

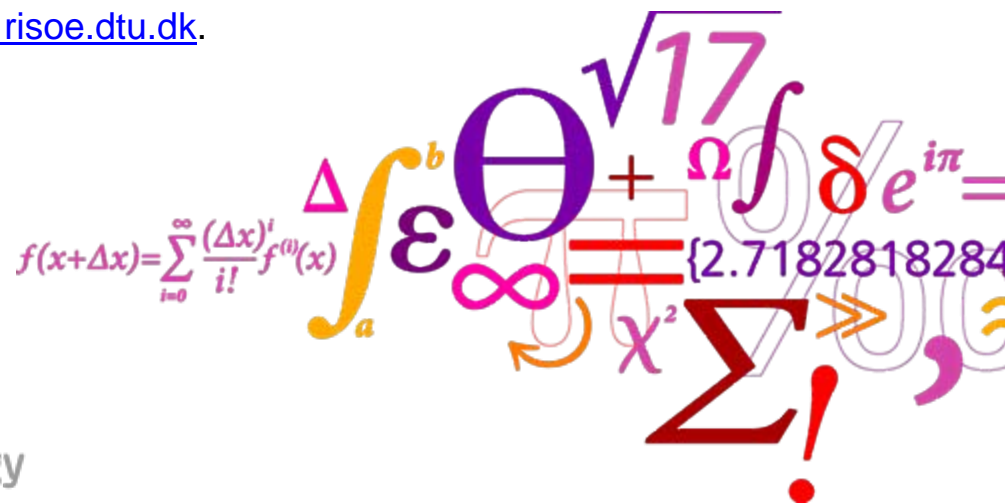
Analysis of Differences in Impedance Spectra

strategies and methods

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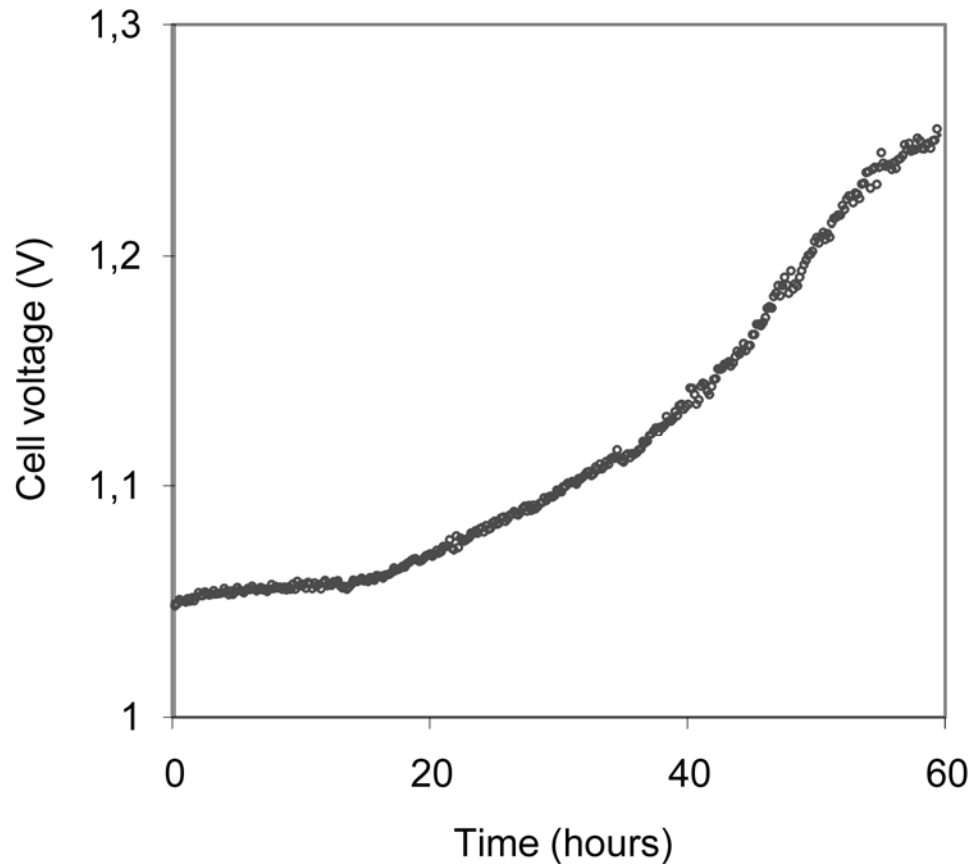
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Example: Solid Oxide Fuel Cell

Performance decreases during electrolysis operation



Operating conditions:

