Coated aluminum bipolar plates for PEM fuel cells applications

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Introduction

Proton Exchange Membrane (PEM) fuel cells are electrochemical devices that convert hydrogen and oxygen into water and electricity. These cells are considered as an alternative to fossil fuel based energy systems. Their low emissions of pollutants and carbon dioxide makes them promising for reducing the environmental impact of some applications and sectors. For example, PEM fuel cells typically operate at temperatures below 100°C, which makes them particularly suitable for compact applications, such as hydrogen-powered electric vehicles [1-2].

One of the key components of a PEM fuel cell is the bipolar plates. These plates serve several essential roles: they ensure the uniform distribution of reactive gases (hydrogen and oxygen) across the electrodes, collect the electric current generated by the electrochemical reactions, and are also used for the removal of water produced during the process [3-4].

The development of suitable bipolar plates for PEM fuel cells presents several technical challenges, particularly concerning their durability and electrochemical properties. Bipolar plates must withstand the acidic and humid environments of a fuel cell without corroding. They must also resist to temperatures up to 100°C without significant degradation of their properties, particularly their electrical conductivity [3-4].

In addition to durability and electrochemical performance, the weight of the bipolar plates is another significant challenge, particularly for transportation applications. Bipolar plates often account for more than 80% of the total weight of a fuel cell, which can limit their use in systems where weight is a constraint, such as in vehicles [3-4].

Historically, bipolar plates for fuel cells were made from machined graphite. Graphite bipolar plates offer advantages in terms of conductivity and corrosion resistance, but they have also significant drawbacks, such as brittleness and high weight of the plate due to their thickness.

To overcome these limitations, modern bipolar plates are often made from coated metals, such as stainless steel or titanium. These coated metallic materials offer the advantage of producing thinner and lighter bipolar pates, while still providing good electrical conductivity and resistance to corrosion [3-4].

In this context, research is increasingly focusing on exploring new metallic materials, particularly aluminum, as a potential alternative due to its light weight and cost-reduction potential.

Methodology

Two methods can be considered for the production of coated aluminum bipolar plates. The first involves deforming the plate after the coating treatment, while the second involves deforming the plate prior to coating. The deformation process can be carried out using various techniques, such as hydroforming and stamping. The first production method is easier to implement for high-speed bipolar plate manufacturing, as it allows for the coating to be applied using a roll-to-roll process. In contrast, the second method is less efficient for industrial applications, as it requires batch processing [5].

Moreover, two different coating techniques will be used. The first is Physical Vapor Deposition (PVD) coating, where a thin layer is deposited onto the substrate by physical means in a vacuum environment. The second is wet chemistry coating, where a liquid is applied to the substrate and forms a thin layer after the solvent evaporates. The coating will be characterized by different electrochemical and physical techniques, such as X-ray Photoelectron Spectroscopy, Scanning Electron Microscopy, Interfacial Contact Resistance tests, and corrosion tests.

Discussion

Current research in this field aims to address several key questions, including the selection of suitable aluminum material (alloy, thickness of the plate) for bipolar plates, and the development of efficient manufacturing processes.

The use of aluminum substrates is challenging due to aluminum oxide formation, which affects conductivity. Protective coatings play a central role in this research, as their role is to prevent corrosion and ensure the stability of the electrical properties of the plates over time.

It is also important to enhance the coating adhesion through optimized interface and surface preparation to avoid delamination either during the channel formation or upon fuel cell use.

Conclusions

Following the results obtained in a previous project, in which a coated stainless steel solution was developed, this PhD project aims to replace stainless steel with an aluminum substrate to reduce the PEM fuel cell's weight and volume. The goal is to develop and optimize lightweight, strong and economically viable aluminum bipolar plates for PEM fuel cells, by combining vacuum techniques (PVD) and wet chemistry processes.

References

[1] Department of Energy. Fuel Cells. Retrieved September 5, 2024, from https://www.energy.gov/eere/fuelcells/fuel-cells

[2] Department of Energy. Comparison of Fuel Cell Technologies. Retrieved September 18, 2024, from https://www.energy.gov/eere/fuelcells/comparison-fuel-cell-technologies

[3] Tang, A., Crisci, L., Bonville, L., & Jankovic, J. (2021). An overview of bipolar plates in proton exchange membrane fuel cells. Journal of Renewable and Sustainable Energy, 13, 022701. https://doi.org/10.1063/5.0031447

[4] S. Lædre, "Bipolar Plates for PEM Systems," Doctoral thesis, NTNU, 2016. Accessed: Dec. 05, 2024. [Online]. Available: https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/2417913

[5] Porstmann, S., Petersen, A. C., & Wannemacher, T. (2019). Analysis of manufacturing processes for metallic and composite bipolar plates. In Konferenzband der ersten FC³ Fuel Cell Conference Chemnitz 26. und 27. November 2019 (p. 25).