Novel Structured Metal Bipolar Plates for Low Cost Manufacturing

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Project ID# : FC105

Project Overview

Timeline

- Project start date: Jan. 15, 2017
- Project end date: Jan. 31, 2019
- Percent complete: 100%

Budget

- Total Funding in 2018: $100,000
- Total Project Value: $537,500
- Cost Share Percentage: 20%

Barriers

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

Supporting Partner

- Strategic Analysis, Inc.
- Hawaii Natural Energy Institute, University of Hawaii.

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Objective of the Project

- <u>Overall Objective:</u> Develop lower cost metal bipolar plates to meet performance target and 2020 cost target (<$3/kW)
  - Develop large scale manufacturing process for the doped titanium oxide coating technology demonstrated in previous SBIR project.
  - Investigate the relationship between processing conditions and doped titanium oxide properties for production quality control system development.

Key Technical Targets

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

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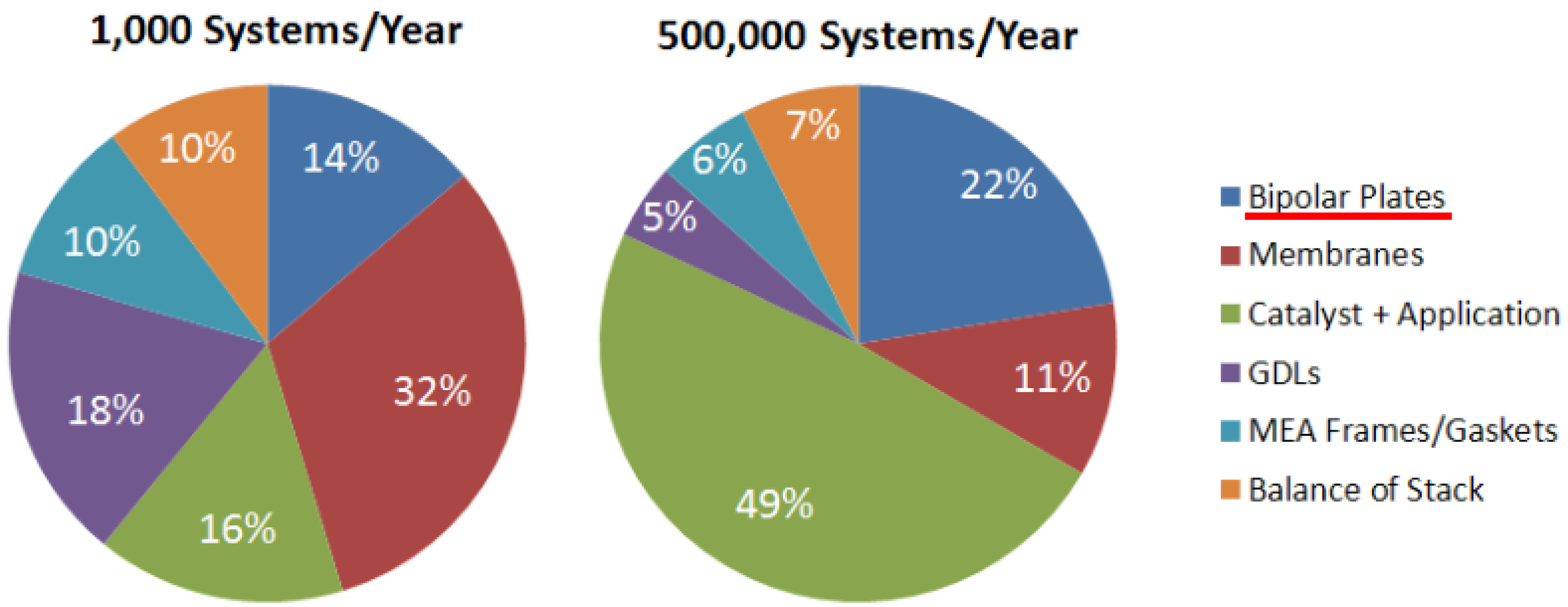
Relevance

Bipolar Plate Cost is a Major Portion of Stack Cost



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

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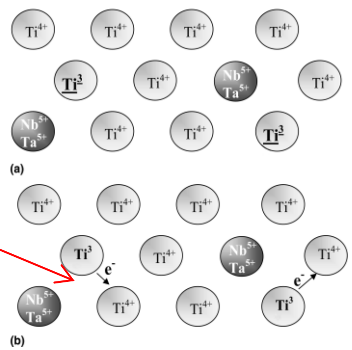
Approach: Coating Material for SS Plates