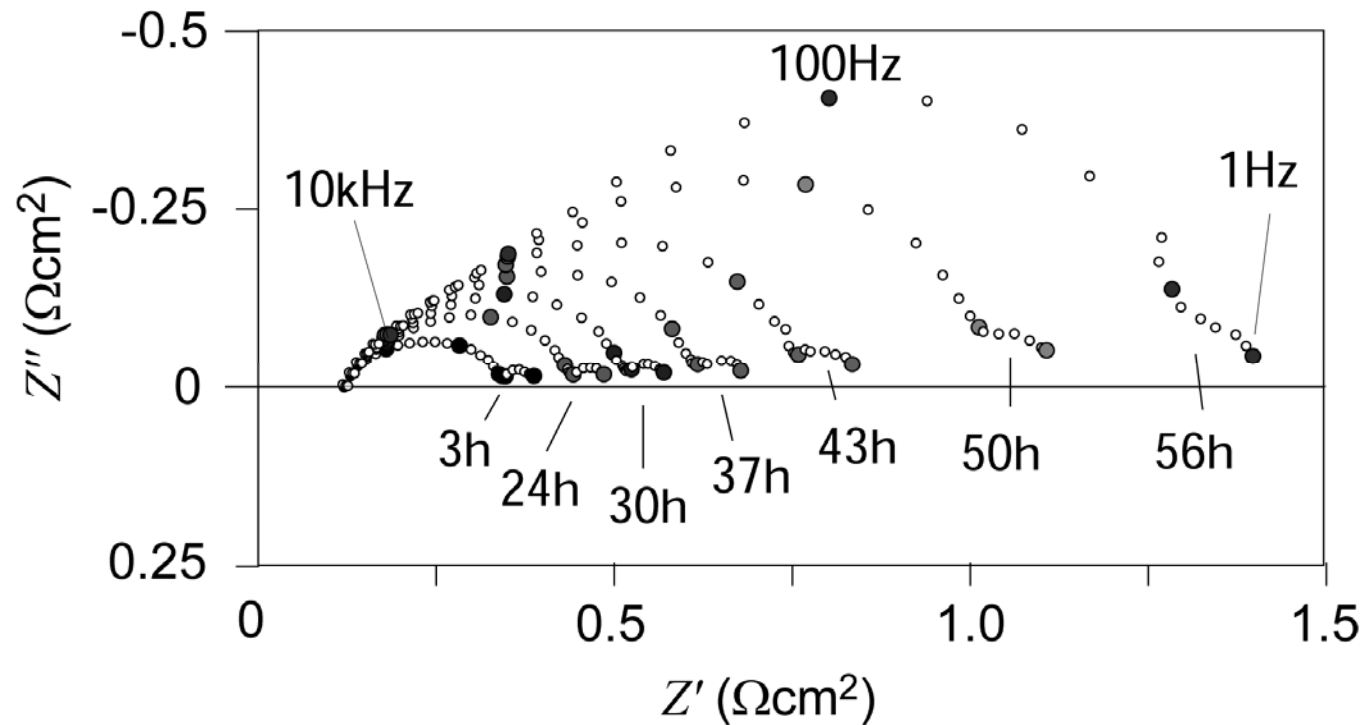
750 °C
-0.25 A/cm²

gas to LSM-electrode:
O₂ (10 l/h)

