Locally resolved electrochemical impedance spectroscopy of PEFC single cells

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Introduction

Presently, the behaviour of fuel cells is mainly investigated integrally, which is not sufficient for a detailed understanding of the fuel cell performance and durability. Locally resolved data about the fuel cell operation can help to create a more detailed understanding, therefore, simulations are frequently performed with high spatial resolution.
An applied experimental approach for local investigation is the current density measurement, which is related to the local electrochemical mass conversion. The DLR has developed a tool for the current density measurement based on a printed circuit board.

Printed circuit board for current density measurements

The tool used for current density measurements is a printed circuit board (PCB). The side facing the elctrode has a normal machined flow field. This side is also segmented, and the dimensions of the segments define the local resolution of the current density measurement. Each segment is connected via individual resistances to the back side of the PCB, which is the current collector. The voltage drop in the iresistance, which is correleted to the current in the related segment is measured. In addition, temperature sensors are integrated in the PCB so the temperatures at different positions can be measured. The measurement rate is limited by the used equipment for the voltage measurement in the system.
The PCB technology for the current density measurements can be used for different stacks and cell designs. Only the PCB layoutand the sealing must be adapted. Printed circuit boards for different fuel cells with active areas between 6.3 and 225 cm^2 were developed at DLR. The PCB technology for the current density measurement can be used in single cells as well as in complete stacks. Printed circuit board are an mass product, so this technology is also interesting for control systems, which uses local data of the fuel cells in order to avoid critical operating conditions or to optimize the performance with respect of the state of the fuel cell.

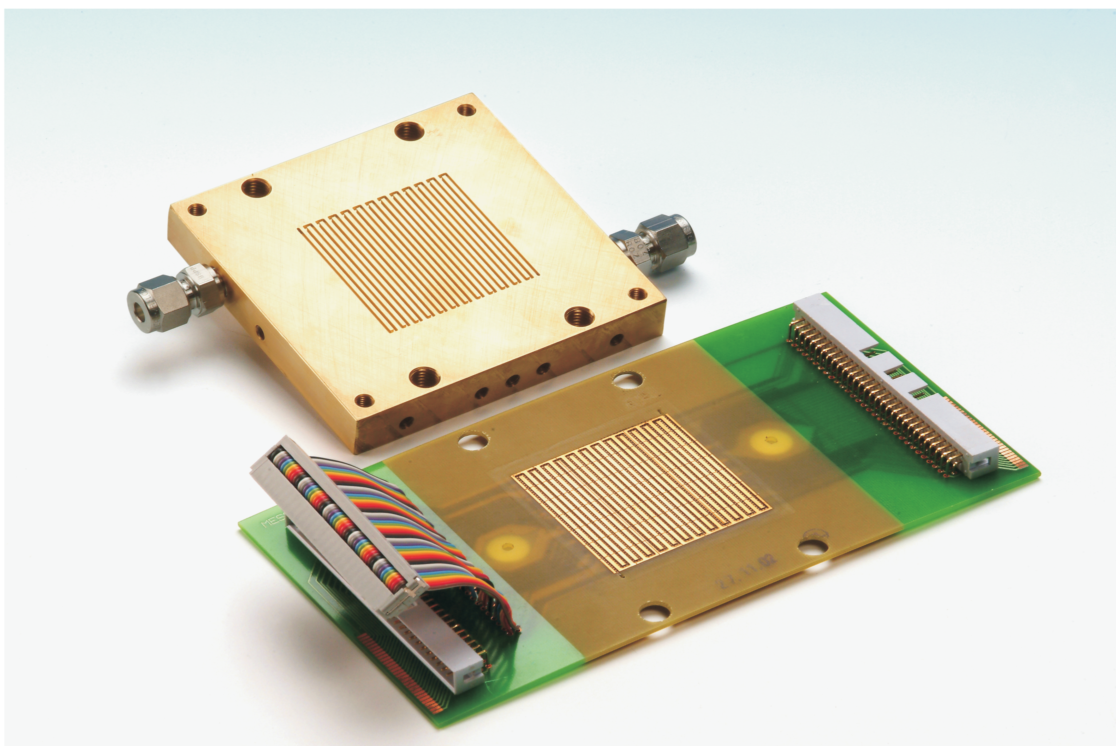

Fig. 1: Single cell with printed circuit board (49 segments)

