Test Module 04
Electrochemical Impedance Spectroscopy

(Version 3.9, 08 May 2017)

Objective and Scope

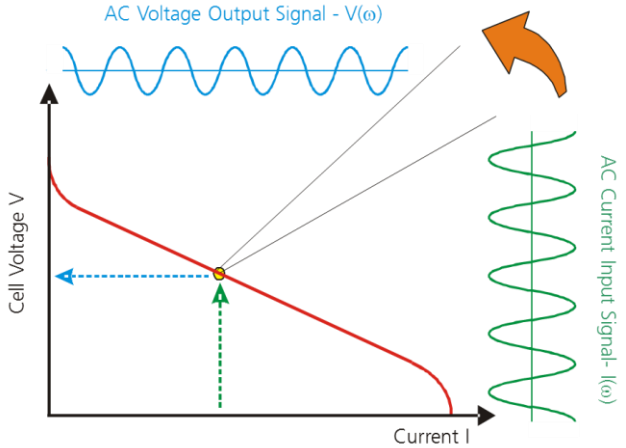
This test module deals with measuring of the electrochemical impedance spectra (EIS) of solid oxide cells (SOC) or stacks operated either as fuel cells (SOFC) or as electrolysers (SOEC). By varying the frequency of the sinusoidal excitation signal and measuring the corresponding response signal the different electrochemical processes taking place in the electrochemical system can be analysed. It is a general characterization method that can be used in SOC R&D and for quality assurance.

Main Test Input Parameters (TIPs)

Static TIP	Variable TIP
Direct current (I)	Frequency (υ)
Flow rates of inlet gases (f_{in})	
Temperature of the oven (T_{oven})	
Amplitude of alternating current ($\bar{I}$) or alternating voltage ($\bar{V}$)	
Composition of inlet gases ($x_{i,in}$)	
Pressure of outlet gases (p_{out})	

Test Procedure

- Connect the EIS system (waveform generator and frequency response analyser) according to the operating mode (SOFC, SOEC) to the test object.
- Impose the DC current under which the test object shall be examined.
- Impose an AC sinusoidal excitation signal (current or voltage) with small amplitude and measure the corresponding response signal (voltage or current).
- Choose an adequate number of measuring periods and number of measuring points per decade (compromise between measuring time and precision).
- Vary the frequency stepwise from high values (kHz) to identify the ohmic resistance to low values (mHz) to identify the overall resistance.



Input / Output signals of EIS

Critical Parameters and Parameter Controls

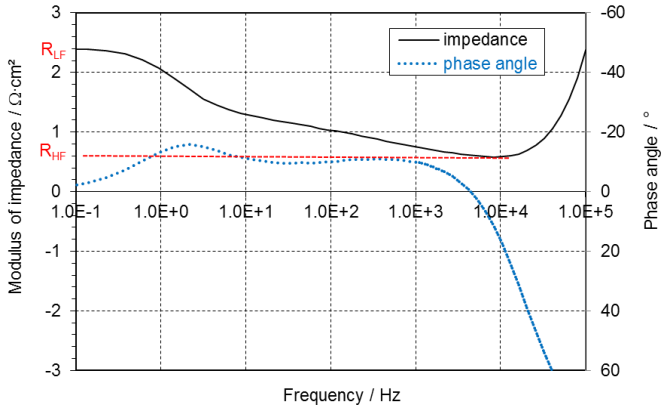
- Stability of all static TIPs is necessary to minimize voltage changes / fluctuations during the measurement.
- In SOEC mode, special attention is to be paid to a stable supply of steam to limit SOC voltage fluctuations to within a specified value e.g., +/-10 mV per cell or repeat unit.

Main Test Output Parameters (TOPs) and Derived Quantities

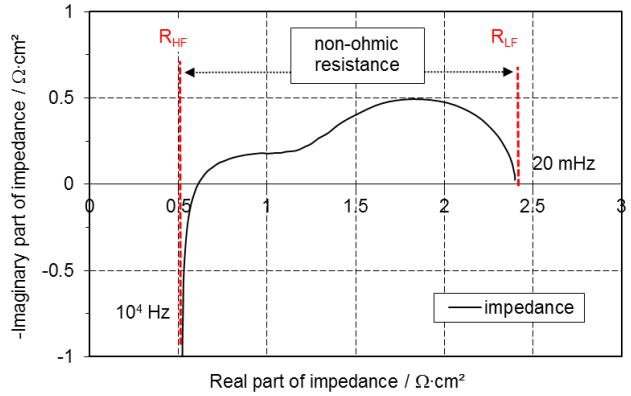
TOP	Derived Quantities
Alternating voltage (V) or alternating current (I) signal	Impedance (Z) Modulus of impedance ($\|Z\|$)
Phase angle (φ)	Real part of impedance (Z')
Temperature of cell/stack (T)	Imaginary part of impedance (Z'')
Temperature of gas streams at cell/stack inlet/outlet, temperature of cell/stack (T)	Low frequency R_{LF} (or total) resistance
Voltage of cell / RU / stack (V)	High frequency R_{HF} (or ohmic) resistance

Data Post Processing and Representation

Representation examples of electrochemical impedance spectra:



Bode plot with modulus of impedance and phase angle vs. frequency



Cole-Cole plot representing imaginary part vs real part of impedance

SOCTESQA:
Solid Oxide Cell and Stack Testing, Safety and Quality Assurance

Project website: www.soctesqa.eu

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) for the Fuel Cells and Hydrogen Joint Technology Initiative under grant agreement n° 621245.