Novel Structured Metal Bipolar Plates for Low Cost Manufacturing

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FC105

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Overview

Timeline and Budget

- Project Start Date: 03/01/2019
- Project End Date: 12/31/2020
- FY19 total DOE Funding: $407,162
- FY20 Planned DOE Funding: $0

Barriers

- Bipolar plate fabrication cost: ($3/kW)
- Electrical contact resistance: (<5 $m\Omega.cm^2$)
- Corrosion resistance: (< 1 $\mu A/cm^2$)

Partners

- Oak Ridge National Laboratory
  - PI: David Cullen
- TreadStone Technologies Inc.
  - PI: Conghua Wang

Relevance

- 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.

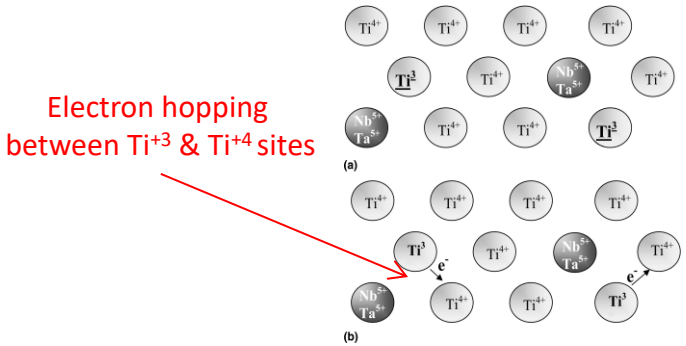
Key Technical Targets

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**

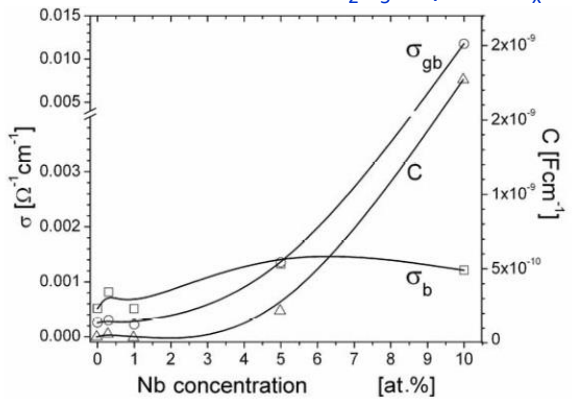
Approach: Coating Material for SS Plates

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.



Electrical conductance of Nb_2O_5 doped TiO_x



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

Challenges to use doped TiO_x coating:

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

TreadStone's approach:

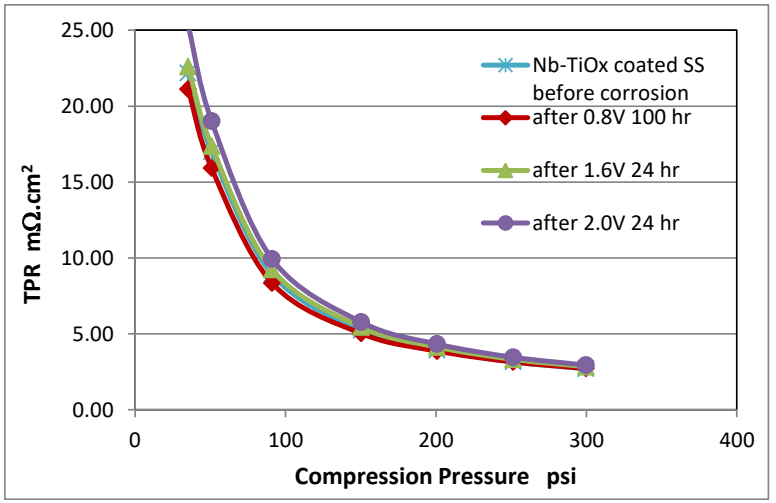
- Coat stainless steel substrate with Ti-Nb or Ti-Ta alloy. Then, grow the doped TiO_x surface layer on the Ti alloy coating layer.

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 Progress

from previous 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 must 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 properties.