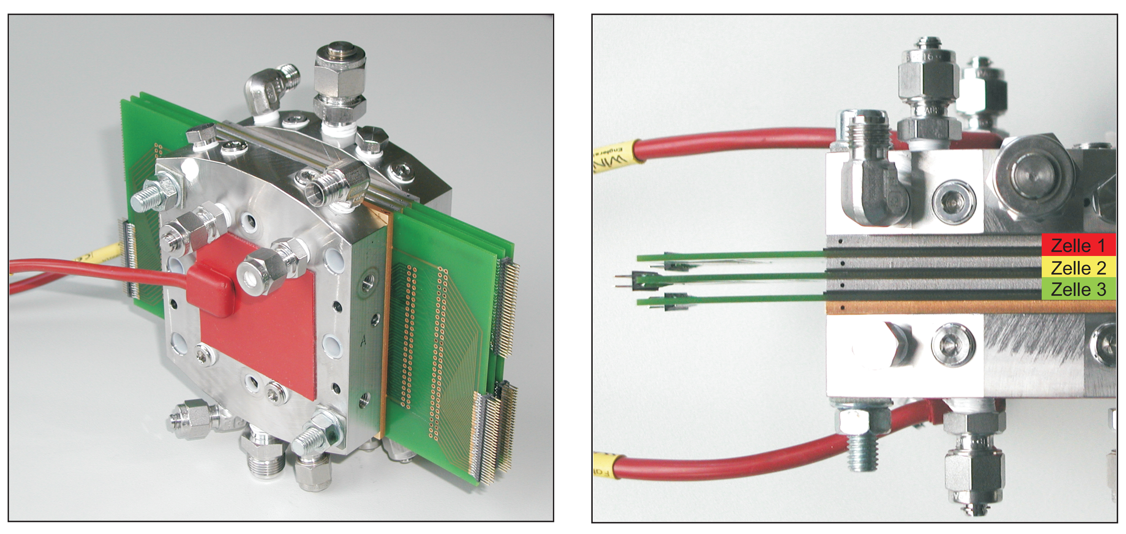

Fig. 2: Short stack with three cells equipped with printed circuit boards

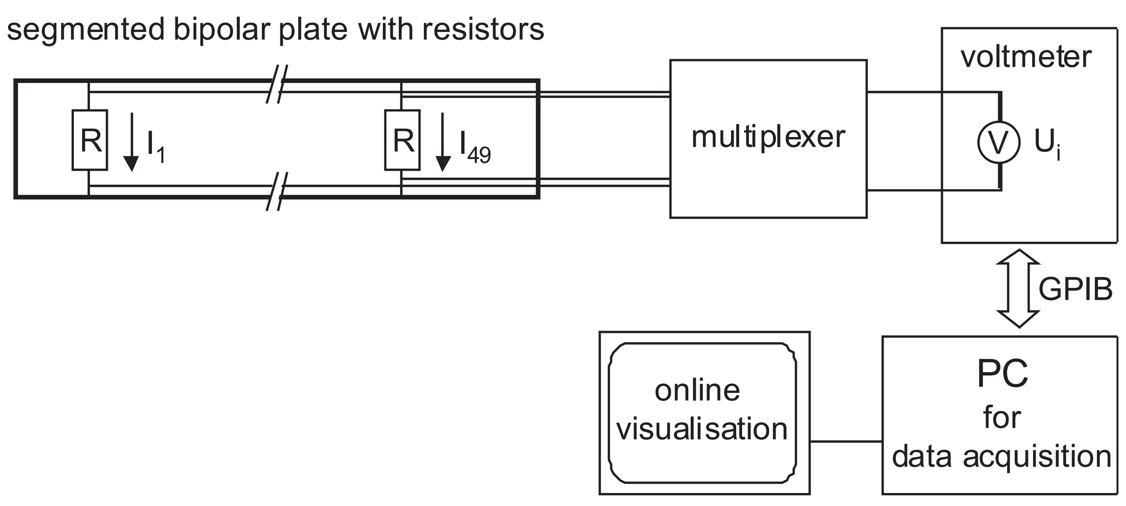

Fig. 3: Measuring system used for the segmented bipolar plate. Only the resistors for segment 1 and 49 are shown for clarity. A similar setup is used for the laboratory cell shown in Fig. 1

The current density measurement gives information about the local mass conversion, but gives no information about the limiting factors. For this purpose additional information are needed. Electrochemical impedance spectroscopy can yield information about specific processes inside the fuel cell like transport limitations or insufficient supply with the reactant gases.

