V.D.1 Novel Structured Metal Bipolar Plates for Low Cost Manufacturing

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Contract Number: DE-EE0007732

Subcontractor:
Hawaii Natural Energy Institute, University of Hawaii, Honolulu, HI

Project Start Date: January 15, 2017
Project End Date: January 14, 2018

Overall Objectives

- Develop the physical vapor deposition (PVD) process for the doped titanium oxide (TiO_x) coating.
- Characterize the doped TiO_x coated metal plates, including the chemical composition and thickness of the doped TiO_x surface layer, electrical contact resistance and the corrosion resistance of the coating for proton exchange membrane (PEM) fuel cell applications.
- Evaluate the coating on low cost stainless steel (SS) and post-coating stamping.
- Analyze the manufacturing cost of the technology.

Fiscal Year (FY) 2017 Objectives

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- Analyze the manufacturing cost of the technology.

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan.

(A) Durability (improve the durability of bipolar plates in fuel cell operation conditions)

(B) Cost (reduce the cost of the bipolar plate production)

(C) Performance (improve the performance of the bipolar plates)

Technical Targets

The technical objective of the project is to further develop the manufacturing process of the doped TiO_x coating for PEM fuel cell applications that meet the following targets.

- Low electrical contact resistance with gas diffusion layer ($<5\ m\Omega.cm^2$)
- Low corrosion resistance: $<1\ \mu A/cm^2$
- Low cost: $3/kW by 2020
- Capable of roll-to-roll coating and post-coating stamping

FY 2017 Accomplishments

- Finished the manufacture cost analysis indicating the proposed technology has the lowest cost comparing with other competing technologies.
- Designed the sputtering target material.
- Determined the TiO_x coating microscopic characterization methods.
- Developed the process to minimize the coating surface composition segregation.

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INTRODUCTION

The components of the transportation fuel cell system and stack play an important role in the cost reduction and performance improvement of the fuel cell system. The metal bipolar plate is an important component in fuel cell stack. For example, the automobile industry has confirmed that metal bipolar plates are essential to ensure rapid start of fuel cell vehicles in cold weather (-40°C). The metal plate cost is a significant part of the fuel cell stack cost. Figure 1 shows results of the PEM stack cost analysis recently (December 2015) conducted by our team partner Strategic Analysis, Inc. It shows that bipolar plates account for 14–27% of the

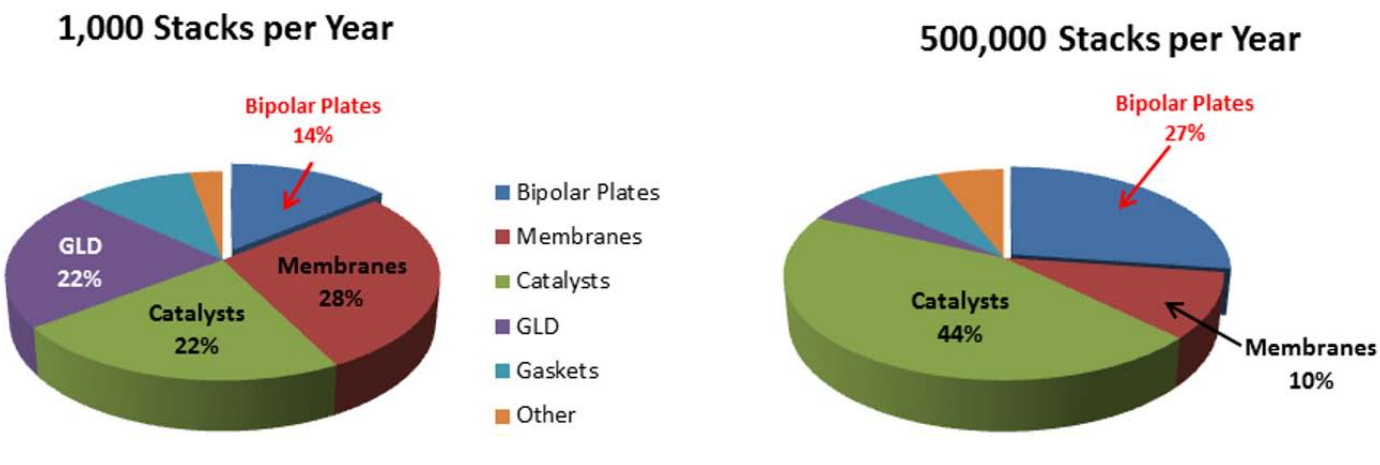

FIGURE 1. Cost breakdown of PEM fuel cell stacks [1]

overall stack cost (1,000–500,000 stacks/yr using 2015 technology) [1]. Therefore, any reduction in plate costs will have significant impact on the overall stack cost.

