

Protective Coatings for SOFC Alloy Components

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Introduction

Alloys that form electronically conductive chromia scales have been investigated for cell-to-cell interconnects in solid oxide fuel cell stacks for many years. Due to the elevated temperature operation (>850°C) of solid oxide fuel cell, the alloys are limited to relatively expensive Ni-based superalloys or difficult to fabricate Cr-based alloys. Recent efforts in reducing the operating temperature to <850°C may enable the use of low-cost alloys for interconnects as well as for heat exchangers and other BOP components. A barrier to implementation of these low cost alloys is the severe degradation process caused by the vaporization of Cr containing gaseous species in humid air¹. The primary species vaporized is CrO₂(OH)₂ and this is known to degrade rapidly the cathode performance.

One possible way of reducing Cr vaporization is by the use of protective coatings². It is important that the coating be well adhered, electronically conductive, and thermally compatible with the alloy. The overall objective of this work is to determine the oxidation rates, electronic conductivity, thermal cycling behavior, and Cr vaporization rates of coated and uncoated 430 stainless steel sheets, between 650-850°C, in air. Oxidation and thermally cycling data are focused on here.

Experimental

A commercial 430 SS sheet (150µm in thickness) was selected for this study. The 430 SS sheet was cut into 1cm x 1cm plates, followed by polishing both sides with #1200 grit SiC sandpaper. MnCo₂O₄ spinel powders were prepared by glycine nitrate combustion synthesis. After combustion, the powder was baked 2 hrs at 1100°C in air to remove residue carbon. The powder was attritor milled then dispersed in IPA (isopropanol) with 5wt% HPC (hydroxypropyl cellulose) to form the slurry, which was sprayed on the surface of the as-polished 430SS by an aerosol spray gun. Oxidation kinetics and thermal cycling experiments were conducted by suspending the samples in a Cahn microbalance. The weight gains of the samples were measured over time at 850°C in stagnant air. The total oxidation duration was 120 hours. The spallation behavior of the coating was investigated by cyclic oxidation at 850°C in stagnant air. Samples were placed in an alumina crucible, heated to 850°C then air-quenched to room temperature every 30 min for a total of 120 hours. The weights of the samples were measured every several cycles.

Results

The Mn-Co-O coating formed on the 430 SS is

dense and continuous even after 240 thermal cycles as shown in Figure 1. The measured parabolic rate constant for the coated sample at 850°C was $k_p \sim 1.1 \times 10^{-13} \text{ g}^2 \text{ cm}^{-4} \text{ s}^{-1}$. The rate constant of the coated sample was more than one order of magnitude lower than that of the uncoated one.

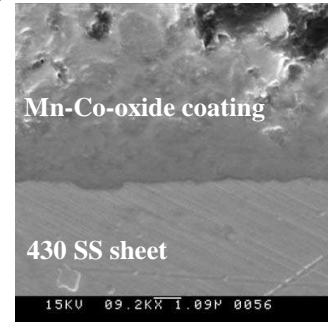


Figure 1 - Cross-section SEM of coated 430 SS after thermal cycling in air.

During thermal cycling the uncoated sample showed severe spallation of the formed chromia scale while the coated sample did not flake off even after 240 rapid thermal cycles. The thermal compatibility of the coating with the 430 SS is probably due to the improved thermal expansion match between the MnCo₂O₄ and the 430 SS. The Co containing spinels have higher thermal expansion coefficients when compared to the relatively low values for Cr₂O₃ and MnCr₂O₄. An additional factor in the improved adhesion is the graded structure of the interface between the alloy and the coating as shown in the EDX line trace in Figure 2.

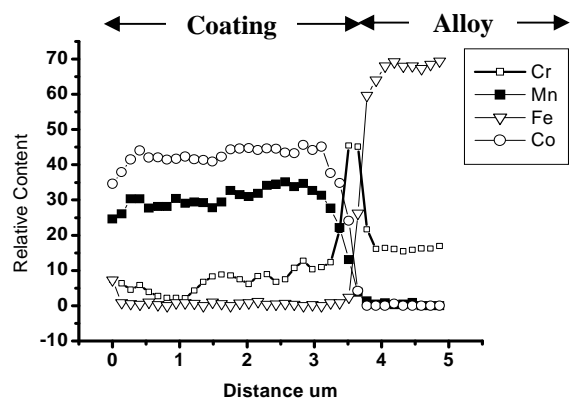


Figure 2 - Line trace EDX of coated 430 SS after thermal cycling (air-quenched).

Conclusions

Highly conductive, thermally compatible protective coatings have been successfully applied to a low-cost commercial alloy (430 SS). The final portion of this work required to assess the viability for SOFC applications is to measure the chromium vaporization rates of coated and uncoated samples in humidified flowing air.

Acknowledgements

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2. S. P. S. Badwal, K. Foger, X. G. Zheng, D. Jaffrey, U.S. Pat. No. 5,942,349, August 24, 1999.