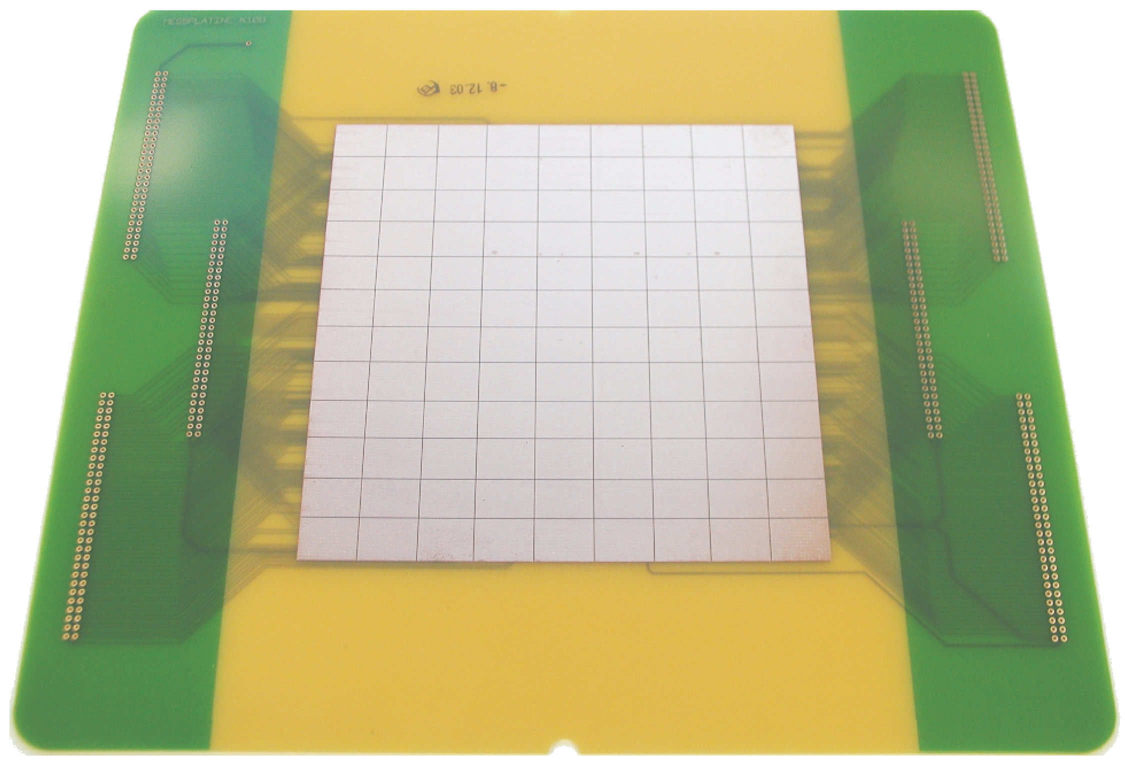

Fig. 4: Printed circuit board with 108 segments, active area 15x15 cm^2

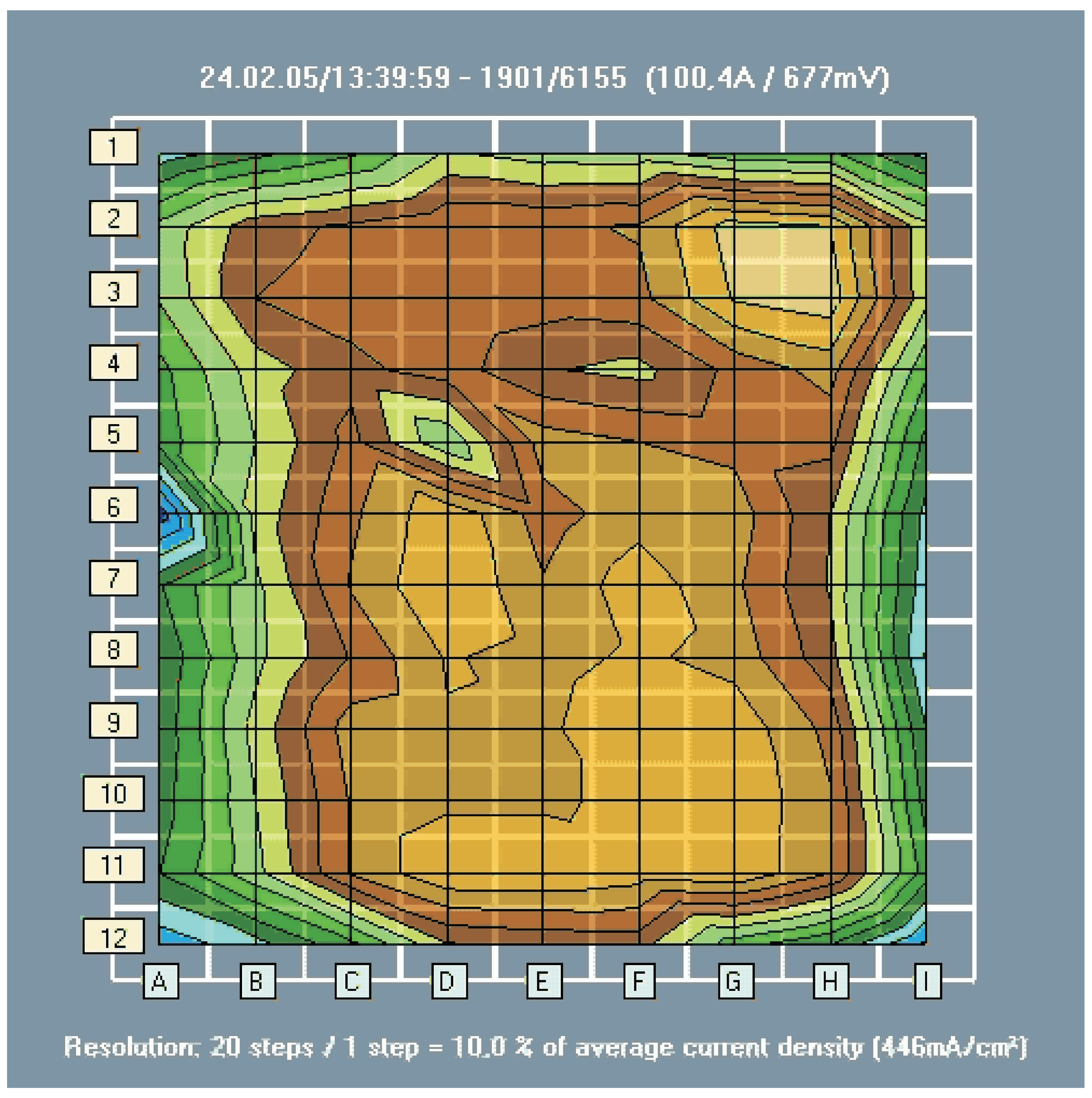

Fig. 5: Current density distribution at 250 A

Electrochemical impedance spectroscopy

Electrochemical impedance spectroscopy (EIS) allows to distinguish different processes in fuel cells, e.g. the anode reaction, the cathode reaction and transport processes. In addition, with EIS membrane resistance can be measured. Typically, EIS is used as an integral method; as a consequence of the integral measurement local difference cannot be detected.
Therefore the PCB technique for the current density measurement is enhanced presently to integrate local electrochemical impedance spectroscopy, which gives information about the local membrane resistance, electrochemical reaction, and transport processes. The issues associated with the implementation of locally resolved impedance spectroscopy, as well as the envisioned solutions will be presented in this contribution.