APPROACH

The technical approach of this project is to develop a precious metal free coating technology for PEM fuel cell applications. The schematic drawing of the technology is shown in Figure 2. The SS foil substrate surface is covered with a thin (~100-nm thick) titanium alloy sub-layer and an ultrathin (several nanometers) electrically conductive doped TiO_x surface layer. This surface oxide layer is grown on the titanium alloy sub-layer surface. The titanium alloy contains the alloy element that is the dopant in the doped TiO_x.

TreadStone's approach overcomes the key technical barriers of using doped titanium oxide semiconductive material [2,3] as the coating material, which are (1) the thickness control of the oxide coating layer and (2) the adhesion of the oxide layer with the metal substrate. The technology utilizes the inherent characteristics of titanium alloys to overcome these barriers and makes it reliable at large volume fabrication and low cost.

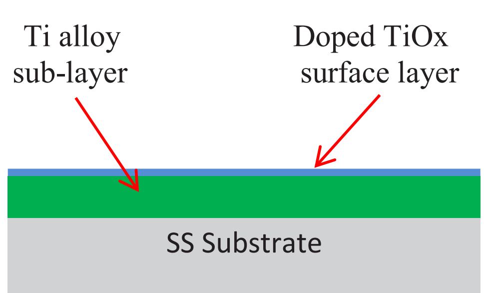

FIGURE 2. Schematic drawing of TreadStone's doped TiO_x coating on SS foil

RESULTS

The manufacture cost analysis of the corrosion resistant coating using the proposed technology was conducted by our team partner, Strategic Analysis, Inc. The analysis is based on stacks using 377 pieces of bipolar plates with the power density of 1,095 mW/cm^2. The coating is conducted on the stamped and welded plates, using a post-forming coating process. Figure 3 is the coating cost at different production volumes. It shows that the major cost item is the capital cost for PVD equipment. The production cost is related with the production volume. At 500,000 systems/yr volume, the coating cost is $0.14/plate. The total coating cost is $0.85/kW which can meet DOE's requirement.

In previous Small Business Innovation Research projects, it was found that there is composition segregation of the titanium alloy coating in the surface layer. The dopant element Nb or Ta is separated from the surface layer of the alloy coating, which results in a pure titanium surface layer. The pure titanium surface layer can only grow titanium oxide that is not as conductive as doped titanium oxide. In this project we have adjusted the processing condition in the sputtering deposition process to reduce the kinetic energy of doping element to minimize the dopant element penetration into the coating surface. Figure 4 shows X-ray photoelectron spectroscopy core level spectra of a deposited Ti–2Ta alloy coating. It was found that surface layer contains 0.5 at% of Ta. Although this concentration is still lower than the target, it shows the feasibility of control composition segregation of the dopant element using deposition energy control to obtain the doped titanium oxide on the coating surface.

A challenge for the proposed project in the manufacturing process development is high manufacturing cost and long lead time of the PVD target. The project's limited time and budget make it challenging to optimize the process and the composition of the coating. In this project, we have developed a new method to overcome the cost and

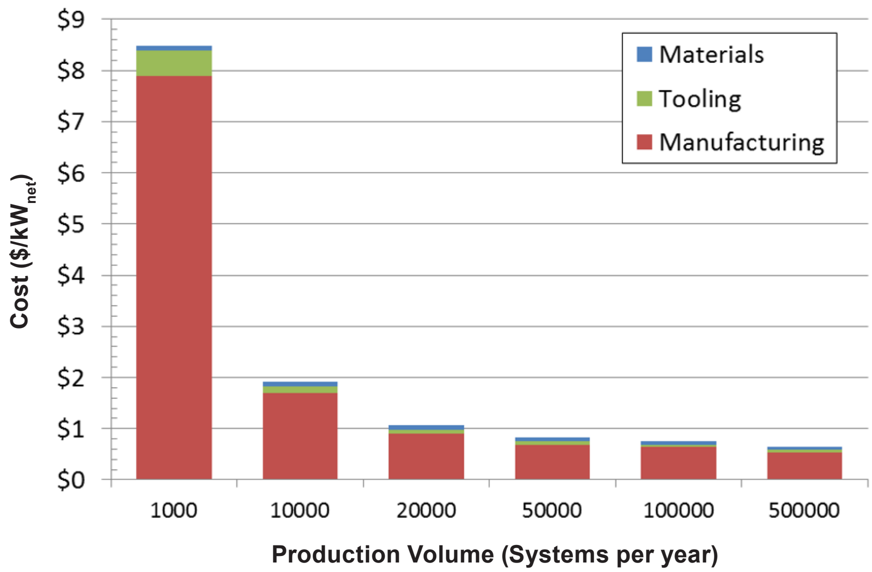

FIGURE 3. The coating manufacture cost of bipolar plates at different production volumes

