Application Note AN-FC-003

Fuel cells part 3 – characterization using EIS

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 FRA32 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 H_2 at the cathode are compared with those with O_2 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.

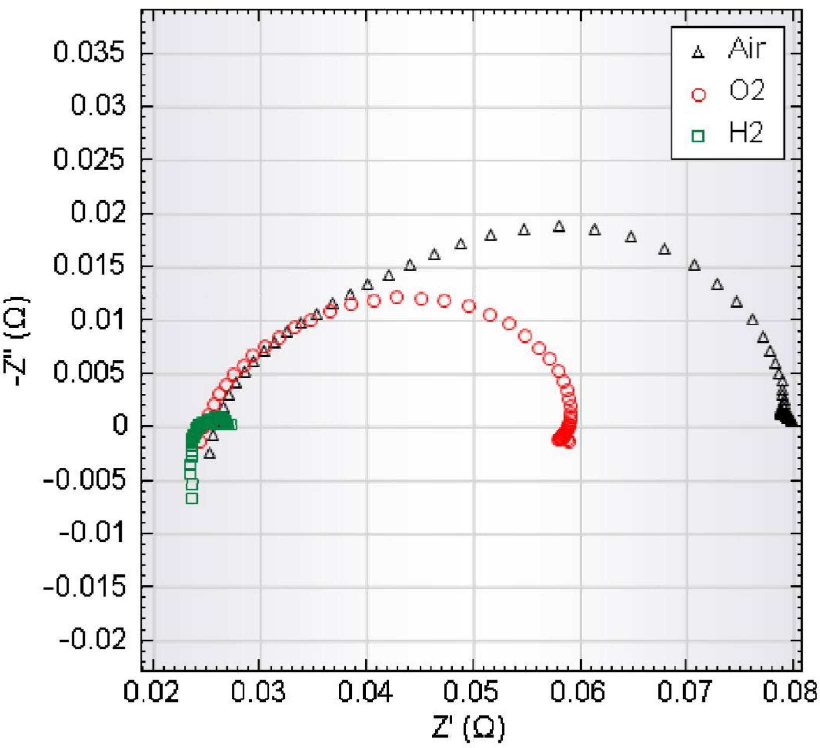

Figure 1. Results of EIS experiment on a PEM fuel cell with H2, O2 and air at the cathode

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.

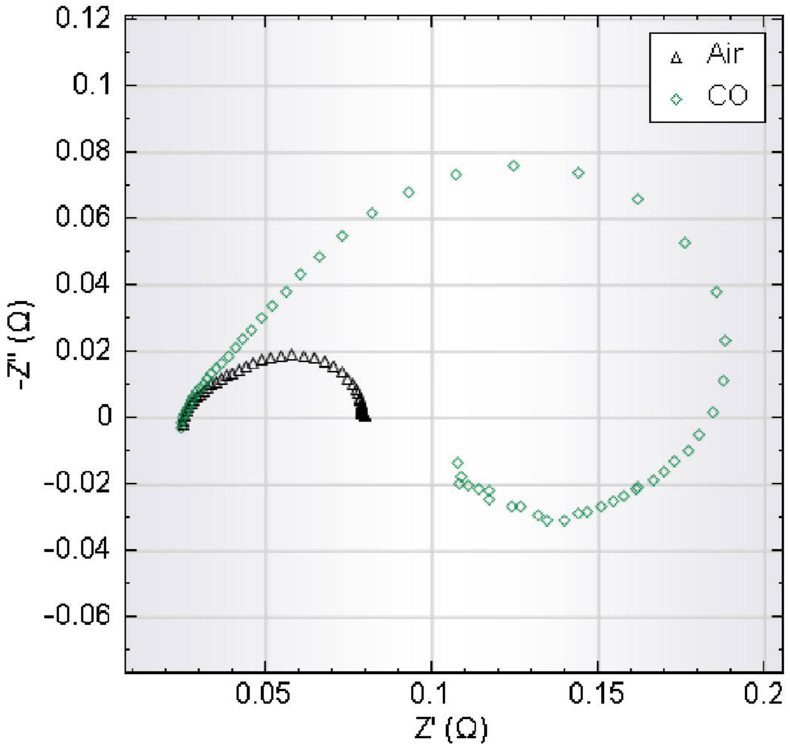

Figure 2. Results of EIS experiments on a PEM fuel cell with air and CO at the anode

