Electrodeposited Mn-Co Alloy Coating For SOFC Interconnects

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Overall Objective

Develop an inexpensive manufacturing process for depositing $(Mn,Co)_3O_4$ spinel coatings onto SOFC interconnects.

Introduction

The decrease in the SOFC operating temperatures from 1000°C to between 650 and 850°C has enabled the use of chromia-forming ferritic stainless steels as interconnects instead of $LaCrO_3$ ceramic.

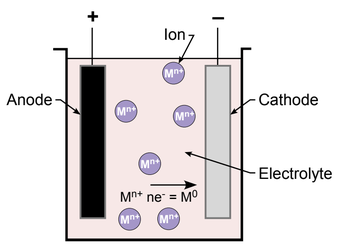
However, even newly developed ferritic alloys such as SS441 and Crofer 22 APU, cannot completely eliminate the chromia scale growth and chromium evaporation into cells that can cause unacceptable degradation in the SOFC electrochemical performance. One attractive method to resolve the chromia scale growth and diffusion issues is to electrodeposit a Mn-Co alloy coating onto the interconnect surface and subsequently convert it to a $(Mn,Co)_3O_4$ spinel. $(Mn,Co)_3O_4$ spinel has high conductivity (60S/cm at 800°C), excellent chromium retention capability and demonstrates good CTE match (11.5 x 10-6/K, 20-800°C) with the cathode materials and ferritic stainless steel interconnects. Electrodeposition is widely considered an inexpensive, scalable, non-line-of-sight industrial manufacturing process.

During Phase I of this program it was demonstrated that the electrodeposition process can produce uniform dense, crack-free, well-adhered Mn-Co alloy coatings of various composition on a 2"x2" 441 stainless steel interconnect surface. A post-deposition thermal treatment converted the Mn-Co alloy coatings to $(Mn,Co)_3O_4$ spinels. A preliminary economic analysis, based on a batch manufacturing electrodeposition process, demonstrated that the innovative coating technology can meet Department of Energy's high volume target of 1,600,000 plates per annum at a cost of ~$1.87 per 25 x 25 cm coated interconnect.

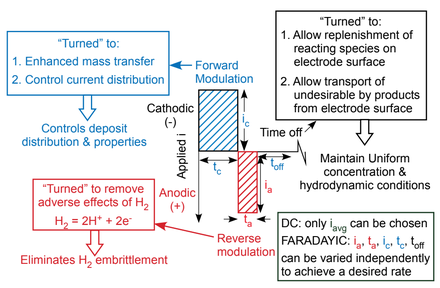
Approach

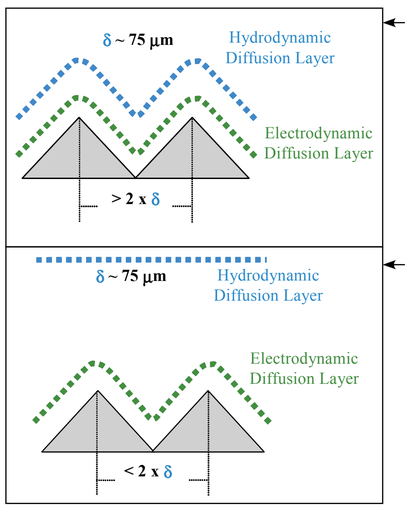
The FARADAYIC Electrodeposition process

Electrodeposition



The FARADAYIC Process





Macroprofile: Diffusion layer tends to follow the surface contour. Mass transport control results in a uniform current distribution or a conformal deposit during deposition.

Microprofile: Diffusion layer thickness surface roughness. Mass transport control results in a non-uniform current distribution.

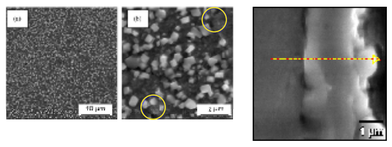
The appropriate waveform can alter the thickness of the pulsating diffusion layer and effectively focus or defocus the current distribution to create non-uniform or uniform deposition respectively.