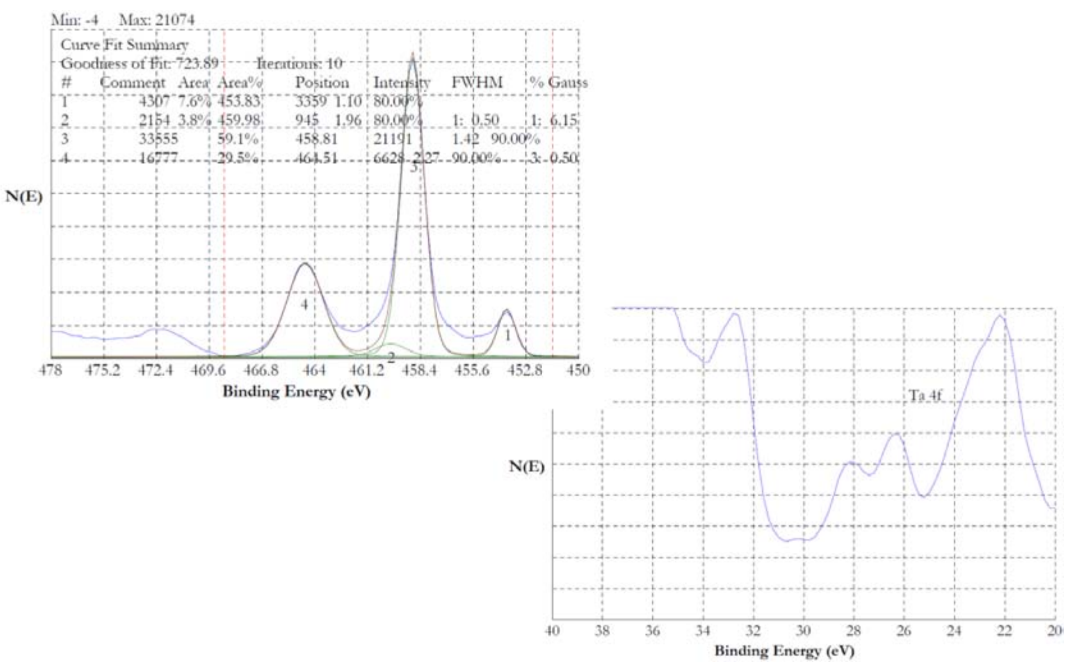

FIGURE 4. The X-ray photoelectron spectroscopy core level spectra of as deposited Ti–Ta coating, showing the existence of Ta in the coating surface layer

lead time barriers. We will use a mosaic-type of target for the deposition. The target is made of strips of target material that are placed in a titanium tray. The coating composition is determined by the width ratio (in combination with the sputtering rate) of each element. For example, the Ti–Nb coating can be obtained with the Nb and Ti strips in the titanium tray, and the ratio of Nb and Ti in the coating can be adjusted using the width of Nb and Ti strips. We have identified a partner PVD coating company whose PVD systems can meet the requirement of the process. We are in the process of developing the manufacturing technology for the doped titanium oxide coating.

CONCLUSIONS AND UPCOMING ACTIVITIES

The project is focused on the manufacture technology development of the novel precious metal free coating technology for PEM fuel cell applications. The manufacture cost analysis indicates the technology will have the lowest production cost, compared with other competing technologies. The project has developed technical solutions to overcome key technical barriers.

The project will continue the development of the manufacture process based on PVD technology. The characterization process of the coating will be developed for the manufacture process quality control method development. The coated SS plates will be evaluated in ex situ corrosion tests and post-coating stamping tests. The substrate material will include 316L SS and lower cost 304 SS. The performance of the coating on both substrates will be compared.

REFERENCES

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3. L.R. Shepard, T. Bak, and J. Norwotny, *J. Physical Chemistry C.,* **112**, 611–617 (2008).