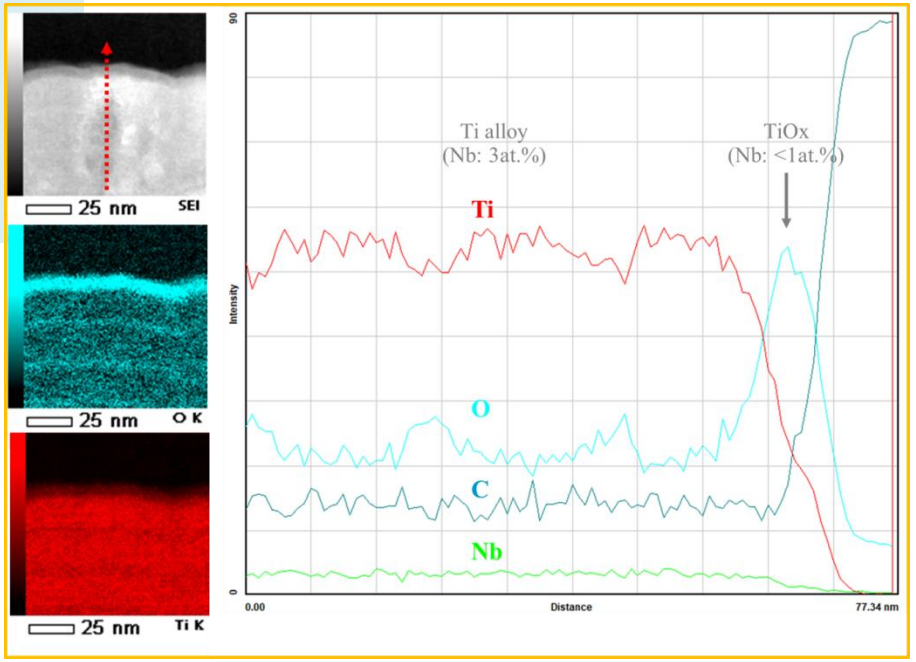


The objective of this project is to develop technical solutions to overcome these challenges.

Achievements and Progress

Coating Surface Composition Control

- Sputtering using Ti-Nb alloy target only obtained Ti in the coating surface layer.
- By adjusting the Ti alloy target composition, the Nb segregation in the coating surface layer can be reduced, as verified using STEM and EDAX analysis.
- The Nb in the surface layer of the Ti alloy coating will lead to the formation of Nb-doped TiOx surface layer.

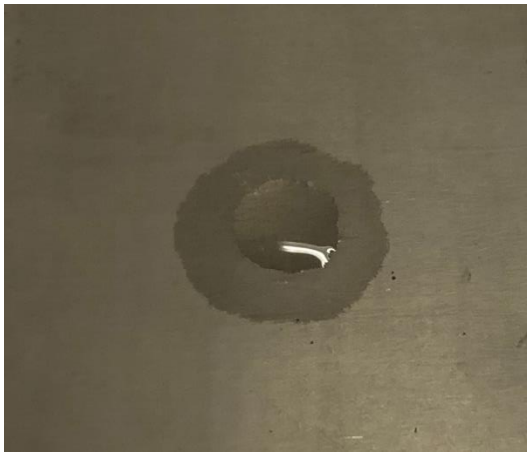


Achievements and Progress

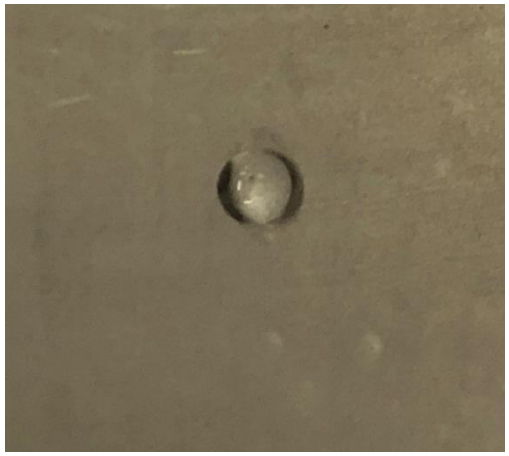
Coating Surface Hydrophilicity

- The TiO_x coating can be tailored to super-hydrophilic or super-hydrophobic properties.
- The “super” surface property can help water management to avoid flooding or overheating in stacks, with proper flow field design.
- The “super” surface property is stable after corrosion tests for 100hrs @ 0.8 V_{NHE} and 6 hrs @ 1.4 V_{NHE}.
- The “super” surface property is stable after several months shelve storage tests.

Water droplet on super-hydrophilic TiO_x coated SS plate.