--- Semiconductive Doped TiO_x

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

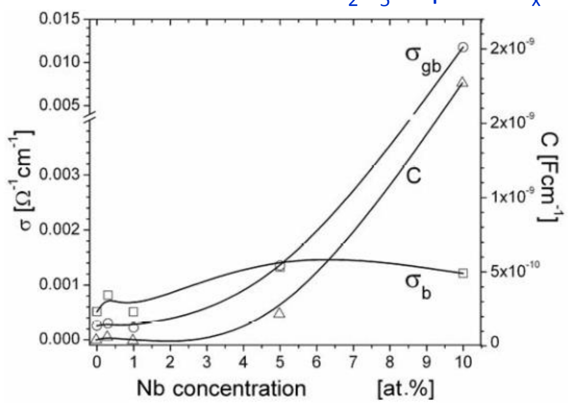
Electron hopping between Ti^{+3} & Ti^{+4} sites



Challenges to use doped TiO_x coating:

1. Doped TiO_x is semi-conductive. The electrical conductivity is not high enough.
2. The week bonding of doped TiO_x to metal substrate surface.

Electrical conductance of Nb_2O_5 doped TiO_x



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

TreadStone's approach:

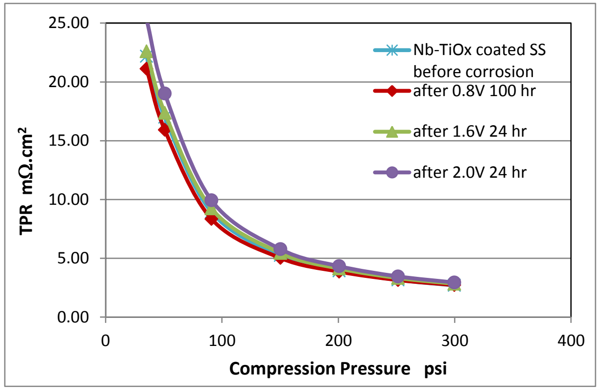
- Coat stainless steel substrate with Ti-Nb or Ti-Ta alloy. Then, grow the doped TiO_x surface layer on the Ti alloy coating layer.

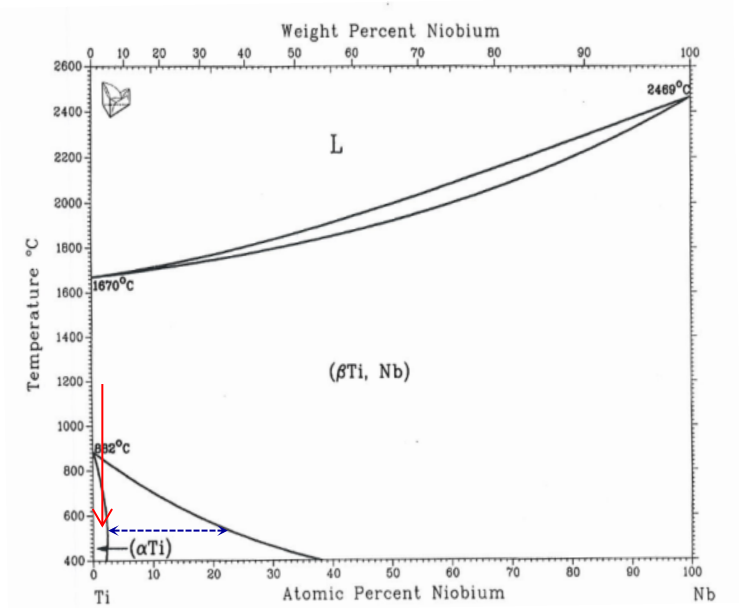
1. The doped TiO_x on Ti alloy surface is thin and reliable.
2. Ti alloy coating has excellent adhesion on metal substrate (stainless steel or aluminum).

Achievements and Challenges

--- from previous SBIR project

- Low contact resistance and superior corrosion resistance have been demonstrated using the doped TiO_x coating on SS substrate for PEM fuel cell applications.
- Challenges:
  - Processing technology has to be optimized to obtain the desired structure of surface oxide layer.
    - Segregation of Nb or Ta alloy element from the coating surface leads to the pure Ti surface oxide layer of the sputtering coated surface.
  - Need to determine the optimized coating composition.
  - Understand the relationship of the processing condition with the surface oxide layer structure.