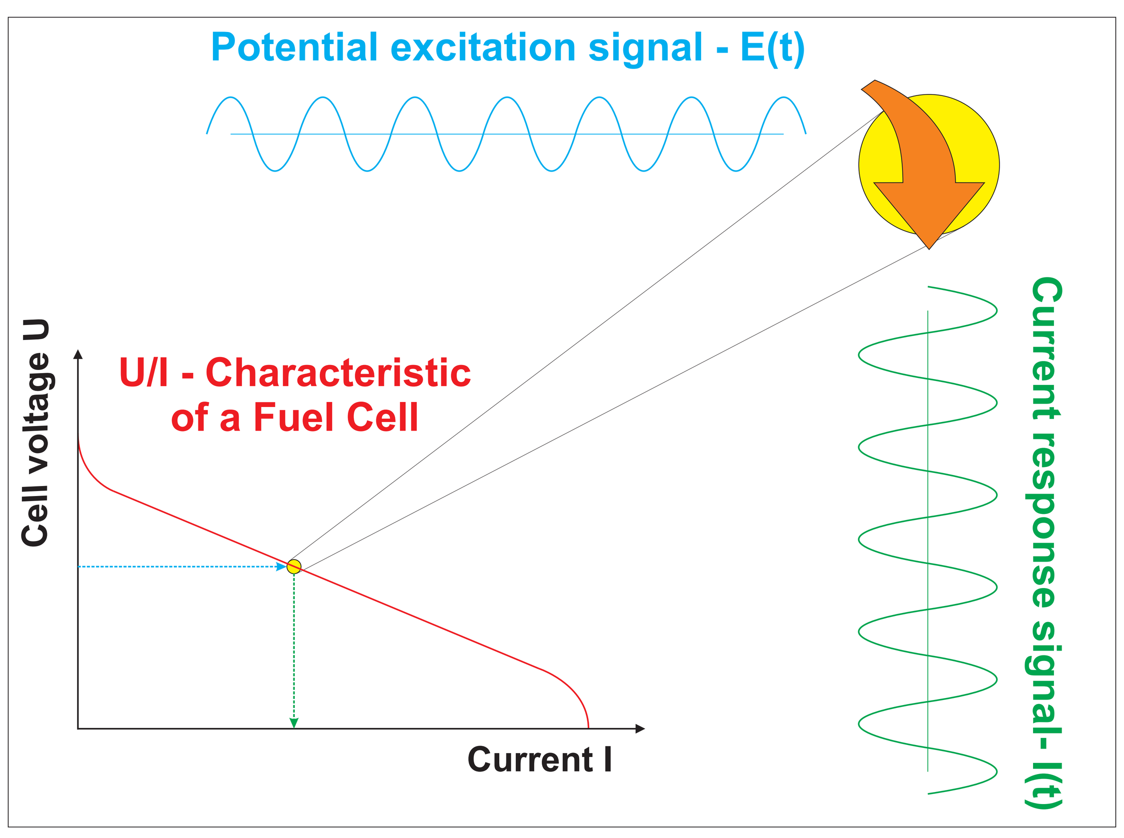

Fig. 6: Principle of electrochemical impedance spectroscopy

Local electrochemical impedance spectroscopy

A problem to realize locally resolved electrochemical impedance spectroscopy is the measurement time, especially if the different segments are measured sequencially. A main cause is the stabilization time, because the system must by stable during the measurement. Therefore, it is advantageous to measure the individual segments simultanously. As a consequence of the PCB design the AC signal for the iimpedance spectroscopy is very smal and difficult to detectl. The measurement system developed at DLR uses a multi-channel lock-in amplifier technique to enhance the small signals and to measue the segment simultanously. An additional advantage of this system is that the exitation is not necessarily sinusoidal, which allows a simply integration of the exitation generator into the DC/DC-converter. The multi-channbel lock-in amplifier is realized by programmable individual amplifiers and an digital signal processor.