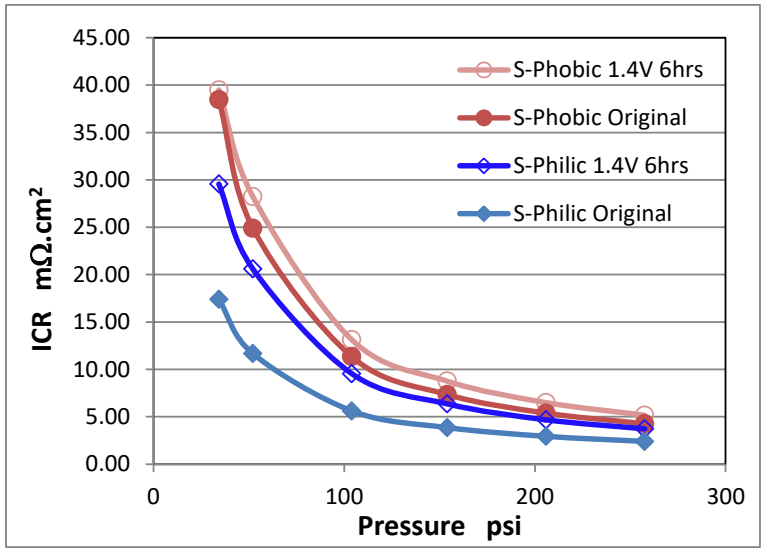
Water droplet on super-hydrophobic TiO_x coated SS plate.



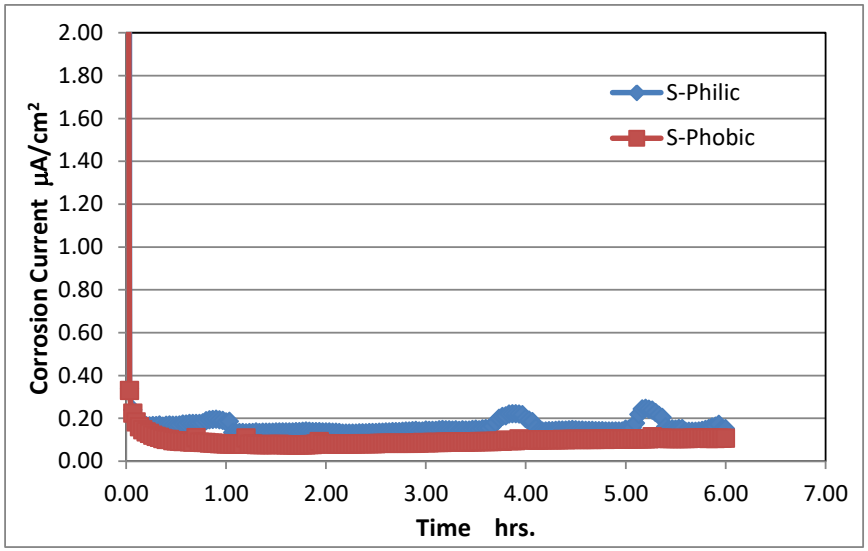
Achievements and Progress

ICR and corrosion resistance of TiOx Coated SS

ICR of super-hydrophilic and super-hydrophobic TiOx coated SS before and after 6 hrs. corrosion tests at 1.4 V_{NHE} in pH3 H_2SO_4 + 0.1ppm HF solution at 80°C.



Corrosion current of super-hydrophilic and super-hydrophobic TiOx coated SS at 0.8 V_{NHE} before potentiostatic tests in pH3 H_2SO_4 + 0.1ppm HF solution at 80°C.



Achievements and Progress

Responses to Previous Year Reviewers' Comments

- This project was not reviewed last year.

Collaboration and Coordination

- Oak Ridge National Laboratory (Prime)
  - Federal Laboratory
  - Funded within the DOE Hydrogen and Fuel Cells Program
  - Electron microscopy characterization and annealing by laser interferometry

- TreadStone Technologies Inc. (sub)
  - Industry
  - Funded within the DOE Hydrogen and Fuel Cells Program
  - Coating technology development and evaluation

Remaining Challenges and Barriers

- Lack of scientific understanding of the electrical conductance and the performance degradation mechanism of the TiOx coating. Fundamental investigation is needed to provide solutions to:
  1. Guide production quality control, for high production yield.
  2. Accelerate technology transfer and market acceptance, without extensive durability tests.
- Lack of the performance demonstration in full size fuel cell stacks.

Technology Transfer Activities

- Filed one provisional patent application in Feb. 2020.

- In discussion with two global coating service companies for technology licensing and market development.

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 coating process to control the coating surface composition.
  - *Developed a low cost manufacture method to achieve the desired properties.*
- ***Future Work:***
  - Scientific understanding of the electron conductance and degradation mechanism of the TiO_x coating in fuel cell operation conditions.
  - Demonstrate the long term durability in fuel cell stack operation conditions.
  - Explore the application of the TiO_x coating in other applications, such as electrolyzers and batteries.

Any proposed future work is subject to change based on funding levels