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Short communication

Impedance measurements of polymer electrolyte membrane fuel cells running on constant load

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Abstract

A new method to measure the impedance of fuel cells connected to a constant load is developed. This method is used to measure the impedance of a polymer electrolyte membrane fuel cell. It is shown that in situ membrane resistance measurements can be made by this new method. © 1998 Elsevier Science S.A. All rights reserved.

Keywords: fuel cell; polymer electrolyte membrane fuel cell; fuel cell impedance spectroscopy

We have proposed recently [1,2] a new experimental method for impedance measurements of electrochemical batteries during discharge. It uses a classical impedance-measurement set to control, under sinusoidal current perturbation, a battery connected in parallel to the load into which it discharges. Impedance-measurements were carried out on sealed Ni–Cd 0.65 Ah batteries using the classical modulated-current method and the proposed method. The results show that the impedance diagrams, obtained during battery discharge through a constant load R, are identical to those obtained during discharge at a constant current with value U_{mean}/R where U_{mean} is the mean voltage of the battery during its natural discharge. These comparative measurements validate the proposed method. Impedance measurements using the new method were carried out on a sealed lead–acid 25 Ah g-cell during its discharge through a 1 Ω constant load. The battery discharge current was then greater than the maximum value that could be supplied by the regulation system. The constant-current measurement method could therefore not be used. The amplitude of the sinusoidal signal used during this study represented 2% of the mean value of the discharge current. The obtained results show that it is possible to study with classical impedance-measurement sets the impedance of high-capacity and low-impedance batteries during their discharge through a constant load.

This new method has been used to measure the impedance of a polymer electrolyte membrane fuel cell (PEMFC) connected to a constant load R (Fig. 1). The PEMFC is a H_2/O_2 fuel cell at 80°C and 4 bars pressure of H_2 and O_2 using a NAFION™ membrane. The fuel cell used for measurements had a square design with an active area of 25 cm^2. The thickness of the membrane was 180 μm under wetted conditions. The first results are shown in the Fig. 2. The impedance diagrams show, at the highest frequencies, an inductive behaviour analogous to that observe for batteries [3,4] and two capacitive arcs. We consider that the resulting diagram is due to the combination of the impedance of the PEMFC running on a constant load in series with an inductance due to connections and the measuring device. Taking the circuit of Fig. 1 into account, the internal resistance R_i of the PEMFC is given by $R_i = R_{HF} R/(R - R_{HF})$ where R_{HF} is the real part of the high frequency measured impedance and is estimated

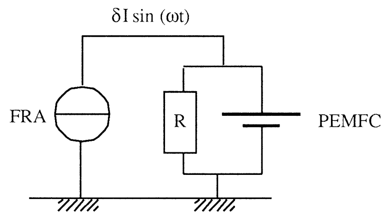

Fig. 1. Connections used for the EIS study of the PEMFC running through a constant load R. FRA : Frequency Response Analyser.

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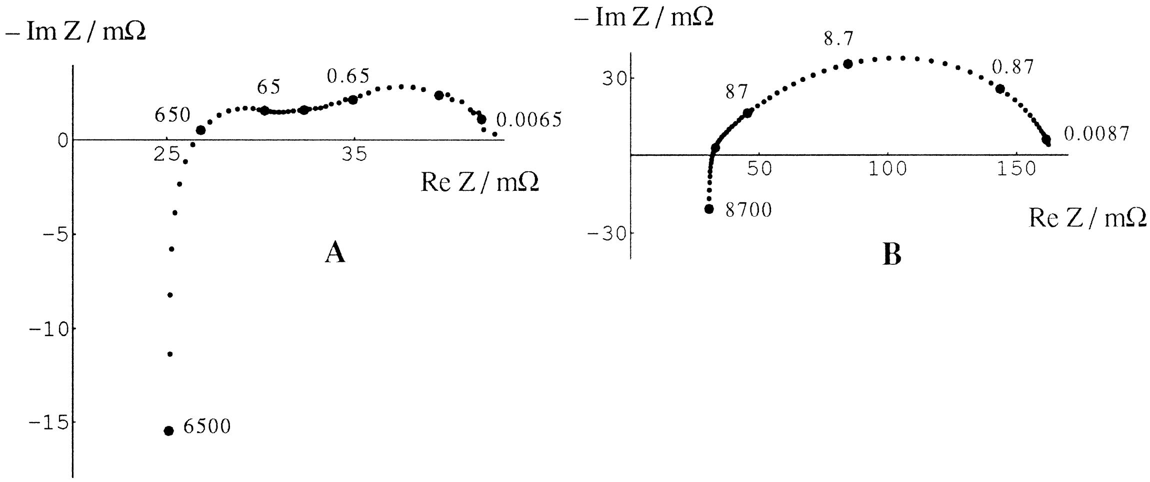

Fig. 2. Nyquist impedance diagram for the PEMFC running through a 0.077 Ω constant load (A) and during the relaxation towards equilibrium (B). $\delta I = 200$ mA, $f \in [6500$ Hz, 5 mHz$]$. Frequencies/Hz indicated on the diagram.

at $R_i \approx 37$ mΩ. In situ membrane resistance measurements in PEMFC have been studied by Büchi et al. [5] using fast auxiliary current pulses. The values we have obtained are compatible with their results. The operation of a PEMFC can be monitored by measuring the impedance as shown by the diagram in Fig. 2B based on measurements during the relaxation of the PEMFC towards equilibrium after its operation. The interpretation of the impedance diagrams and their use for monitoring PEMFC are in progress.

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