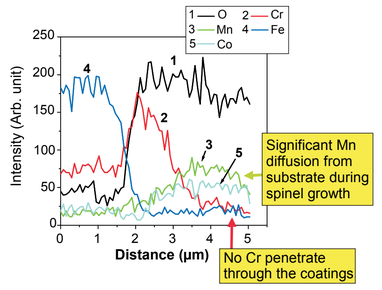
FARADAYIC Electrodeposition process…

- Enables alloy composition control
- Enables control of coating uniformity for flow field patterns
- Maintains fast processing times to enable high throughput manufacturing
- Is an inexpensive manufacturing process for SOFC interconnect coatings

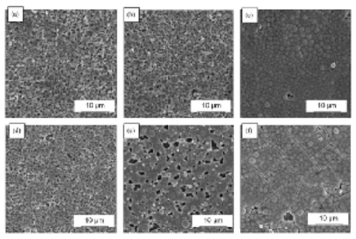
Previous Work at WVU

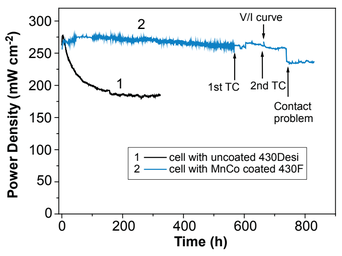
DC Electrodeposition





PC Electrodeposition

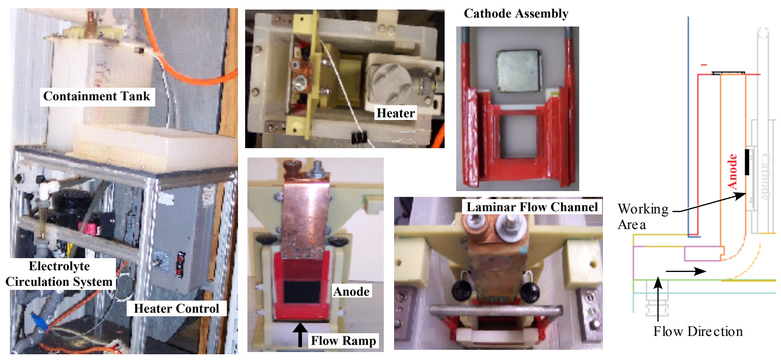




Method

Electrochemical Cell

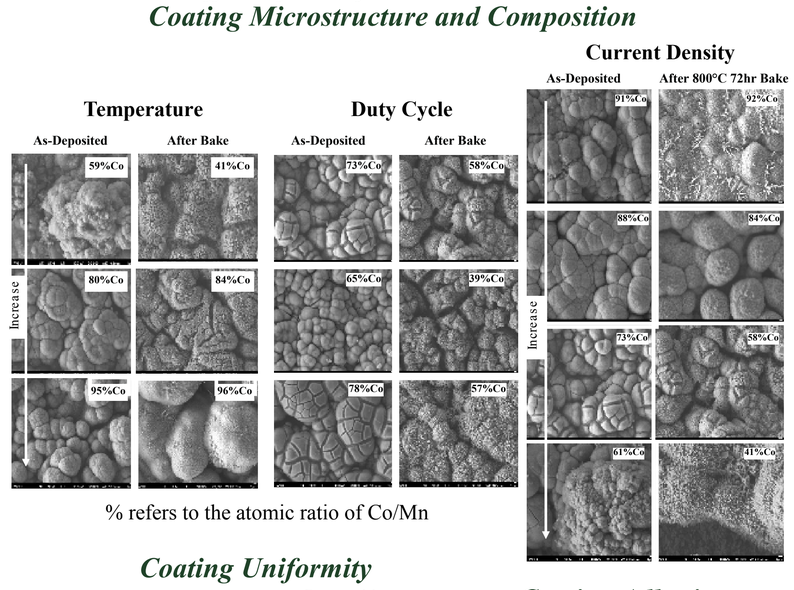
Based upon Faraday's electrochemical cell design that facilitates uniform flow across the surface of a flat substrate (US patent #7,553,401)



Mn-Co alloy coatings were deposited onto unpatterned 2"x2" SS 441 substrates from a sulfate based plating bath that contained Mn, Co, a supporting electrolyte and a buffer using FARADAYIC Electrodeposition.

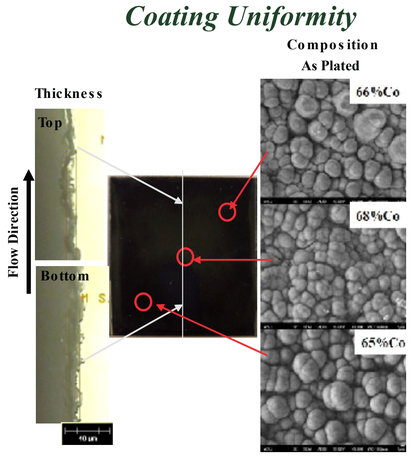
Results

Effect of Waveform Parameters on Coating Microstructure and Composition



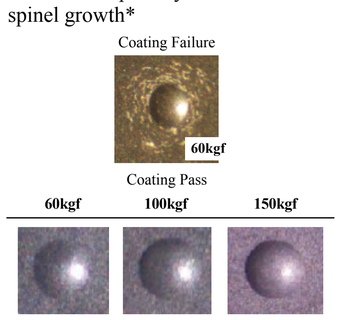
% refers to the atomic ratio of Co/Mn

Coating Uniformity



Coating Adhesion

Rockwell C test with 1/16" steel ball was used to quantify adhesion after spinel growth*