The objective of this project is to develop technical solutions to overcome these challenges..

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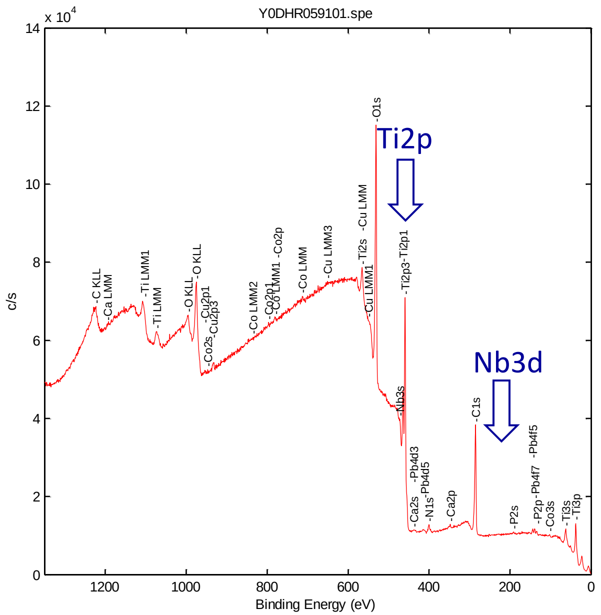
PVD Process Condition Optimization

--- Minimizing Surface Layer Alloy Element Segregation

- Previous Processing Condition

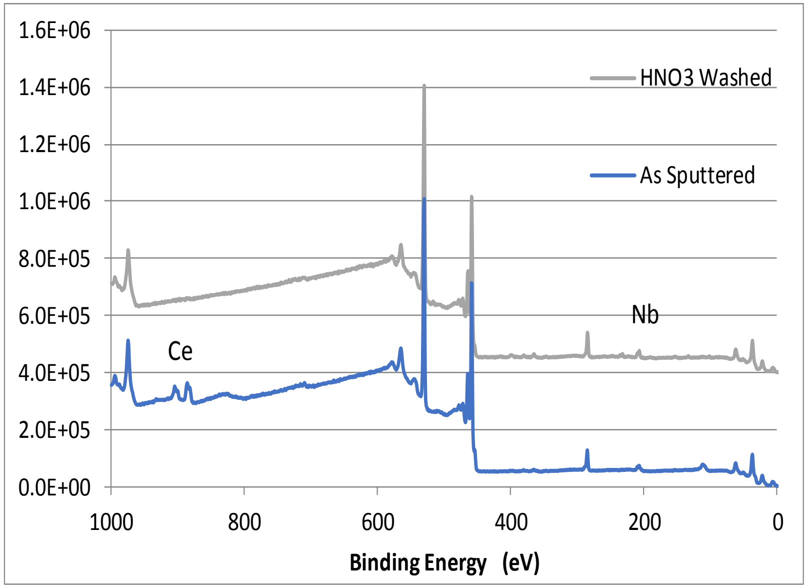
XPS survey spectrum of as-coated Ti3Nb on SS.



No Nb (or Ta using Ti-Ta alloy target) was detected on the coating surface

- Modified Processing Condition

XPS spectra of Ti-Nb-Ce alloy on SS.



- Adding Ce into the target can retain the Nb in the surface layer of the coating.
- Ce can be removed by acid washing.

The modified processing condition has brought Nb to the surface.

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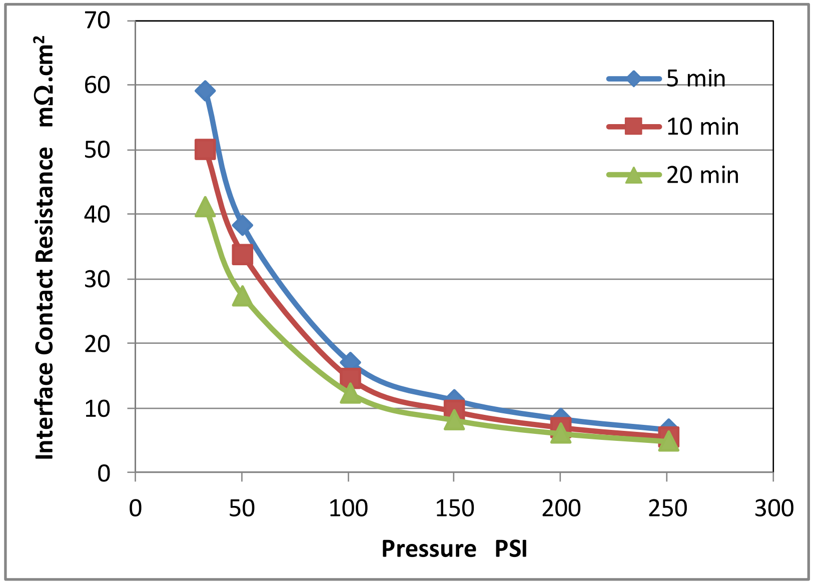
Coating Process Development