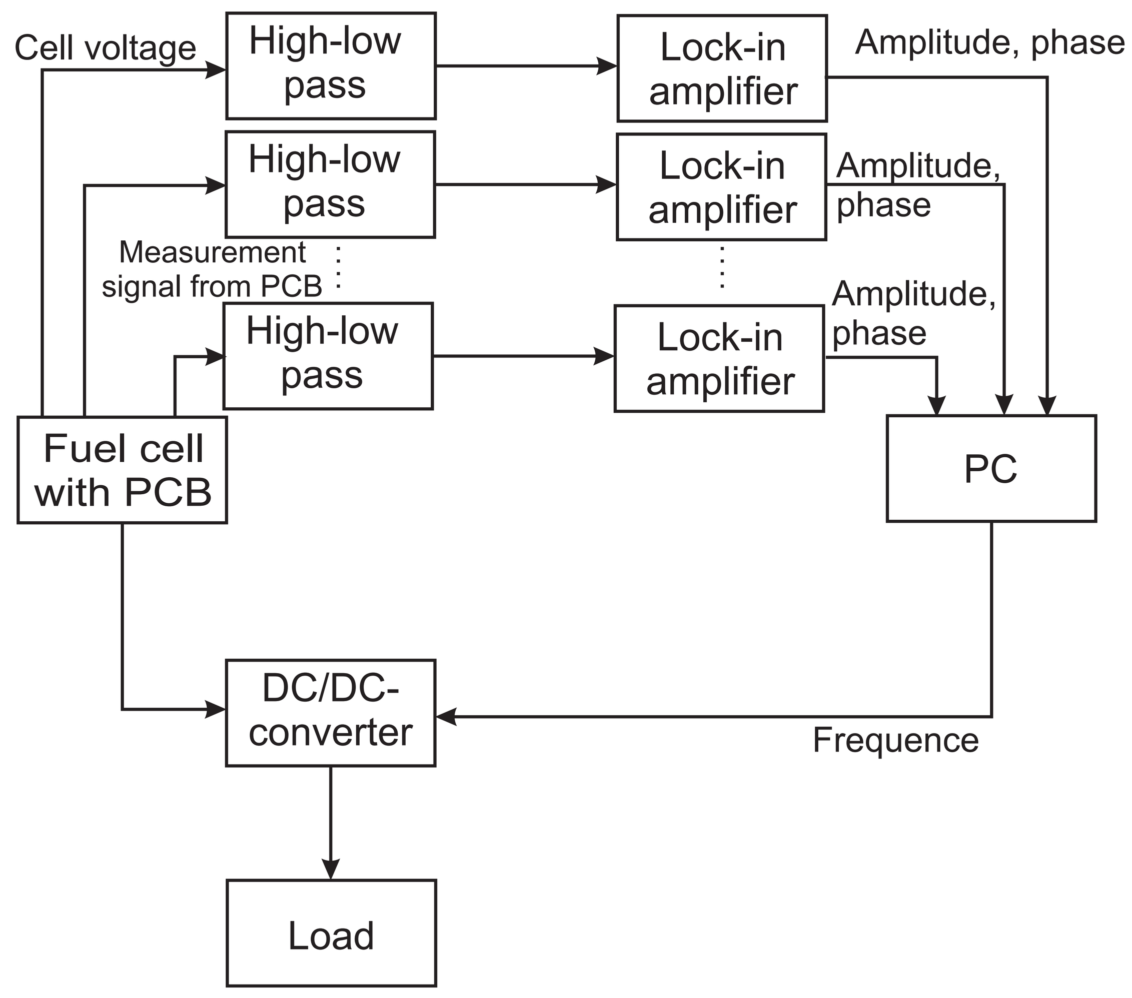

Fig. 7: Scheme of the system for locally resolved electrochemical impedance spectroscopy