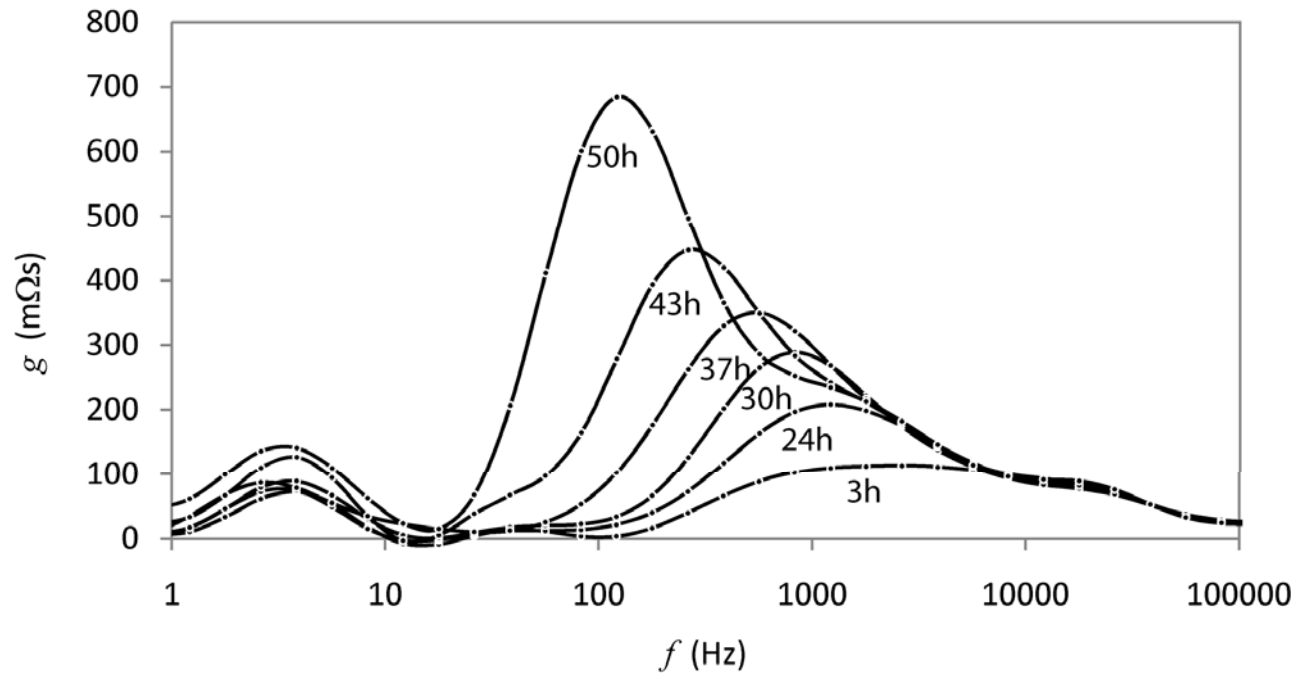
gas to Ni-electrode:
70% H₂O + 30 % H₂ (18 l/h)

Cell area:
16 cm²

Impedance Spectra Measured During Electrolysis Operation



DRT of Impedance Spectra Measured During Electrolysis Operation

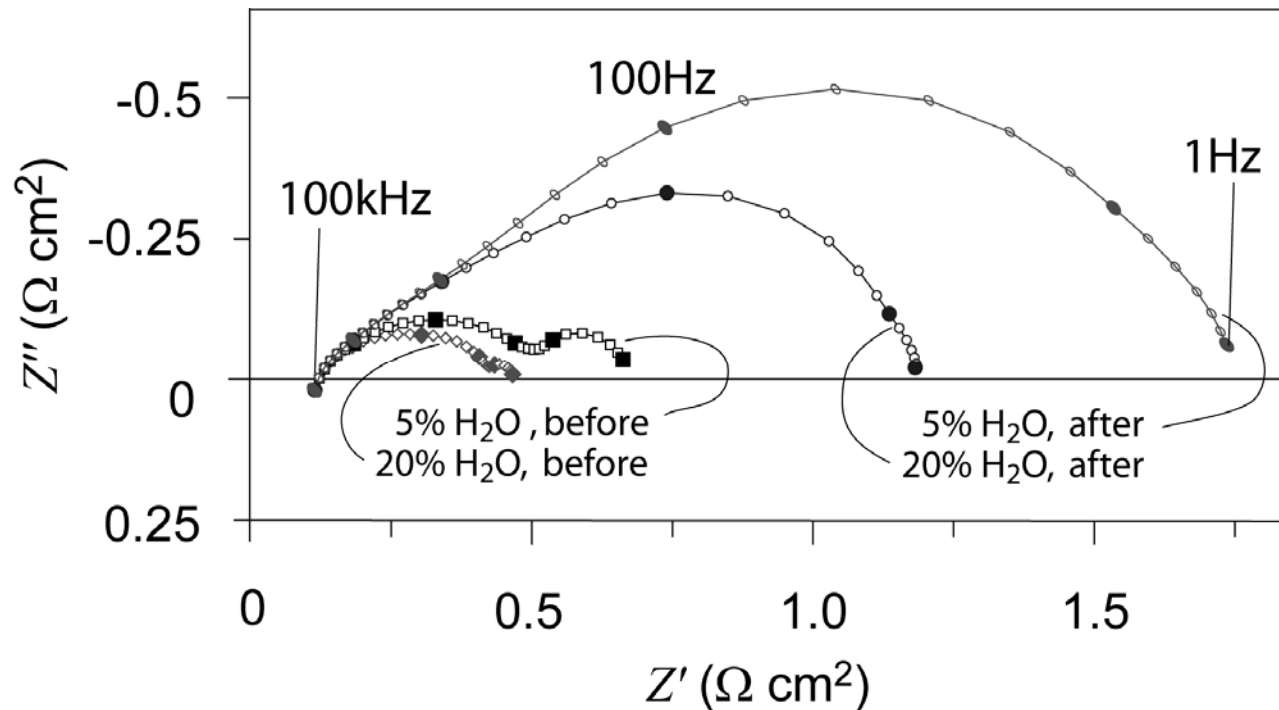


DRT-theory: H. Schichlein, A. C. Müller, M. Voigts, A. Krügel, and E. Ivers-Tiffée, *J. Appl. Electrochem.*, **32**, 875 2002.

