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Autolab Application Note FC03

Fuel Cells
Part 3 – Characterization Using EIS

Keywords

Fuel cell; Electrochemical impedance spectroscopy

Summary

In the previous application notes it was shown that fuel cells are promising power sources as they offer highly efficient and environmentally friendly solution for alternative energy. In recent years considerable research is being done to provide a better understanding of the factors that affect the performance of a fuel cell.

In this application note the use of Electrochemical Impedance Spectroscopy (EIS) for the characterisation of PEM fuel will be demonstrated. It will be shown that EIS is a powerful diagnostic tool for the determination of the following factors that can influence the performance of a PEM fuel cell:

- Electrode composition and structure
- Membrane characteristics
- Operating parameters such as, cell temperature, humidification, gas composition and pressure

The main advantage of EIS as a diagnostic tool is its capacity to resolve in the frequency domain the individual contributions of the various factors that determine the overall PEM fuel cell power losses:

- Kinetic
- Ohmic
- Mass transport

Experimental conditions

The experiments were done on the fuel cell test station at Electrochemistry group in the Department of Chemistry at the North Eastern University in Boston, USA.

The experiments were conducted using an AUTOLAB PGSTAT302N controlled by NOVA software. The EIS measurements were performed using the FRA2 module controlled by NOVA software. The 10 A current booster unit was used as the load.

The fuel cell used for the experiments was a single cell with a geometric surface area of 5 cm^2 comprising a Nafion polymer electrolyte membrane. The electrodes consisted of a thin-film catalyst layer. The electrodes were supplied with pure hydrogen or hydrogen with small quantity of CO at the anode and with hydrogen (for reference measurements), air or oxygen at the cathode.

The EIS experiments were done under potentiostatic control. For the cell with hydrogen at the cathode, the EIS experiments were done at OCP (0.0 V). For experiments with air and oxygen the experiments were done at the applied potential of 0.8 V, 0.6 V and 0.4 V. A frequency range of 10 kHz – 0.01 Hz was used. The amplitude of the AC perturbation was set to 10 mV.

Experimental Results

In Figure 1 the results of the EIS experiment with H2 at the cathode are compared with those with O2 and air at the cathode.

When only hydrogen is at both the anode and cathode side of the electrode there is no reduction reaction that takes place at the cathode and one measures the ohmic losses across the membrane. When the hydrogen is replaced by oxygen at the cathode then the reduction of oxygen at the cathode occurs. The charge transfer resistance of the reduction reaction can therefore be measured. When oxygen is replaced by air at the cathode then the effect of mass transport can be seen. Oxygen has to diffuse through nitrogen present in air to reach the cathode surface, this result in an increase in the polarisation resistance due to the diffusion resistance as seen in Figure 1.

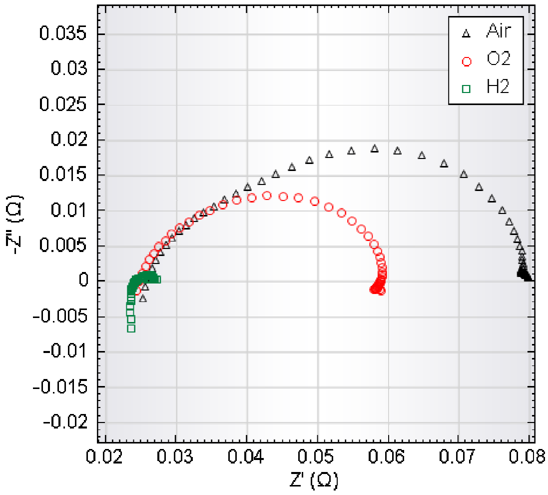

Figure 1 – Results of EIS experiment on a PEM fuel cell with H_2, O_2 and air at the cathode

In Figure 2 the effect of the poisoning of the catalyst by CO can be seen. With the introduction of CO in air on the anode side the charge transfer resistance for the oxidation of hydrogen increases due to the poisoning of the catalyst.

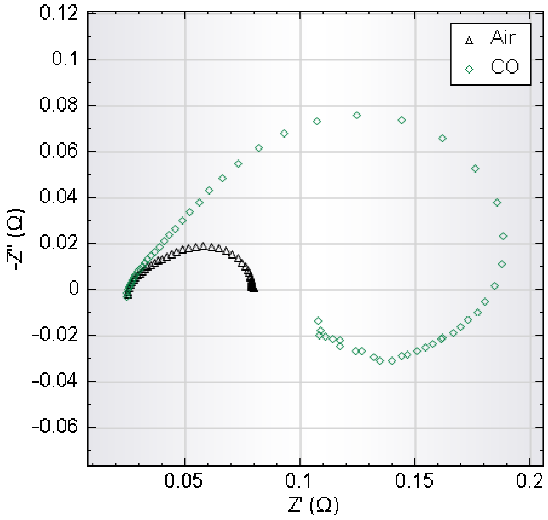

Figure 2 – Results of EIS experiments on a PEM fuel cell with air and CO at the anode

With the introduction of CO in air on the anode side the charge transfer resistance for the oxidation of hydrogen increases due to the poisoning of the catalyst.

References

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