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# Spectroscopy electrochemical impedance characterization of membranes electrode assemblies for PEM electrolyzers

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**Abstract:** Hydrogen is projected as a key energy vector to achieve aspiring global decarbonization goals mainly for those sectors where greenhouse gas emissions are highly challenging to reduce. Therefore, green hydrogen production using water PEM electrolysis has become the aim of numerous recent studies. One of the crucial challenges for improving hydrogen production is reaching a deep knowledge of the role of anodes electrocatalysts. In this investigation we studied and modeled the effect of different anode electrocatalysts and solid electrolyte's configurations in a single-cell PEM electrolyzer performance, using EIS. We assembled and tested PEM electrolysis MEAs with two different configurations. MEA-1 comprises in catalyst-coated membrane (MEA)-type with a geometric area of 25 cm<sup>2</sup> containing Nafion™ 115, 3.0 mg cm<sup>-2</sup> IrRuOx as the anode, and 3.0 mg cm<sup>-2</sup> PtB for the cathode. MEA-2 involves catalyst-coated membrane (MEA)-type with a geometric area of 25 cm<sup>2</sup> containing Nafion™ 117, and 3.0 mg cm<sup>-2</sup> PtB both for the anode and cathode. Sintered Ti plates were used as gas diffusion layers. After hydration and activation steps at room temperature, the polarization curve was performed. Hysteresis curves were achieved to provide information on thermal equilibrium during the measurements. The oxygen and hydrogen production rate were measured and compared to theoretical values. Experiments were carried out at 20 and 40 °C. EIS measurements were performed at different points of the polarization curve, sweeping a frequency range between 10 kHz and 10 mHz, with an

amplitude of 5 mV and taking 10 points per decade. To avoid electrocatalysts area effects in charge transfer reaction, time constants were calculated. It can be clearly observed the trend of resistances and overpotentials according to different process control. Low onset potential for oxygen evolution reaction depicts for MEA-1 means that there will be less power consumption to achieve the same efficiency or same amount of gas generation rate compared to high onset potential case depicted for MEA-2. Although different membrane thicknesses would result in different electrochemical performances due to the change in the ionic resistance, for the thickness studied we did not observe a change in the ionic resistance. The experimental results show an increase in efficiency with temperature, reflected in higher currents for a given potential and lower time constants resulting in the EIS runs.

**Keywords:** green hydrogen; PEM electrolyzer; EIS; membrane electrode assembly

## 1 Introduction

The “hydrogen economy” proposal aims to establish hydrogen as the primary energy vector in society. A hydrogen economy would have unprecedented social implications, decentralizing the energy grid and redistributing power (Bockris, Reddy, and Gamboa-Adelco 2002; Rifkin 2002). Iceland is working to become the first hydrogen-based society by 2030, using geothermal energy for renewable hydrogen production through water electrolysis. When two electrodes are connected by an external continuous power supply, electroreduction or electrooxidation reactions can occur, transforming the chemical species at the electrodes. This system is known as an electrolyzer, which facilitates the electrolysis process (Llorca 2010).

Electrolysis can be carried out through different technologies, depending primarily on its electrolytic medium. Currently, there are three main types of electrolysis: alkaline (the most mature to date), Acid-PEM (under development and highly promising), and solid oxide (capable of operating at temperatures around 1000 °C) (Sanchez Delgado 2019; Scaltritti 2016).

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