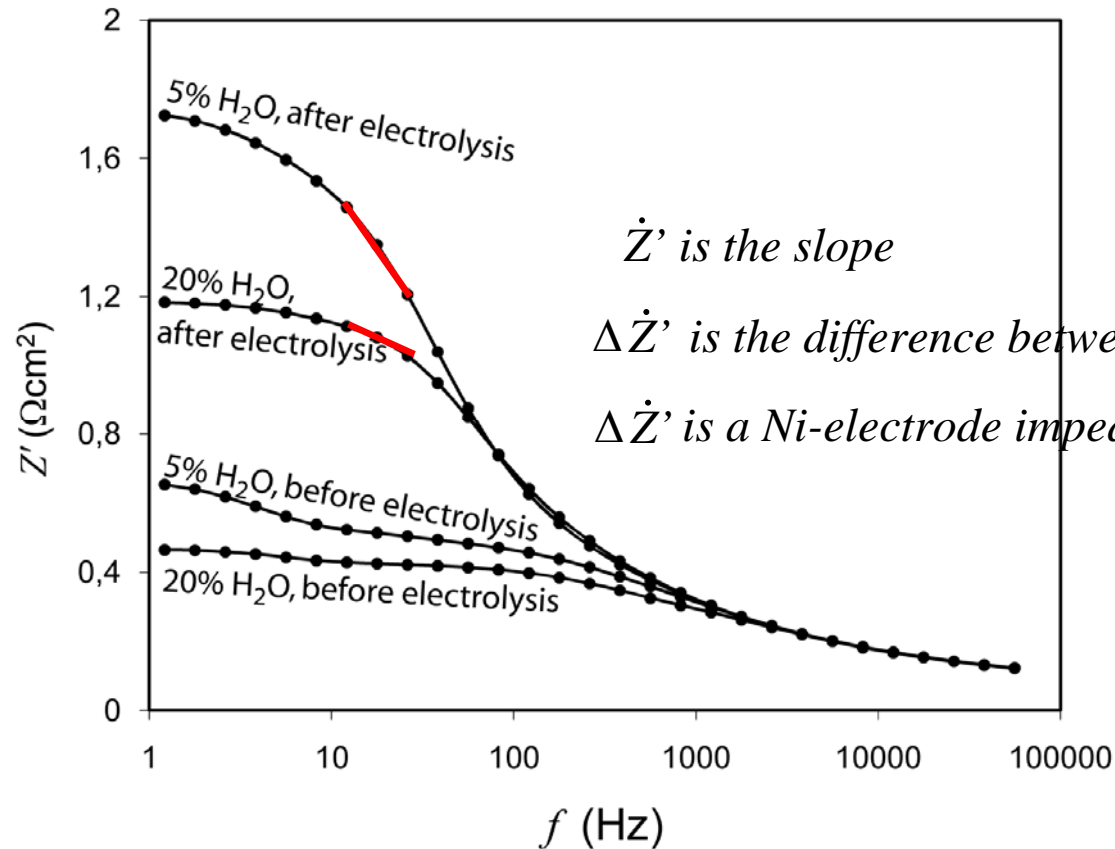
Impedance Spectra Measured Before and After Electrolysis Operation at OCV

