

# Green hydrogen production: Spectroscopy Electrochemical Impedance characterization of a PEM water electrolyzer

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## Introduction

Green hydrogen production through water electrolysis has emerged as a critical strategy for achieving global decarbonization targets. Among various electrolysis technologies, Proton Exchange Membrane (PEM) electrolysis offers the advantage of producing clean hydrogen at high efficiency. This study investigates the charge transfer and mass transport processes in a single-cell PEM electrolyzer under varying operating conditions, including applied potential and temperature, employing Electrochemical Impedance Spectroscopy (EIS) to optimize performance.

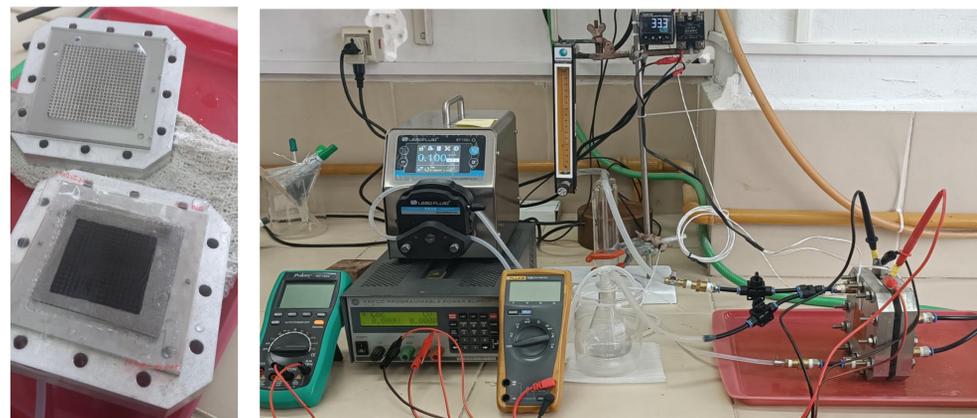


Figure 1. Experimental layout

## Methods

The membrane-electrode assembly (MEA) was prepared using Nafion™ 115 as the proton exchange membrane, with a geometric area of 25 cm<sup>2</sup>. The anode and cathode catalyst layers contained 3.0 mg·cm<sup>-2</sup> IrRuOx and 3.0 mg·cm<sup>-2</sup> PtB, respectively. Sintered Ti plates were used as gas diffusion layers. Prior to assembly and testing in the electrolyzer, the MEA underwent a conditioning process. Figure 1 depicts experimental layout.

The initial step of conditioning involved hydration, during which the MEA was sprayed with deionized water as it was assembled in the electrolyzer. This was followed by a 2-hour anodic-side water recirculation to ensure adequate hydration. After this step, the MEA activation process was commenced applying stepped potential pulses and measuring the resulting current until stable values were achieved. Subsequently, ascending and descending potential sweeps were performed for each MEA, stabilizing the curves and yielding hysteresis curves that provided information on thermal equilibrium. (Fig 2.)

Experiments were conducted at two specific temperatures (20°C and 40°C) and atmospheric pressure. Temperature control was achieved using a heater connected to a thermocouple and a controller. Water flow was regulated using a peristaltic pump, maintaining a minimum of 10% water excess throughout the process.

Polarization curves (Fig. 3) were constructed using linear sweep voltammetry. The applied potential was maintained at each point for 3 minutes, during which time the resulting current and hydrogen production were measured. Based on these data, polarization curves were generated and specific points were selected for EIS measurements.

EIS measurements were performed at the chosen points on the polarization curve, sweeping a frequency range between 10 kHz and 10 mHz, with an amplitude of 5 mV and capturing 10 data points per decade. The experimental EIS values were fitted to an equivalent electrical circuit model (Fig 4).

## Results

Fitted parameter	20°C		40°C	
Potential V	1.6V	1.7V	1.6V	1.7V
Y <sub>01</sub> (S·s <sup>a</sup> )	4.55	3.85	4.40	4.0
a <sub>2</sub>	0.89	0.90	0.91	0.90
R <sub>3</sub> (mΩ)	23	23	20	20
R <sub>4</sub> (mΩ)	22	7.6	8.8	4.5
Y <sub>05</sub> (S·s <sup>a</sup> )	10.3	5.4	13.6	5.1
a <sub>6</sub>	0.42	0.45	0.38	0.46
R <sub>7</sub> (mΩ)	8.0	6.9	7.3	5.5
W <sub>8</sub> (S·s <sup>0.5</sup> )	741e3	654	5.3e3	650