- Recent focus is on cathodic arc evaporation (CAE) process development.
  - More reliable to keep Nb (Ta) in the coating surface layer.
  - Exceptional adhesion of the coating layer on substrate surface.

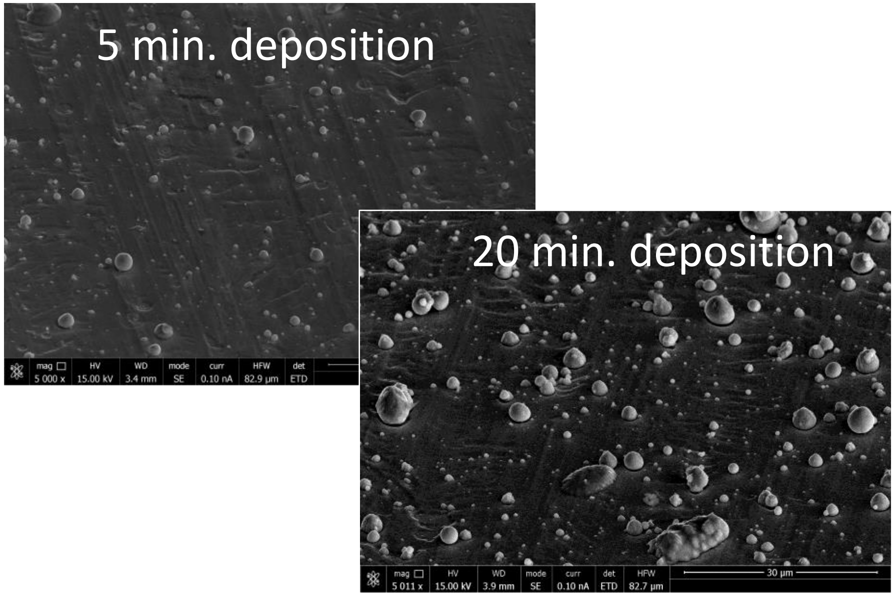
<u>The focus is to reduce the processing time of the coating process.</u>

ICR comparison of stainless steel with Ti coating with the CAE deposition time



with ~ 15nm TiO_2 on the surface

SEM pictures of SS with Ti coating deposited by CAE.



DOE's targets: < 10 mΩ.cm^2

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Future Work

- Large scale manufacture process development.
  - Compare various deposition technologies to select the low coat, large volume production method.
- The mechanism study of the low contact resistance doped TiO_x surface oxide with fuel cell GDL.
  - Using advance surface characterization technologies to study the mechanism of the low electrical contact resistance of the doped TiO_x coating and determine the criteria for large scale production quality control and inspection.
- Durability Evaluation
  - Conduct *in-situ* cell/stack durability tests of the doped TiO_x coating for PEM fuel cell applications.

Summary

- ***Objective:***
  - Develop low cost fabrication process of the doped TiO_x coating for PEM fuel cell applications.
  - Investigate the relationship of the properties of the doped TiO_x surface layer with processing condition and its durability in PEM fuel cell operation environment.
- ***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:***
  - Identified processing factors for the coating layer surface composition control.
  - *Developed a low cost method for coating composition optimization.*
- ***Future Work:***
  - Detailed development of the PVD process for the optimized coating properties.
  - Investigation the relation of the surface oxide layer properties with processing conditions and its durability.
  - Conduct *ex-situ* and *in-situ* tests to demonstrate the performance of the coating processed with low cost fabrication process.

Acknowledgements

- DOE EERE Fuel Cell Team.
- DOE SBIR Program.
- Supporting Partners.
    - Manufacture cost analysis: Strategic Analysis, Inc.
    - *in-situ* durability test: HNEI, U. Hawaii