gas to Ni-electrode: H_2 with either 5% or 20% H_2O

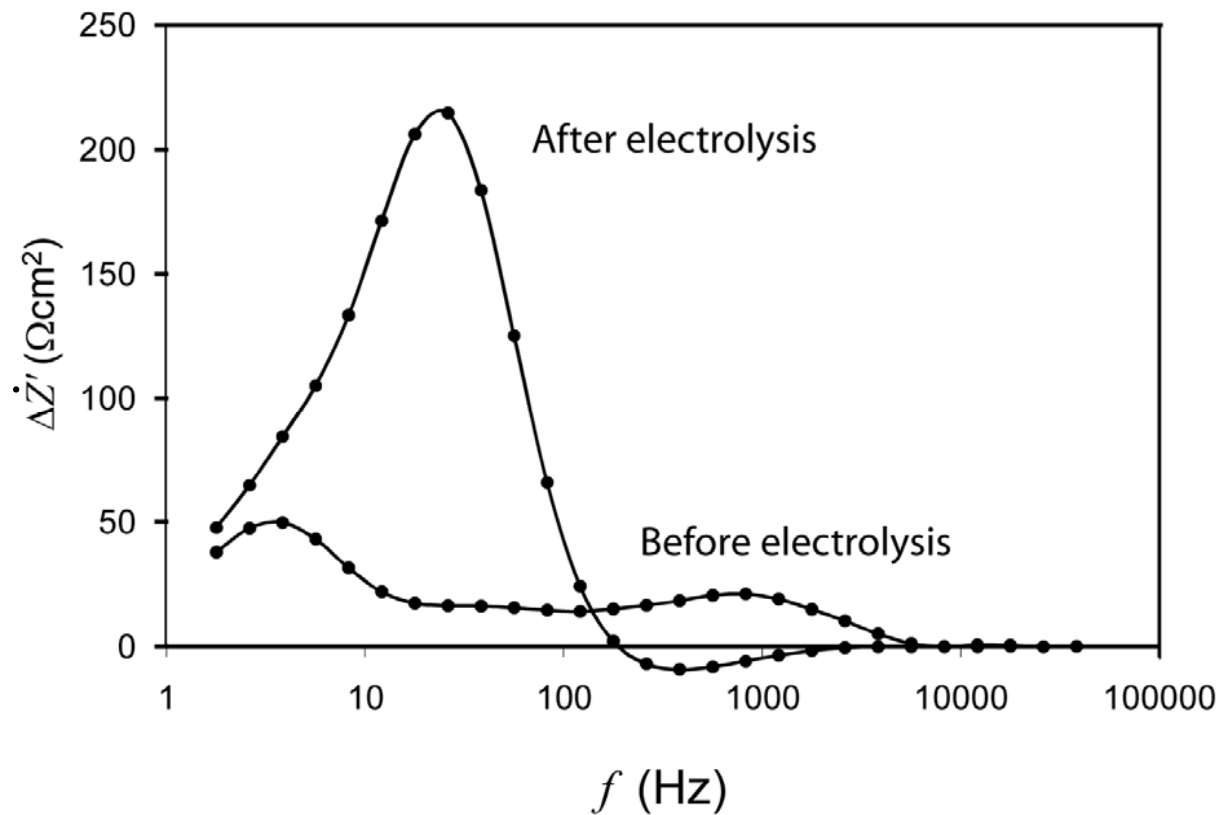
gas to LSM-electrode: air before electrolysis and O_2 after electrolysis



