Jordy Santana Villamar
jorasant@espol.edu.ec
FCNM

Martin Andersson
Lund University
Department of Energy Sciences

Tingshuai Li
University of Electronic Science and Technology of China

Mayken Espinoza-Andaluz
masespin@espol.edu.ec
FIMCP/CERA

Unveiling the Mechanisms Behind Temperature-Dependent Impedance Behavior in PEM Fuel Cells at High Current Loads

PROBLEM

The necessity to move away from fossil fuels due to their role in global warming is an imperative. PEM Fuel Cells offer a clean energy alternative, but their widespread adoption is limited. A key challenge lies in understanding their micro-scale behavior, particularly the transport of gases and charge within the Membrane Electrode Assembly (MEA).

OBJECTIVE

This study aims to identify impedance behavior using electrochemical impedance spectroscopy across a wide range of temperatures and high current densities. Therefore, unveiling the mechanisms behind the cell's impedance, particularly at high current densities where concentration losses are significant.

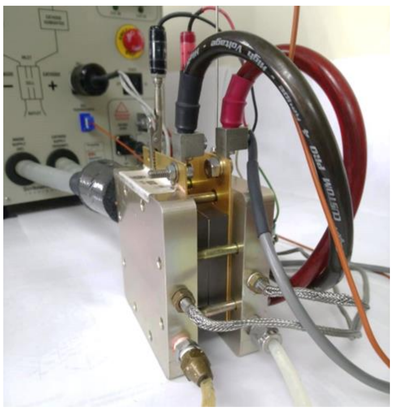


Fig. 1. Experimental PEM Fuel Cell

METHODS

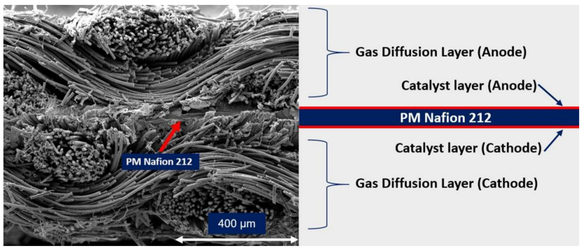
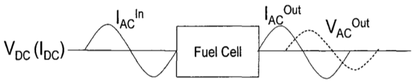


Fig. 2. Microscopic view of the Membrane



$$I(\omega) = I_{AC} \cdot \sin(\omega \cdot t)$$

$$V(\omega) = V_{AC} \cdot \sin[(\omega \cdot t) - \theta]$$

$$Z(j\omega) = \frac{V(j\omega)}{I(j\omega)}$$

$$Z' = \mathrm{Re}(Z) = |Z|\cos\theta$$

$$Z'' = \mathrm{Im}(Z) = |Z|\sin\theta$$

Fig. 3. Electrochemical Impedance Spectroscopy equations

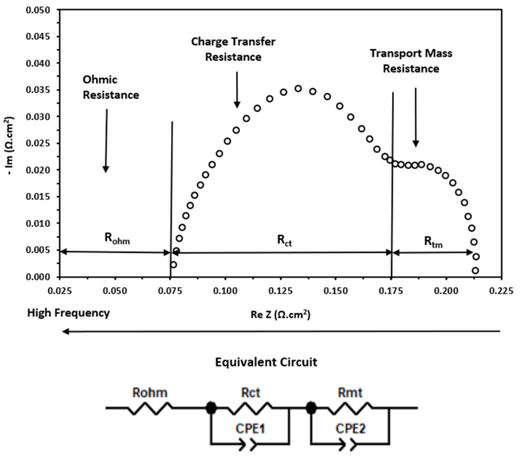


Fig. 4. Interpretation of Nyquist Diagram

RESULTS

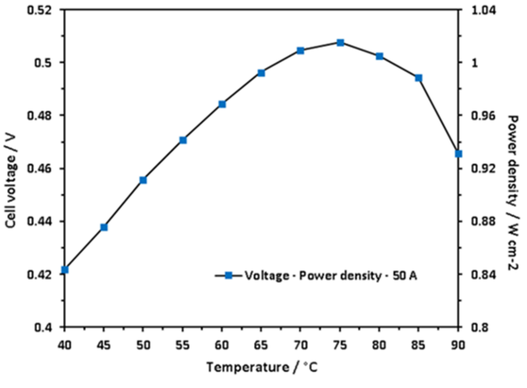


Fig. 5. Voltage-Power performance curve

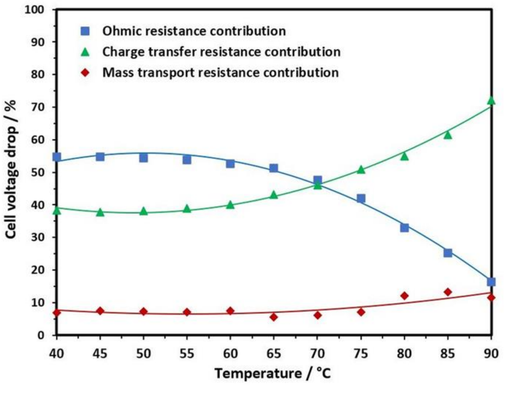


Fig. 6. Unveiling the individual polarization losses

CONCLUSIONS

- Ohmic Resistance is Dominant below 70°C, max 54 % at 40°C. Dependent on temperature and membrane hydration.
- Charge and Mass Transport Resistances have a minimal effect below 60°C. Charge transfer resistance significant above 60°C, max 72% at 90°C.
- Reducing charge transfer resistance crucial for works at high current densities.

ACKNOWLEDGMENTS

- This research was funded by Escuela Superior Politécnica del Litoral (ESPOL), grant number FIMCP-33-2022. Computational and physical resources provided by ESPOL are also very grateful.