Role of Alloy Oxidation on Performance of Solid Oxide Fuel Cells for Clean Energy Generation

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Optimization of Metallic Interconnectors for Clean Energy Power Systems

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Introduction and Background

Solid Oxide Fuel Cells (SOFCs) are energy-generating devices that convert chemical energy into electricity. These advanced systems can be used in a variety of applications, such as transportation, submersible vehicles, and stationary power generation. SOFCs use electrochemical reactions to generate electricity and water by consuming hydrogen or hydrocarbon fuel at operating temperature between 500-900ºC. A single SOFC cell consists of two porous electrodes, a dense electrolyte, and an interconnect (IC) that acts as a current collector on both electrodes. Fuel and oxidant (O_2) moves through interconnect manifolds as shown in the Figure 1.

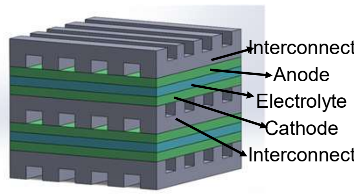

Figure 1- Schematic illustration of a 2-stack of SOFC fuel cell. This is used to convert stored chemical potential energy stored in fuel molecules into useable electrical energy.

Several single cell SOFC cells are connected in series, referred to as SOFC stacks, for generating a high voltage at the output. Compared to other types of fuel cells, SOFCs offer several benefits such as fuel type flexibility (hydrogen, hydrocarbons, etc.), use of inexpensive catalysts, negligible limitations in cell design and construction, and higher electrical efficiency. Increasing the operating temperature of individual cells can lead to the formation of more oxides and corrosion on the interconnect of these cells. A chromia forming alloy for interconnect can reduce costs while maintaining efficiency. However, chromia forming alloy also leads to chromium poisoning resulting in SOFC performance degradation. This work explores the role of conducting Ni based coating fabricated using ALD on advanced alumina forming alloys and understand the surface resistances of the alloys at high temperature.

Conclusion

Experimental results show that improvement in the ASR of advanced steel alloys exposed under SOFC conditions. High-temperature tests show there is significant increase in ASR (>2000mΩ.cm^2) for the uncoated steel at 700C. In contrast, significant reduction in ASR is observed (<100mΩ.cm^2) for Ni coated steel. Additional experiments are in progress to study the oxidation process and develop mechanistic understanding.

References

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2) Ming-Jui Tsai, Chun-Lin Chu⁎, Shyong Lee, La0.6Sr0.4Co0.2Fe0.8O3 protective coatings for solid oxide fuel cell interconnect deposited by screen printing, 2009

Acknowledgments

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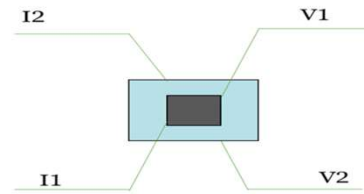


Figure 2- Schematic illustration of experimental setup. The apparatus is used in collecting the resistance data.

4 probe setup is used to measure ASR at SOFC operating temperature of 700C in air atm.

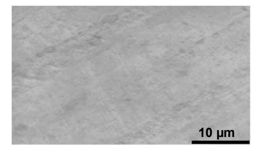


Figure 3- As received Alumina-forming alloy SEM.

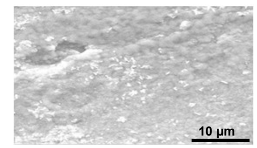


Figure 4- 0.5 µm ferric coated surface morphology using SEM after 100hrs at 700C

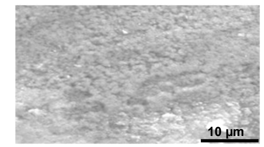
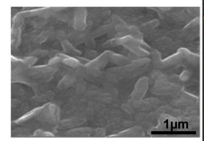


Figure 5- Uncoated alumina forming alloy surface morphology using SEM after 100hr at 700C



Quantitative Results for: Base(3)

Element Line	Net Counts	Weight %	Weight % Error	Atom %	Atom % Error	Formula	Compnd %
C K	124	1.92	±0.20	5.47	±1.15	C	1.92
O K	1896	23.80	±0.46	50.91	±1.99	O	23.80
Al K	460	2.29	±0.12	2.90	±0.30	Al	2.29
Cr K	4052	9.38	±0.18	6.17	±0.24	Cr	9.38
Fe K	8595	24.86	±0.48	15.23	±0.59	Fe	24.86
Ni K	7102	27.60	±0.48	16.09	±0.56	Ni	27.60
Ag L	3475	10.15	±0.50	3.22	±0.32	Ag	10.15
Total		100.00		100.00			100.00

Figure 6- Elemental mapping using EDS that shows the presence of Fe from base metal and Cr and Al with O indicating possible oxide formation

Scanning electron microscopy images show morphological changes in as received steel and Ni coated steel samples exposed at SOFC operating condition (700C- Air) for ~50h.

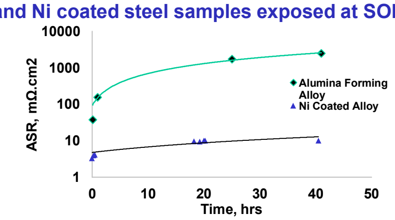
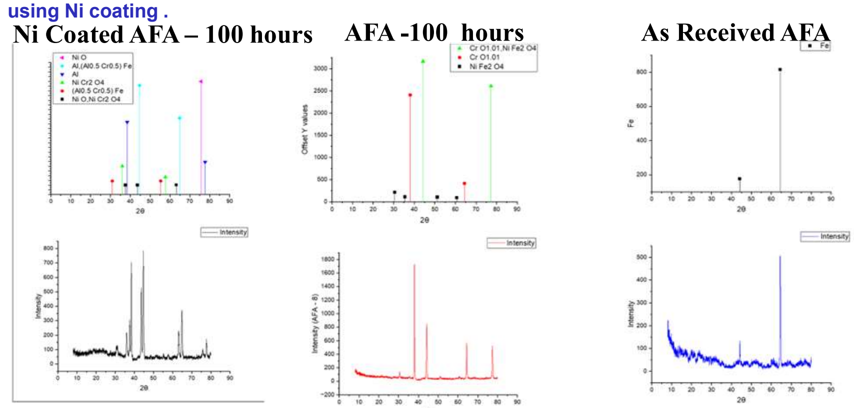


Figure 7- Comparison between Alumina Forming Base Alloy and Ni Coated Alumina Forming Alloy. This indicates the base alloy has a significantly higher ASR value than one not coated.

High-temperature (700C) experiment results indicate significant reduction in ASR (mΩ.cm^2) using Ni coating .



X-ray diffraction (XRD) shows presence of oxide layers on as received steel and Ni coated steel samples exposed at SOFC operating condition (700C- Air). Formation of conducting oxides reduce the ASR