Impedance Spectra Measured Before and After Electrolysis Operation

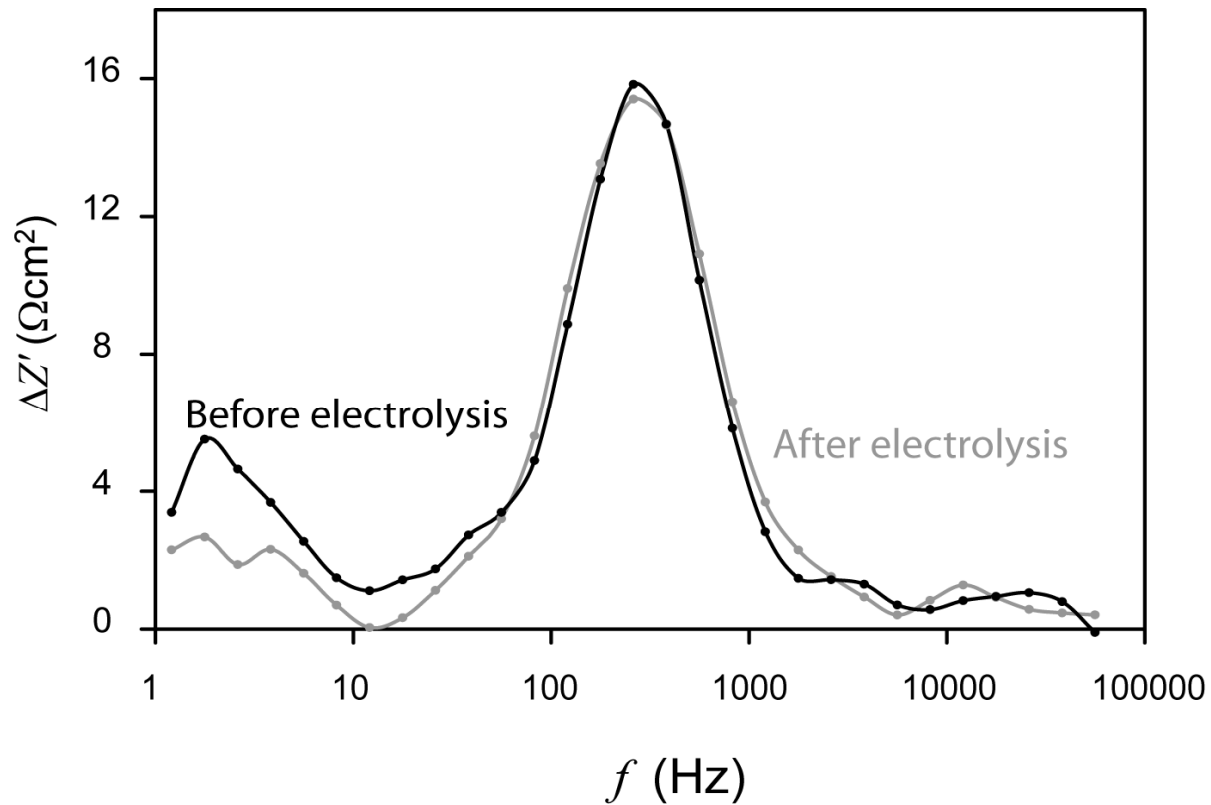


Ni-electrode Impedance Characteristics

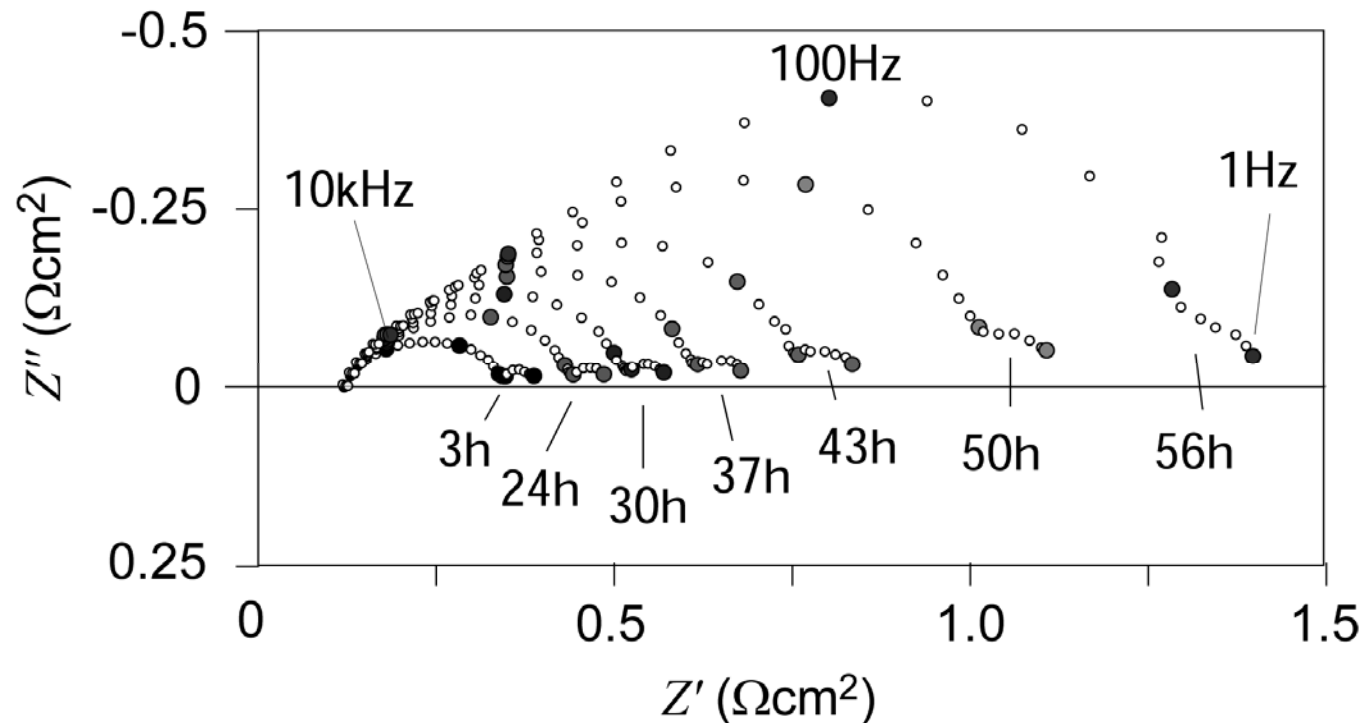


LSM-electrode Impedance Characteristics

...based on gas shifts at the LSM-electrode from air to O₂



Impedance Spectra Measured During Electrolysis Operation



