Electrodeposited Mn-Co Alloy Coating For SOFC Interconnects

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Overall Objective

Develop, optimize & validate an inexpensive manufacturing process for coating metallic SOFC interconnects with Co and Mn.

Introduction

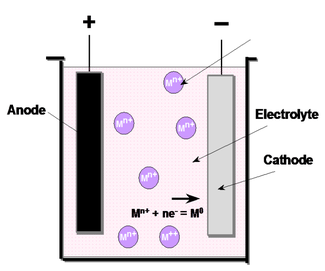
Reducing SOFC operating temperatures below 1000 ºC has permitted less resistive and expensive ferritic stainless steel interconnects to replace ceramic materials. However, even specially developed ferritic alloys operated at elevated temperatures for lengthy periods of time form a chromia scale that increases the interconnect resistance and results in chrome diffusion from the interconnect to the cathode that causes a reduction in cathode 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.

Under funding from the Department of Energy, Faraday Technology and WVU are developing, optimizing and validating an electrodeposition process to apply Mn-Co alloy coatings to SOFC interconnects. The FARADAYICSM Electrodeposition Process is used to deposit a Mn-Co alloy that is subsequently oxidized to a spinel by thermal exposure at high temperatures in an oxidizing environment. Coatings exposed to extended thermal soaks exhibited relatively dense, crystalline microstructures that prevented chrome diffusion through the coating and maintained low area specific resistance. Faraday has scaled its process capabilities to industrial size SOFC interconnects with gas flow features.

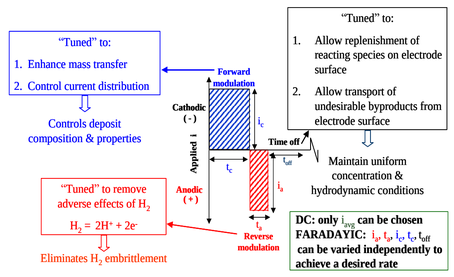
Approach

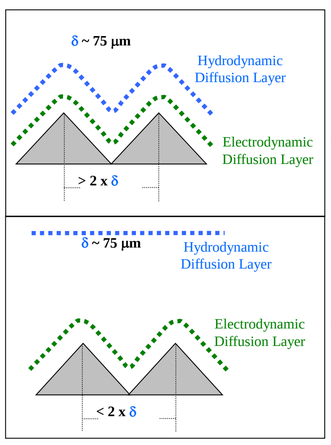
The FARADAYIC^{SM} Electrodeposition Process

Electrodeposition



The FARADAYIC^{SM} Process





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.

← 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 FARADAYIC^{SM} Electrodeposition process…

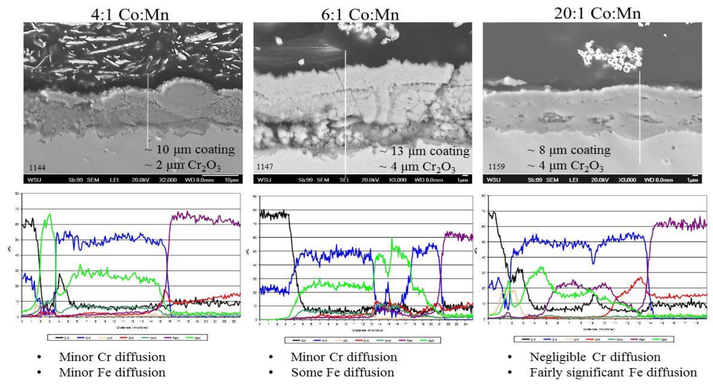
- Enables alloy composition control
- Enables control of coating uniformity for flow field patterns
- Maintains fast processing times to enable high throughput manufacturing
- Is an inexpensive manufacturing process for SOFC interconnect coatings

Milestones

Fiscal Year	*Title*	*Planned Completion*	*Percent Complete*
2011	1. Design/modification of 10" x 10" electrodeposition cell	May 2011	100%
2012	2. Long-term high temperature, thermal evaluation	September 2012	100%
2012	3. Process development for 4"x4" planar interconnects	May 2012	100%
2013	4. Process development for 4"x4" pattern interconnects	June 2013	75%
2013	5. Long-term on-cell performance evaluation	August 2013	75%
2013	6. Qualification/demonstration of IC in single cell test rig	September 2012	0%

Previous Accomplishments

Varying Cobalt Concentration



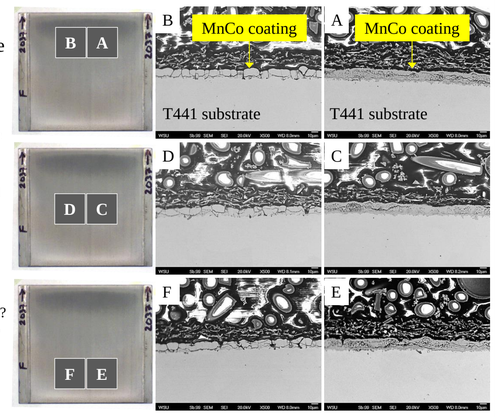
- Minor Cr diffusion
- Minor Fe diffusion

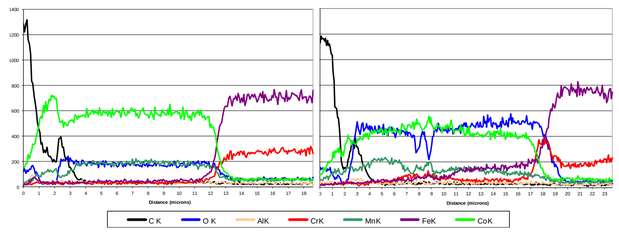
- Minor Cr diffusion
- Some Fe diffusion

- Negligible Cr diffusion
- Fairly significant Fe diffusion

Process Scale-up from 25 cm^2 to 100 cm^2

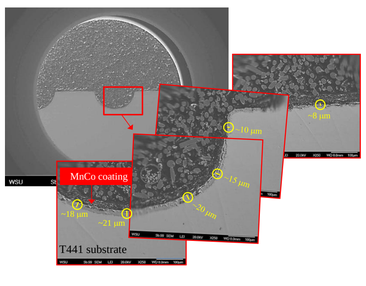
- Addition of $NaC_6H_{11}O_7$ to electrolyte
  - Observed benefits
    - Boric acid dissolves completely
    - Improved buffer capacity
    - Complexing metal ions prevents hydroxide formation
    - Anode fouling doesn't occur
    - Improved coating adhesion in as-deposited state
    - Coating deposition rate appears linear
    - Coating thickness doesn't decrease upon spinel conversion
  - Associated challenges
    - Can a high enough Mn content be obtained?
    - Can the microcracking issue be addressed?
    - Is the coating deposition rate acceptable?
    - Is the process repeatability improved?



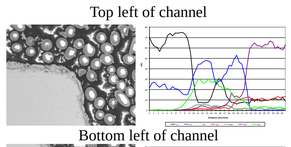


25 cm^2 430 Stainless Steel Interconnect With Gas Flow Fields

- 3 channel serpentine pattern
- Channel width ~ 0.9 mm
- Rib width ~ 0.8 mm
- Channel depth ~ 0.45 mm



Top left of channel



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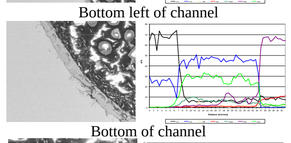

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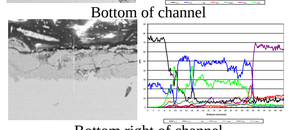

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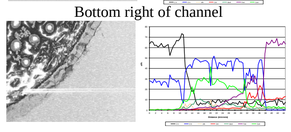
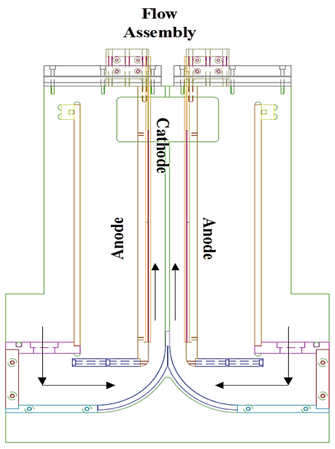


Processing Equipment

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)

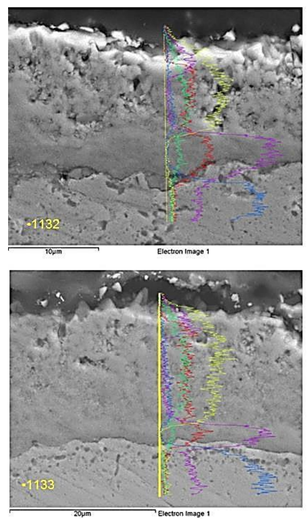


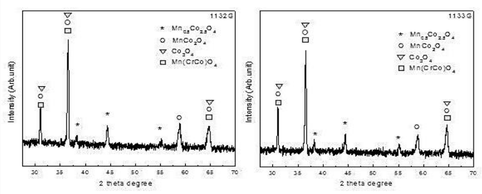
Modified FARADAYIC^{SM} Electrodeposition Cell for coating patterned interconnect substrates ranging in size from 6.5 cm^2 to 625 cm^2

Results

2000 Hour Thermal Soak

Sample No.	2 hour thermal soak pre-treatment	Mn-Co coating thickness (µm)	Chromia scale thickness (µm)	ASR (mΩ cm^2)
1132H	H_2	12	5	27.6
1133H	Air	17	4	29.1
1135H	Air	14	5	30.6
1136H	H_2	16	6	21.6
1137H	Air	15	5	26.0



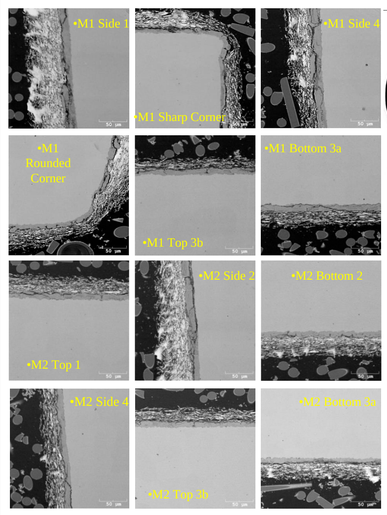


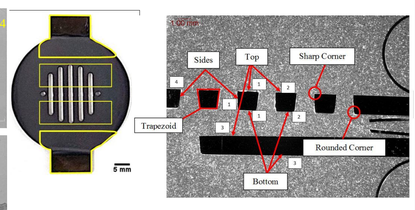
Mixture of spinel phases

- $Mn_{0.5}Co_{2.5}O_4$ and $MnCo_2O_4$
- Co_3O_4
- $MnCrCoO_4$
  - Believed to form from Cr contamination in furnace due to uncoated areas of samples

Negligible differences observed between samples

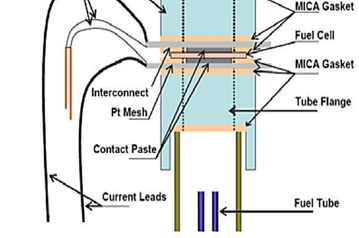
Long-term On-cell Performance Evaluation





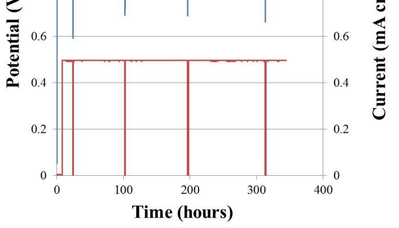
Analysis Location	Coating Thickness (µm)
M1 Side 1	18.5
M1 Sharp Corner	7.8
M1 Side 4	18.9
M1 Rounded Corner	9.0
M1 Top 3b	10.2
M1 Bottom 3a	10.8
M2 Top 1	10.0
M2 Side 1	17.2
M2 Bottom 2	9.9
M2 Side 4	14.8
M2 Top 3b	9.5
M2 Bottom 3a	11.5

Cell Test Fixture



Constant Current Performance (0.5 A cm^{-2})

1.2 % voltage decay after 344 hr.



Accomplishments/Future Work

FY 2013 Accomplishments

- Completed 2000 hour thermal soak evaluation
- Initiated long-term on-cell performance evaluation using 3.8 cm ϕ 441 stainless steel button cell
- Began coating industrial scale interconnects

Future Work

- Complete long-term on-cell performance evaluation of button cells
- Qualification/demonstration of interconnect coating in single cell test rig under ideal SOFC operating conditions by potential commercial partners

Acknowledgements

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