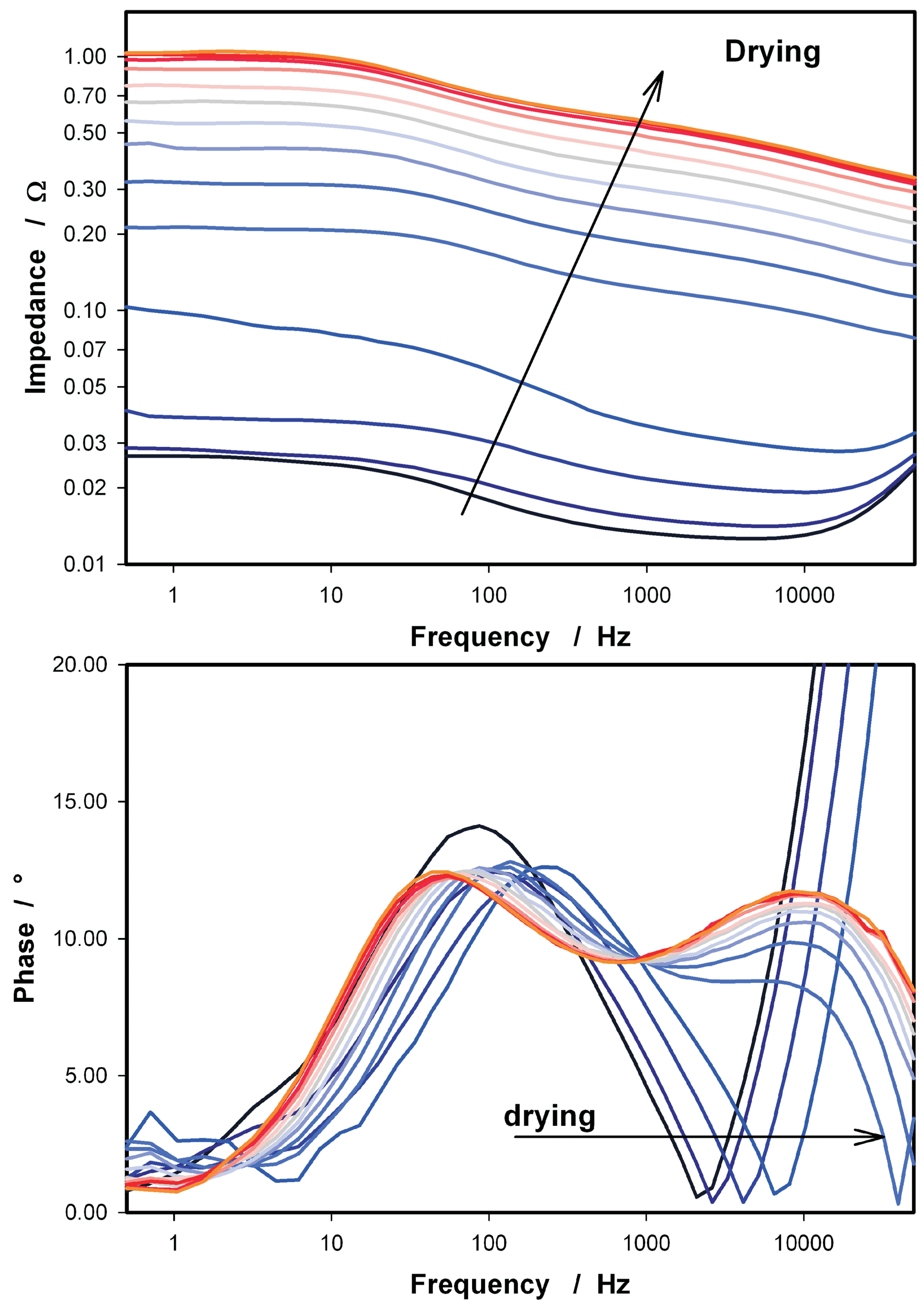

Fig. 8: Alteration of the electrochemical impedance spectra during drying

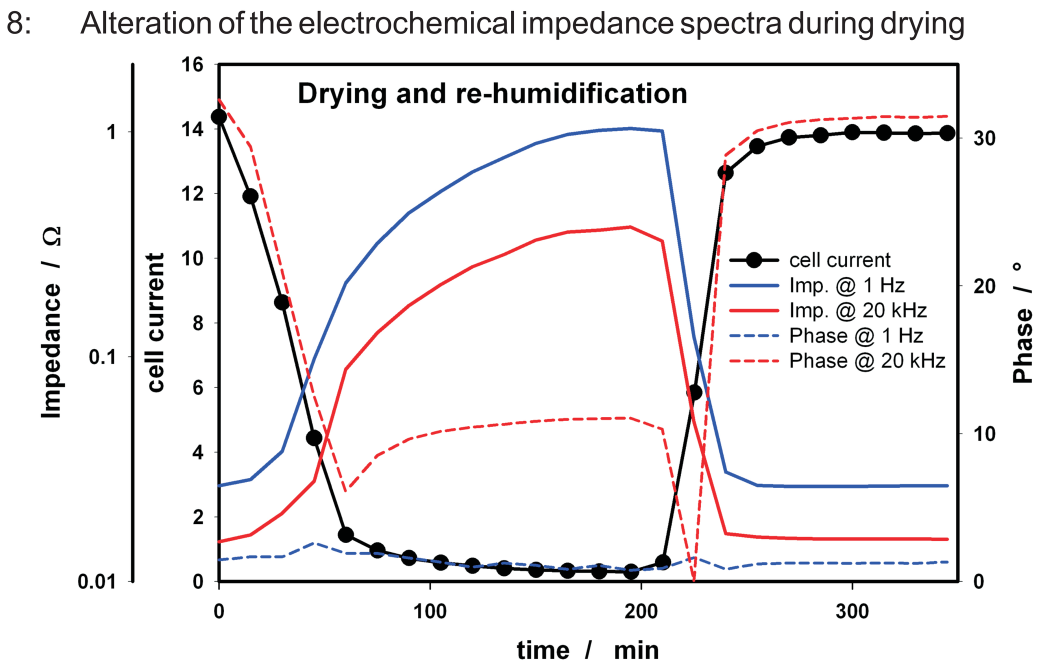

Fig. 9: cell current (25 cm^2) during drying and re-humidification