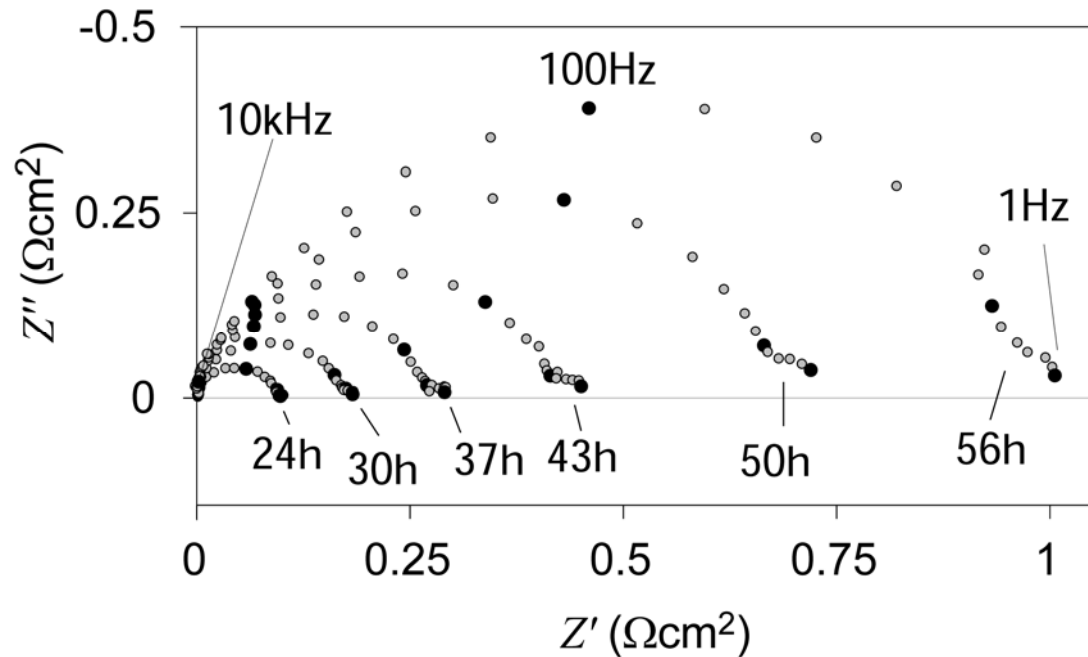
What contribute to these impedance spectra?

...LSM-electrode, Ni-electrode, Electrolyte and Wire inductance

...too many variables in an equivalent circuit model

Difference spectra (x h – 3 h)

...the spectra reflect changes in the Ni-electrode impedance



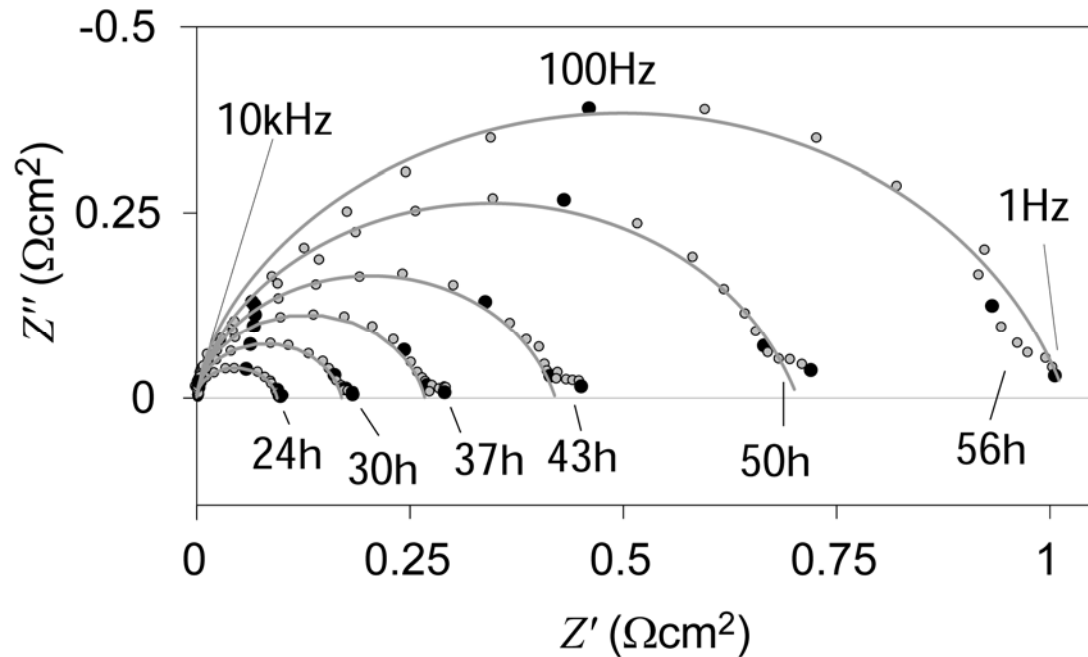
...fewer variables to model the spectra.