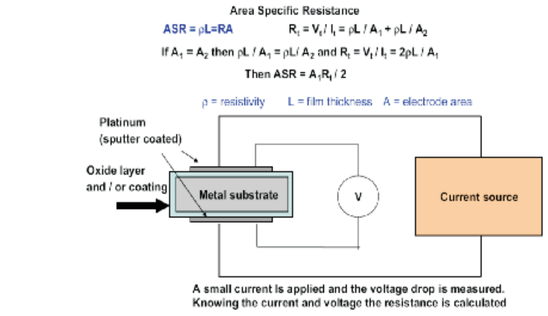
*Sun, X., et. al. JPS, **176** (2008) 167

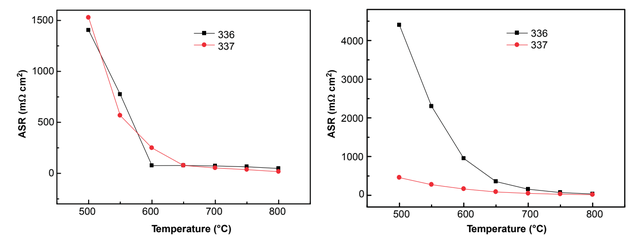
Results

Test Matrix for Samples Undergoing a 500 hour Thermal Exposure

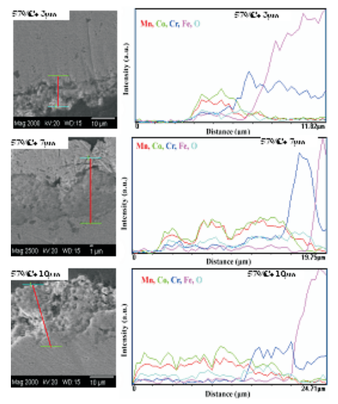
Sample No.	Deposit Thickness(μm)	% Co Composition Before 800 °C Bake	% Composition After 800 °C Bake
332	3	65	40
333	7	65	40
334	10	65	40
335	3	80	85
336	7	80	85
337	10	80	85
338	3	78	57
339	7	78	57
340	10	78	57

Coating Stability – Area Specific Resistance

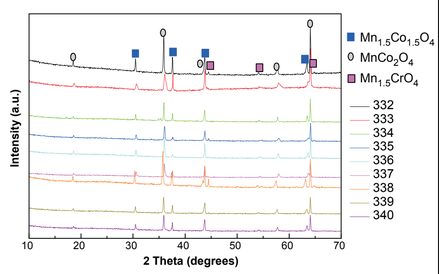




Coating Porosity and Composition After 500 hour Thermal Exposure

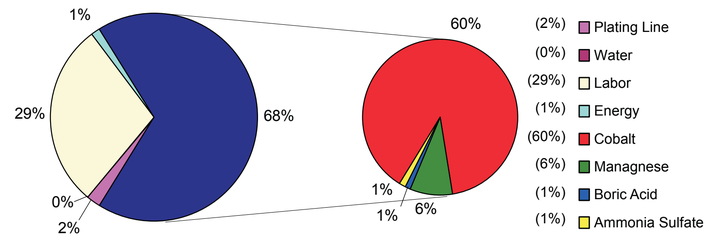


Crystal Structure After 500 hour Thermal Exposure



Preliminary Economic Analysis

Based on batch manufacturing, the DOE's high volume target of 1,600,000 plates per annum at a cost of ~$1.87 per 25 x 25 cm coated interconnect can be achieved.



Conclusions/Future Work

Conclusions

- Deposit thickness or composition did not have a large effect on the crystallinity or ASR
  - ASR is meets or exceeds requirements set by the DOE
  - Surface crystal structure consists of either $Mn_{1.5}Co_{1.5}O_4$ or $MnCo_2O_4$
- 3μm thickness is capable of preventing Cr diffusion
- Coatings prepared using the FARADAYIC Process have uniform composition and thickness
- Coatings exhibit excellent adhesion to substrate

Future Work

- Deposit coating onto patterned interconnects
- Determine nominal coating thickness and as-deposit composition that exhibits durability over full cell lifetime
- Scale-up from 2"x2" substrate to 4"x4" and eventually 10"x10" substrates
- In-situ testing in single cell and short stack SOFC systems

Acknowledgements

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