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

1. M. Ciureanu, R. Roberge, J. Phys. Chem. B, 2001, 105, 3531-3539

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Autolab PGSTAT204

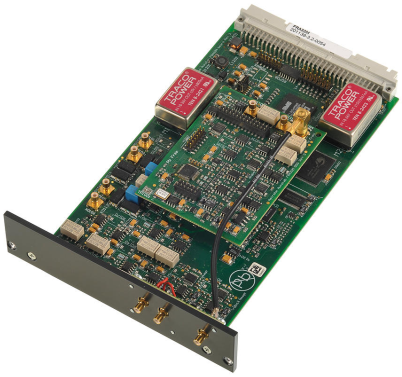
The PGSTAT204 combines the small footprint with a modular design. The instrument includes a base potentiostat/galvanostat with a compliance voltage of 20 V and a maximum current of 400 mA or 10 A in combination with the BOOSTER10A. The potentiostat can be expanded at any time with one additional module, for example the FRA32M electrochemical impedance spectroscopy (EIS) module.

The PGSTAT204 is an affordable instrument which can be located anywhere in the lab. Analog and digital inputs/outputs are available to control Autolab accessories and external devices are available. The PGSTAT204 includes a built-in analog integrator. In combination with the powerful NOVA software it can be used for most of the standard electrochemical techniques.

Autolab PGSTAT302N

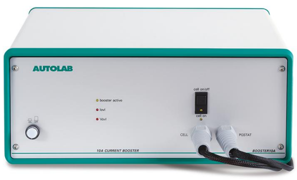
This high end, high current potentiostat/galvanostat, with a compliance voltage of 30 V and a bandwidth of 1 MHz, combined with our FRA32M module, is specially designed for electrochemical impedance spectroscopy.

The PGSTAT302N is the successor of the popular PGSTAT30. The maximum current is 2 A, the current range can be extended to 20 A with the BOOSTER20A, the current resolution is 30 fA at a current range of 10 nA.



Electrochemical impedance spectroscopy module

The FRA32M provides the means to perform impedance and electrochemical impedance measurements in combination with the Autolab. This module allows one to perform both potentiostatic and galvanostatic impedance measurements over a wide frequency range of 10 µHz to 32 MHz (limited to 1 MHz in combination with the Autolab PGSTAT). In addition to the classical EIS, the NOVA software also allows the users to modulate other outside signals such as rotation speed of a rotating disk electrode or the frequency of a light source to perform Electro-hydrodynamic or Photo-modulated impedance spectroscopy.
The FRA32M module comes with a powerful fit and simulation software for the analysis of impedance data.



Booster 10A

The Booster 10A module increases the maximum current of the PGSTAT100N, PGSTAT128N, PGSTAT302N, PGSTAT204 or M204 to 10 Ampere. The compliance voltage of the system is 20 V in combination with the Booster10A.
With its fast response time, the Autolab Booster 10A has been optimized to perform electrochemical impedance measurements, in combination with the FRA32M module, on fuel cells, batteries and super-capacitors. The booster is able to handle active as well as passive cells. The Booster 10A can be used to measure the charge and discharge characteristics of super-capacitors, perform measurements on fuel cells or perform DC or AC measurements on large area electrodes.

Advanced software for electrochemical research

NOVA is the package designed to control all the Autolab instruments with USB interface.

Designed by electrochemists for electrochemists and integrating over two decades of user experience and the latest .NET software technology, NOVA brings more power and more flexibility to your Autolab potentiostat/galvanostat.

NOVA offers the following unique features:

- Powerful and flexible procedure editor
- Clear overview of relevant real-time data
- Powerful data analysis and plotting tools
- Integrated control for external devices like Metrohm Liquid Handling devices

Download the latest version of NOVA