Which Impedance Element do Best Model the Ni-electrode Impedance?

$$Z_{(RQ)} = \frac{R_{(RQ)}}{1 + (j\omega/\omega_0)^n} \quad ?$$

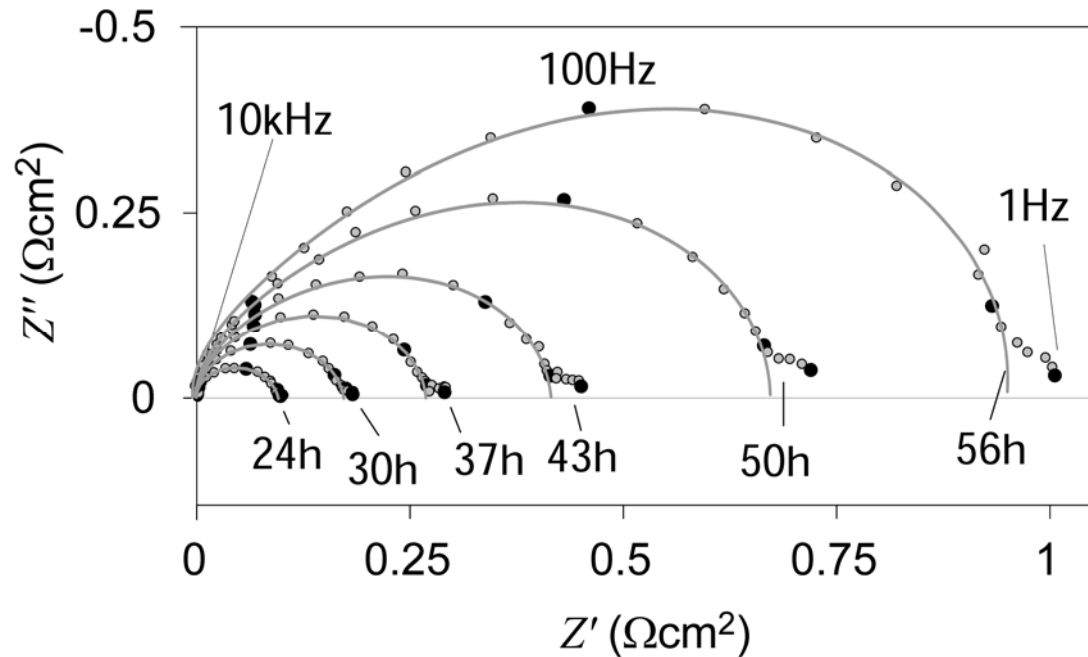
$$Z_{Ge} = \frac{R_{Ge}}{\sqrt{1 + (j\omega/\omega_0)^n}} \quad ?$$

Impedance spectra measured before and after electrolysis operation



$$\Delta Z_{(RQ)_{xh}} = \frac{R_{xh}}{1 + \left(j\omega / \omega_{0xh} \right)^{n_{xh}}} - \frac{R_{3h}}{1 + \left(j\omega / \omega_{03h} \right)^{n_{3h}}}$$

Impedance spectra measured before and after electrolysis operation



$$\Delta Z_{Ge\ xh} = \frac{R_{Ge\ xh}}{\sqrt{1 + \left(j\omega / \omega_{0\ xh} \right)^{n_{xh}}}} - \frac{R_{Ge\ 3h}}{\sqrt{1 + \left(j\omega / \omega_{0\ 3h} \right)^{n_{3h}}}}$$

Conclusion

- Analysis of differences in impedance spectra before and after an operation period can be used to determine how much the electrodes are affected by the operation period
- Modeling of differences in impedance spectra may reduce the number of model variables. This can enhance the modeling accuracy
- A Gerischer impedance element model the Solid Oxide Fuel Cell Ni/YSZ-electrode impedance more precise than a (RQ)-element

Thank you for your attention

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- Colleagues at Fuel Cells and Solid State Chemistry Division, Risø National Laboratory for Sustainable Energy, Technical University of Denmark
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