Table 1. ECM EIS Fitted parameters results

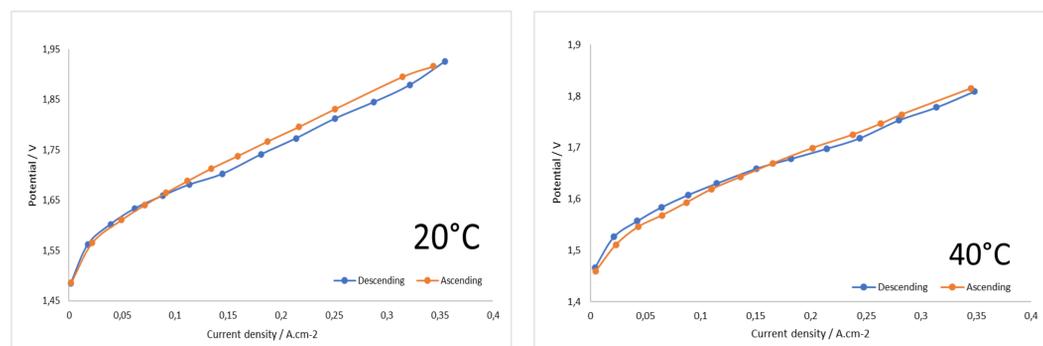


Figure 2. Ascending/descending polarization curves for 20°C and 40°C.

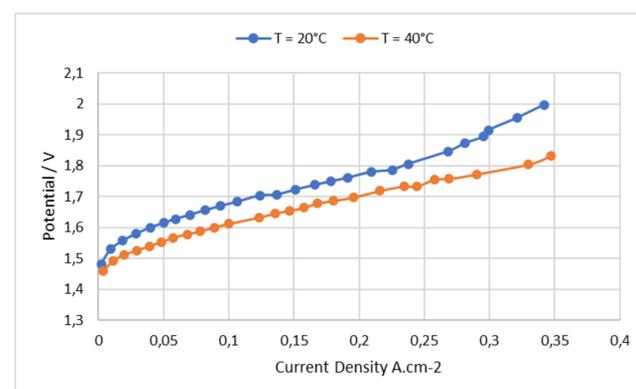


Figure 3. Polarization curves for 20°C and 40°C.

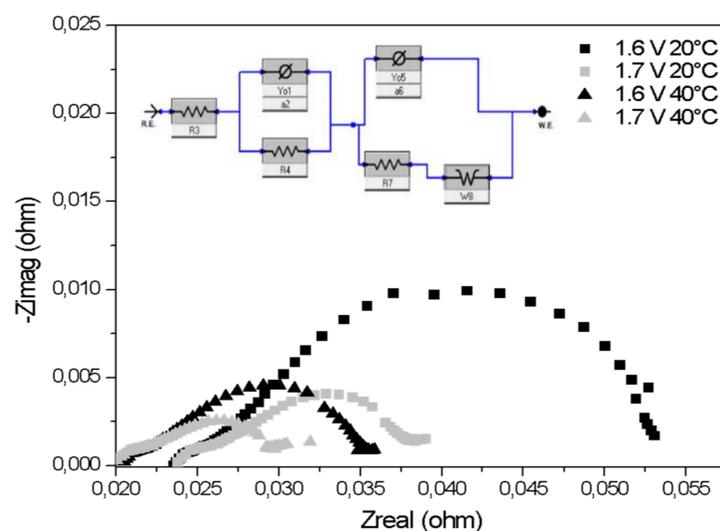


Figure 4. Nyquist plots for 20°C and 40°C (experimental and fitted data)

## Conclusions

- ✓ An enhanced electrochemical reaction efficiency at higher temperature and potential was observed.
- ✓ This fact was evidenced by lower resistances and higher anodic and cathodic rate constants.
- ✓ The studied potentials suggested a consistent reaction mechanism, with noticeable efficiency improvements at 40°C and 1.7V.
- ✓ Ohmic resistance remained constant, as expected for ohmic resistance, while charge transfer resistances decreased with increasing temperature and potential, likely due to reduced activation energy barriers in charge transfer reactions. (Table 1, Fig. 4).
- ✓ The small hysteresis observed between the ascending and descending polarization curves, in both cases, suggests that thermal equilibrium was achieved during the measurements. (fig. 2).
- ✓ Enhanced electrolysis efficiency at 40°C indicated reactions were thermofavored. Therefore, temperature is crucial in the electrochemical system's performance, its optimization can reduce overpotentials and increase efficiency (Fig.3).

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