Ageing phenomena identification of PEMFC using the DRT tool

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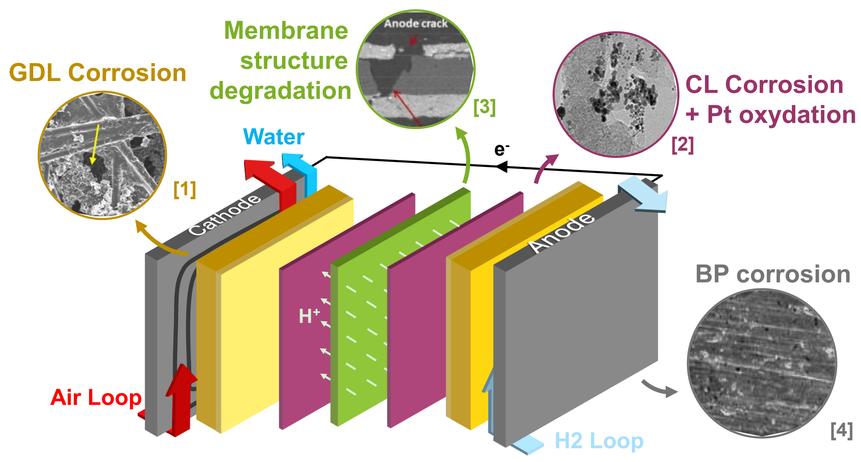
Objectives

- Apply DRT to a PEMFC short-stack ageing data to identify ageing phenomenon tendencies
- Analysis of methodology in a robust and meaningful way

Ageing of Proton Exchange Membrane Fuel Cell

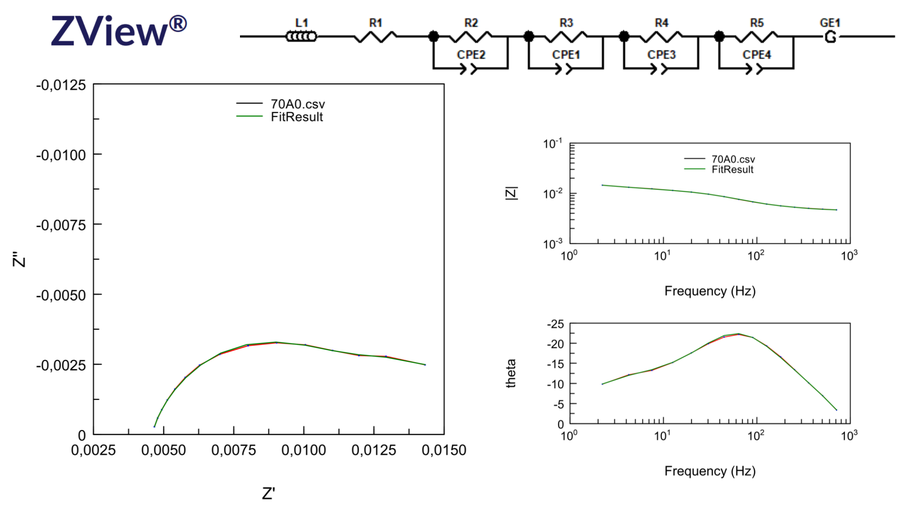


$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O + \text{electricity} + \text{heat}$$

- Membrane
- