Novel Structured Metal Bipolar Plates for Low Cost Manufacturing (SBIR Project)

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SBIR Phase II Project Overview

Timeline

- Project start date: May 15, 2014
- Project end date: May 14, 2016

Budget

- Total Funding Spent:
  as of 3/31/14: $0.00
- Total DOE Project Value: $991,774
- Cost Share Percentage: 0%

Barriers

- Barriers Addressed : Bipolar Plate Durability and cost
  - Cost: < $3/kW (2020)
  - resistivity < 10 mohm-cm^2
  - corrosion < 1 x10^{-6}A/cm^2

Partners

- Hawaii Natural Energy Institute, University of Hawaii.

  Dr. Jean St-Pierre

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Objective of DOE FY13 SBIR II Project

- Overall Objective: Develop lower cost metal bipolar plates to meet performance target and 2020 cost target (<$3/kW)
  - Scale up and optimize doped titanium oxide coating technology demonstrated in Phase I project
  - Full size short stack demonstration under automobile dynamic testing conditions.

Key Technical Targets

Characteristic	**Unit**	**2011 Status**	**2017 Targets**	**2020 Targets**
Cost	$ /kW	5-10	**3**	**3**
Corrosion	μA/cm^2	<1	**<1**	**<1**
Resistivity	Ω.cm^2	<0.03	**<0.02**	**<0.01**

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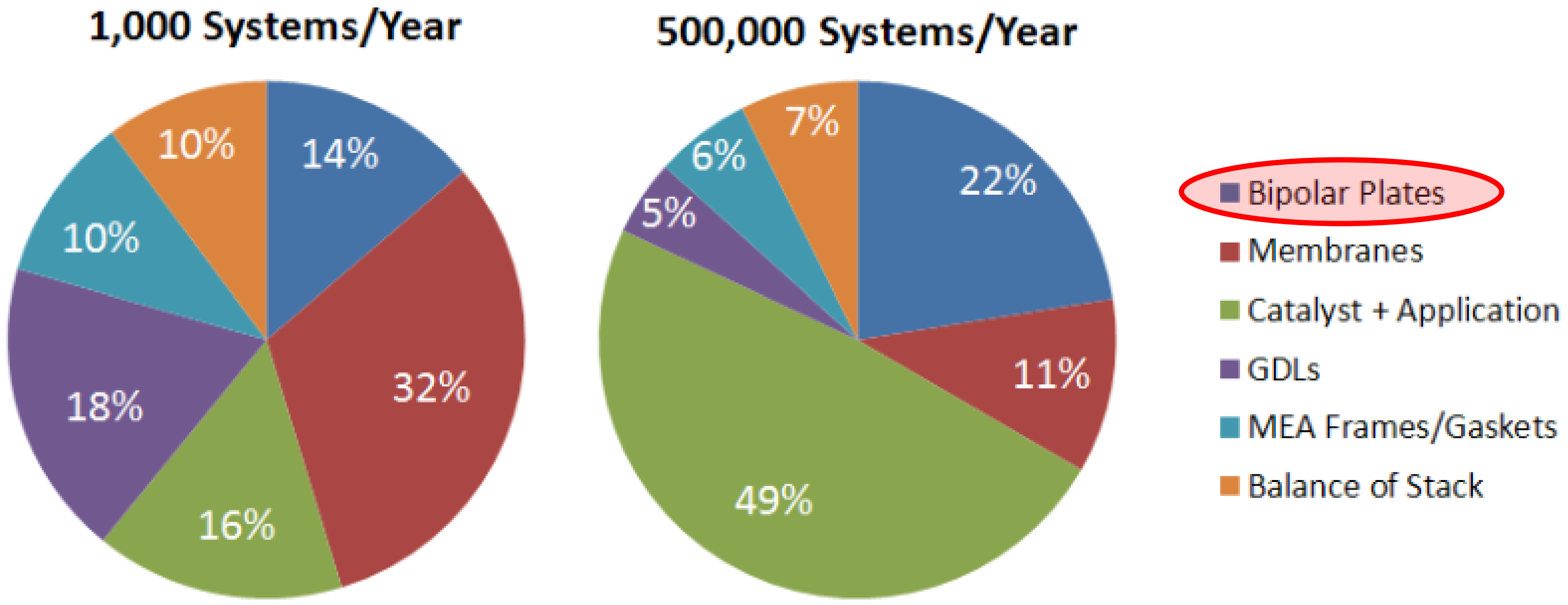
Relevance

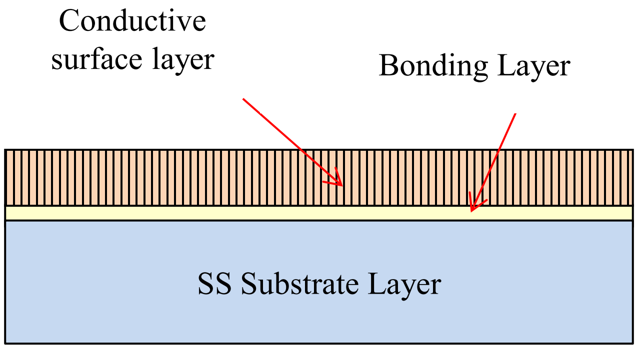
Bipolar Plate Cost is a Major Portion of Stack



J. Spendelow, J. Marcinkoski, "Fuel Cell System Cost – 2013"
DOE Fuel Cell Technology Office Record # 13012

Technical Approaches

- Based on industrial available roll-by-roll sputtering technology for the coating materials deposition.
  - Ready for high volume production
- Focused on the electrical conductive and corrosion resistive doped titanium oxide as the coating materials.
  - Low cost materials.
- Focused on the deposition and post coating treatment conditions to obtained the desired structure of the surface coating.
  - Superior adhesion of coating layer with substrate.
  - Post deposition treatment for the desired phase structure of the coating layer.



Applied Materials SmartWeb®
roll-by-roll casting system

Approach

SBIR Phase II Work Plan and Milestones

- **Task 1. Target Material Optimization (Month 1-9)**
  - Identify the proper doping elements and concentration.

Milestone 1.1. Coated stainless steel plate prepared by the end of 4th month.

Milestone 1.2. The composition of the coating layer selected by the end of 9th month.

- **Task 2. PVD process development (Month 6-21)**
  - Develop the deposition process and demonstrate in cell tests.

Milestone 2.1. Deposition Process Demonstrate by the end of 8th Month.

Milestone 2.2. Coated SS metal plates demonstrated with the ex-situ and in-situ tests by the end of 21th month.

- **Task 3. Demonstration in automobile fuel cell stacks (Month 13-24)**
  - long term operation under dynamic operation conditions.

Milestone 3.1. Components are prepared for the stack assembly and test. By the end of 17th month.

Milestone 3.2. Long-term stable operation of the metal plates demonstrated by the end of 24th month.

Project Duration: 24 months

SBIR Phase I Technical Accomplishments

Candidate Coating Materials

Materials		Electrical Resistivity (Literature Reported) μΩ.cm
Silicide	Tantalum Silicide	33-55
	Niobium Silicide	6.3-24.5
	Titanium Silicide	13-16
Carbides	Tantalum Carbides	3030
	Niobium Carbides	39-255
	Chromium Carbides	75-127
Oxides*	Doped Titanium Oxides	1000 -2000

* The resistivity of doped Titanium oxide is still too high.

- has to be used as a ultra-thin film coating,
- has excellent adhesion on metal substrates.

SBIR Phase I Technical Accomplishments

Through Plate Resistance of Coated SS

Coating Materials		TPR (mΩ.cm²) at 150 psi	
		As Coated	After CV Scan*
Silicide	Tantalum Silicide	49.3	-
	Niobium Silicide	75.1	-
	Titanium Silicide	9.35	790
Carbides	Tantalum Carbides	10.27	350
	Niobium Carbides	10.59	630
	Chromium Carbides	3.50	3 - 5
Oxides	Doped Titanium Oxides	2 - 20	2 - 20

* CV scan (potentiodynamic scan) in pH 3 H_2SO_4 +0.1 ppm HF at 80°C between OCP to 1.4 V_{NHE}

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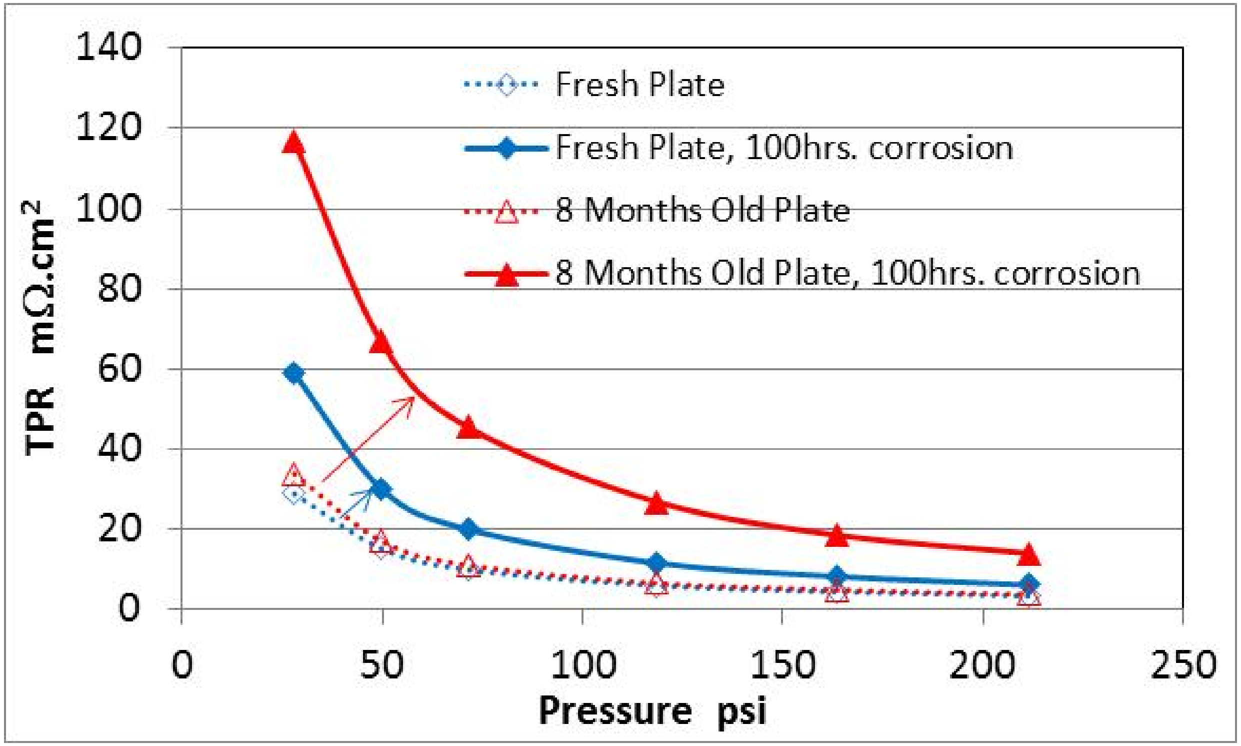
SBIR Phase I Technical Accomplishments

Stability of CrC_x Coated SS



- TPR increased after the corrosion test.
- The TPR increase is more significant after the plate was stored in air for 8 months.

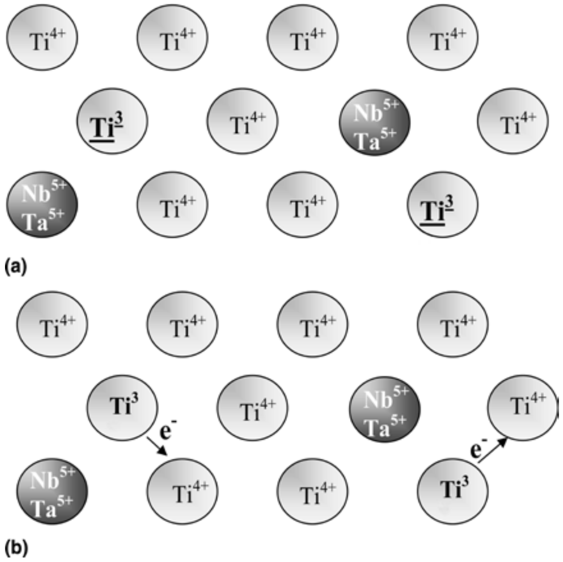
Corrosion test condition: 100 hrs. $0.8V_{NHE}$ in pH3 + 0.1 ppm HF solution at 80°C

- The stability of the CrC_x coated plate is reduced after long term storage
- The project is, then, focused on doped Ti oxide coating

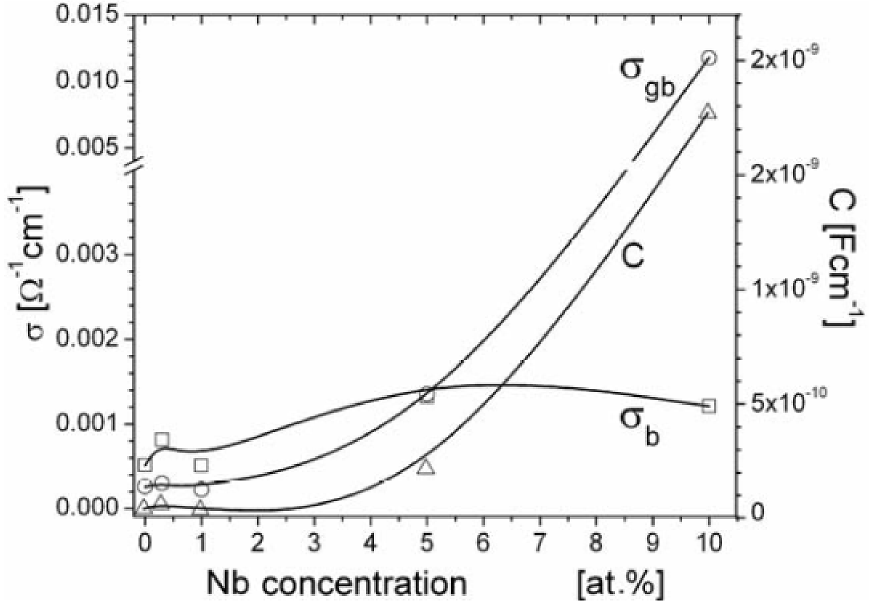
SBIR Phase I Technical Accomplishments

Properties of Doped TiO_x

Doping TiO_2 with +5 valence elements will enforce the formation of Ti^{+3} in TiO_2 lattice structure, and result in the higher electronic conductivities.



Electron hopping between Ti^{+3} & Ti^{+4} sites



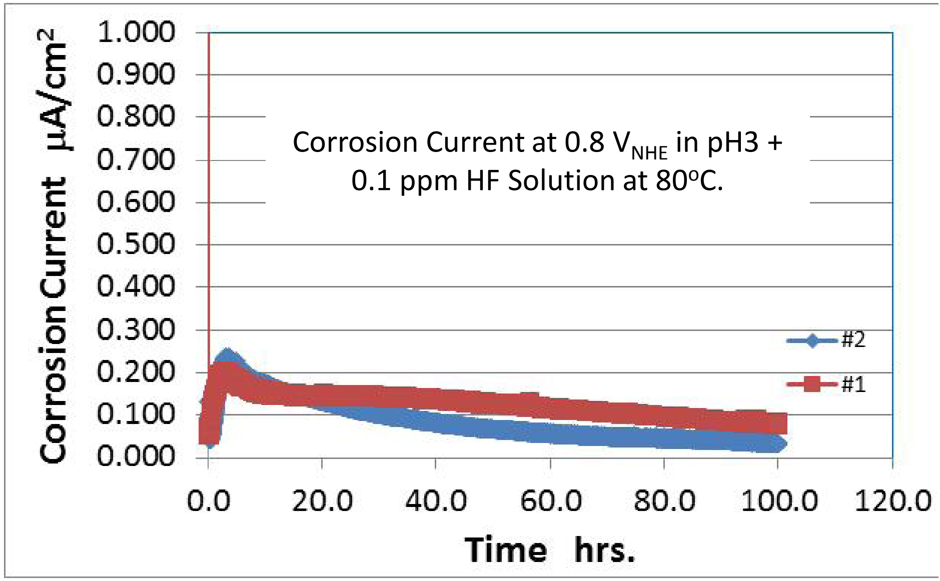
A. Trenczek-Zajac, M. Rekas, Materials Science-Poland, Vol. 24, No. 1, 2006

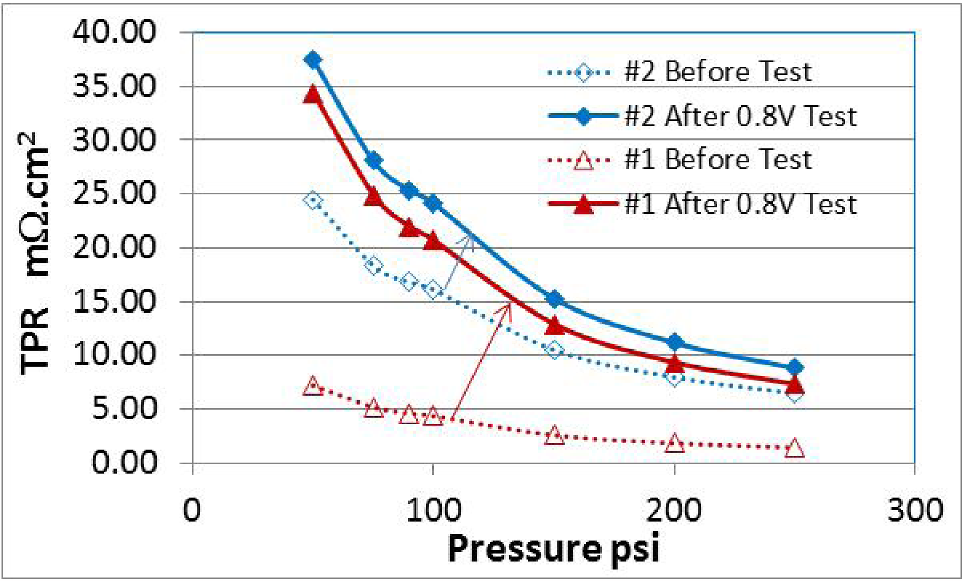
SBIR Phase I Technical Accomplishments

Long Term Stability of doped TiO_x Coated SS

Comparison of the plate before and after the 0.8 V_{NHE} 100 hours test in pH3 + 0.1ppm HF solution at 80°C

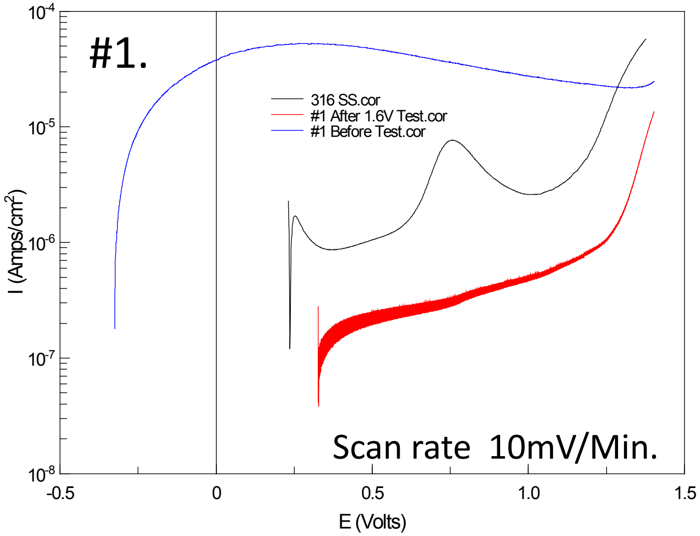
#1 has the lower resistance. #2 has the lower corrosion current and resistance increase after the 100 hours corrosion test at 0.8V_{NHE}.

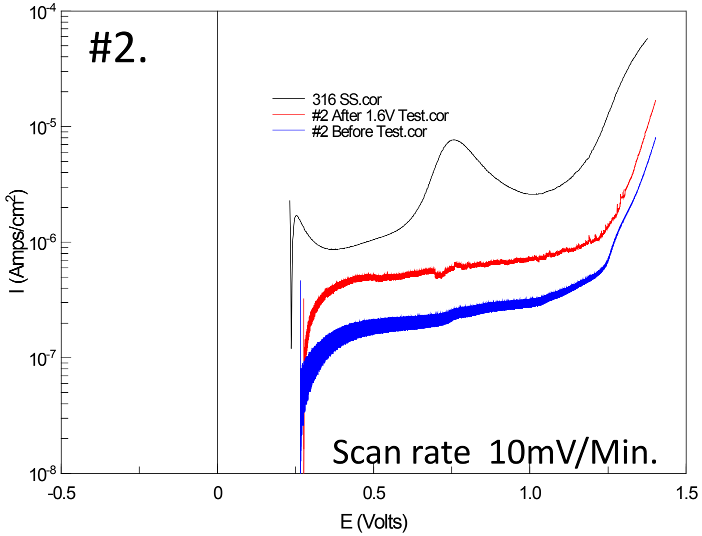




SBIR Phase I Technical Accomplishments

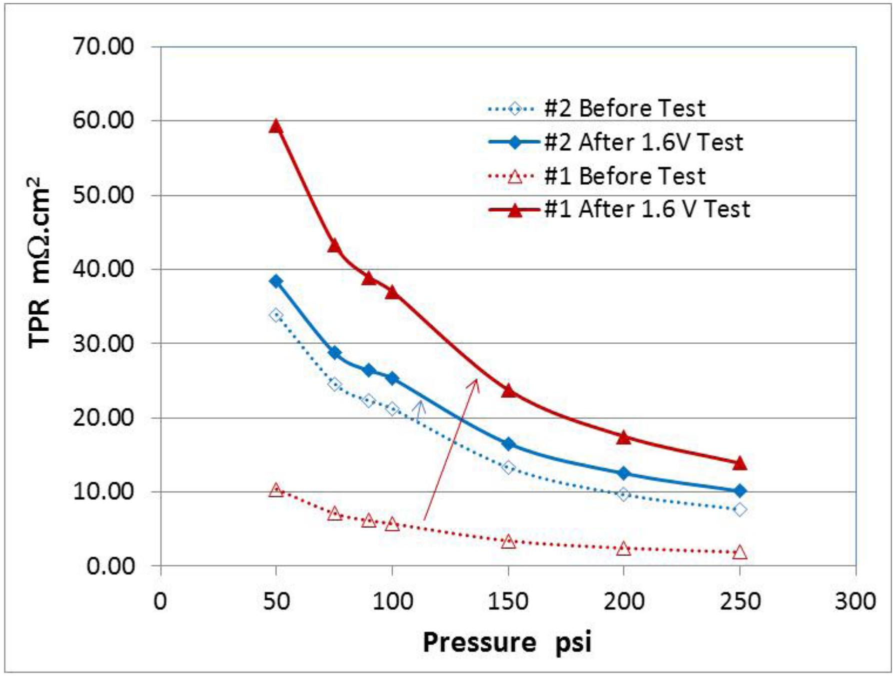
Stability of doped TiO_x Coated SS at High Potential Condition





Comparison of the plate before and after the 1.6 V_{NHE} 6 hours test in pH3 + 0.1ppm HF solution at 80°C

Both #1 and #2 have low corrosion current ($<1\ \mu A/cm^2$ at $0.8V_{NHE}$) after the $1.6V_{NHE}$ test. #2 has lower resistance after the test.



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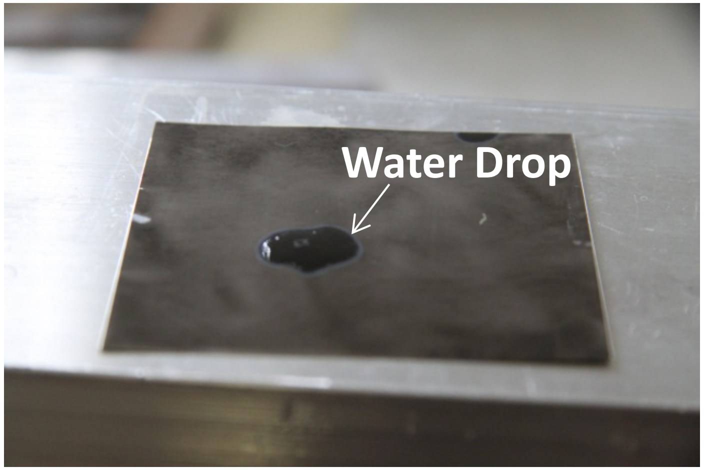
SBIR Phase I Technical Accomplishments

Coated 316L SS Plates

Surface Property:

- Coated plate is dark color with hydrophilic surface property.



Electrical Contact Resistance:

between two metal plates

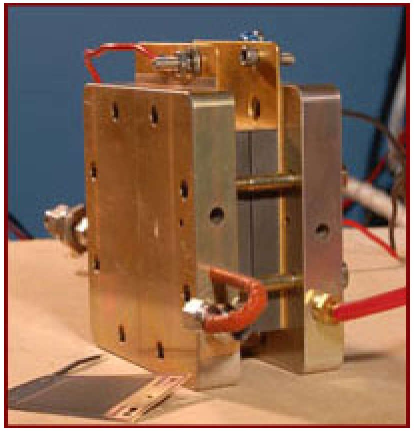
Electrical contact resistance (mΩ.cm^2) at 150 psi between doped TiO_x coated 316L SS foil before and after 500 hours soaking tests at 80°C

Soaking Environment	Before	After
DI Water	1.24	1.46
50% EG-Water	2.31	2.47
Air	3.20	1.24

- Annealed 316L is very soft that leads to high measurement error of contact resistance. (difficult to have flat samples)
- Other measurements indict that the coated metal plate to plate contact resistance is <1.5 mΩ.cm^2 and very stable.
- Can be use to eliminate laser welding of the bipolar plates.

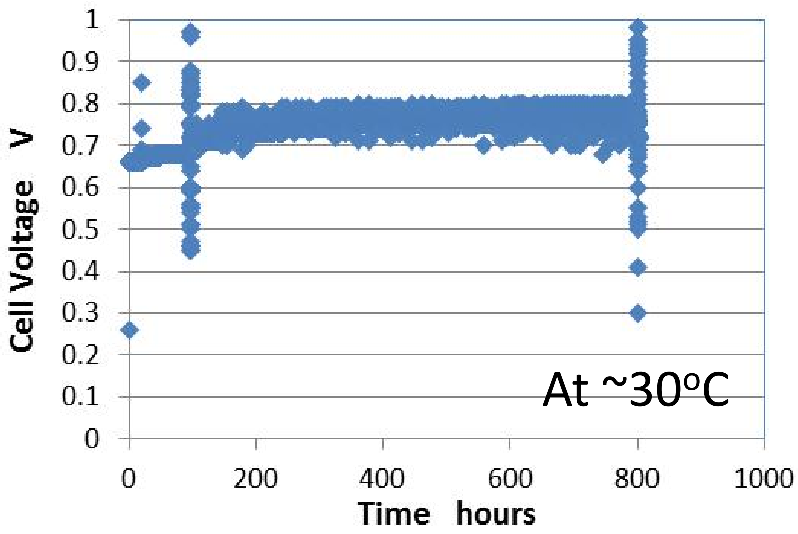
SBIR Phase I Technical Accomplishments

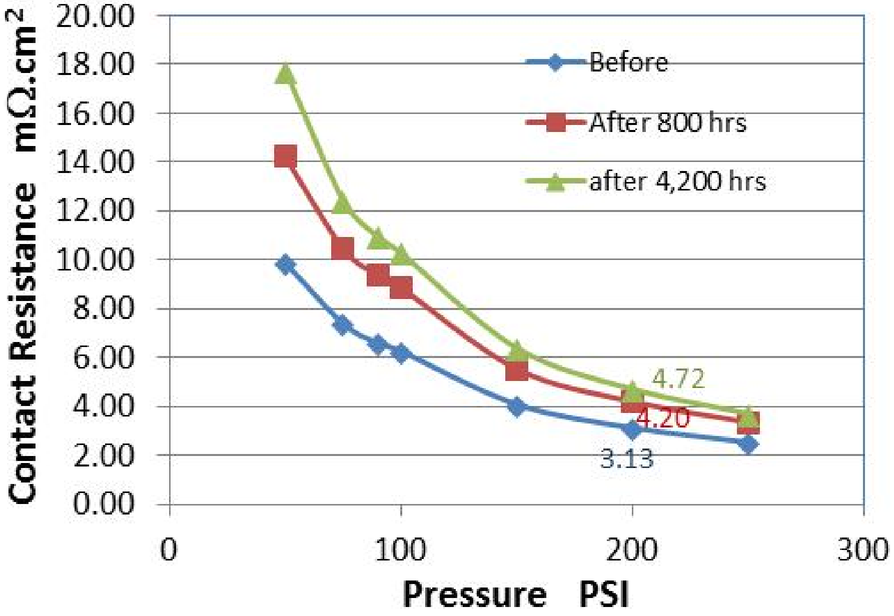
Single Cell Test with doped TiO_x coated SS Plates



16 cm^2 active area cell using Fuel Cell Technology hardware

Contact Resistance with GDL before and after 800 hrs. and 4,200 hrs. cell tests





Collaborations

Team Partner:

HNEI, Univ. Hawaii

5 kW stack testing under automobile dynamic operation conditions.

Dr. Jean St-Pierre

Application Support:

Ford Motor Company

General Motors Corporation

Summary

- ***Relevance:*** Reducing the metal bipolar plate cost to meet FY20 requirements.
- ***Approach:*** Using doped TiO_x coating on metal plates surface for fuel cell applications..
- ***Accomplishment (Phase I Project):***
  - Down selected doped TiO_x semi-conductive as the coating material.
  - Demonstrated 4200 hours stable operation in small single cell testing using doped TiO_x coated SS plates.
  - Doped TiO_x coated SS plates shows hydrophilic surface property and low metal plate to metal plate contact resistance.
- ***Collaborations:***
  - Teaming with HNEI, Univ. Hawaii for the 5 kW stack test in Phase II.
  - Supported by Ford and GM.
- ***Phase II Work:***
  - Scale-up the metal plate production process.
  - Demonstrate its performance in 5kW stack durability test to 2,000 hrs.

Acknowledgements

- DOE EERE Fuel Cell Team.
- Team Members. HNEI, U. Hawaii
- Industrial Partners. Ford, GM