interconnect design that uses materials that are well suited for the local atmosphere, and provides compliance to the structure. In our work, ferritic alloys that form a \( \text{Cr}_2\text{O}_3 \) scale were found to offer good oxidation resistance following appropriate surface treatment, permitting their use in SOFC applications. The interconnect design and the evaluation of resistance measurements are discussed below.

**INTERCONNECT DESIGN**

The challenges in interconnect development must be addressed using a combination of materials, processing, and design in order to achieve low cost and high performance. In contrast to conventional monolithic interconnects, a compliant interconnect design was developed (4). The design allows separation of the structural and electrical functions, enabling selection of materials best suited to each function and atmosphere.

The interconnect schematic is shown in Figure 1. The interconnect is composed of four element types: a separator plate, edge seal rails, anode and cathode compliant structures, and conductive coatings. Different conductive coating and compliant structure materials are preferred for the air and the fuel sides. The separator plate and edge seal rails are the only elements exposed to both the air and fuel atmospheres and their functions include isolation of air and fuel streams. The separator plate also conducts current as a conventional monolithic interconnect. Mechanical contact is made between the cell and separator plate by the compliant structure and the edge seal rails. Electrical connection between the cell and separator plate may be made by the compliant structure directly, or by a conductive coating supported by the compliant structure. The compliant structure is a corrugation of perforated or expanded thin gauge metal. The separator plate and the air corrugation may be made of the same ferritic alloy. The separator plate and the air-side corrugation are pre-treated to impart a dense, thin, conductive, and adherent scale layer. An additional conductive coating, such as a perovskite, is applied to the separator plate and the air corrugation to provide in-plane conduction and diminish Cr evaporation. The anode side does not need such a coating on the compliant structure as nickel is typically used as the structure. Experience has shown that this design is much easier to fabricate than a monolithic metal design. This design allows selection of atmosphere-appropriate materials for flow channels, which retain some level of compliance.

**SURFACE TREATMENT**

Surface treatment of the native metal surface along with controlled oxidation was found to provide two benefits: well-adhered oxide scale and a significant reduction in oxide scale growth rate. The oxide scale was also found to provide an intimate interface with the perovskite coating that was applied and heat treated in a subsequent operation. The controlled growth of the oxide scale was performed at 900°C for one to two hours. The
resulting oxide scale was typically two to five microns in thickness. Prior to resistance measurement, a perovskite material was painted as a slurry and heat treated. Various perovskite materials, typically cobaltite or modified cobaltite, were examined for adhesion using scanning electron microscopy. Figure 2 shows the interfaces between the metal (left), oxide scale and the perovskite layer. The oxide scale and the perovskite layer were found to give resistance values of 10 to 1000 milliohm.cm² in air at 850°C, in a symmetric pellet arrangement of metal-oxide/perovskite/oxide-metal. Figure 3 shows some examples of the resistance values measured in 150 hour screening tests comparing different controlled oxidation techniques. The best combination of process was tested for extended periods and the resistance values as low as 5 milliohm.cm² were found to be stable over 1,000 hour test duration as shown in Figure 4. A constant current of 200 mA/cm² was maintained during the course of the test period.

SUMMARY

Ferritic stainless steel, with surface modification, is shown to provide a stable interfacial resistance in air at 850°C. A multicomponent design was adopted to utilize atmosphere-appropriate sub-components. Thermal cycle properties of the material need to be assessed. Evaluation of the material in fuel atmosphere is currently in progress.

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Figure 1. Schematic of interconnect design.
(Similar edge rails and corrugation on the other side of the separator plate are not shown)

Figure 2. Metal-oxide-perovskite interfaces.

Figure 3. Interfacial resistance measured in air using pre-oxidized metal
(metal-oxide/perovskite/oxide-metal configuration).

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Figure 4. Interfacial resistance in air under an applied current.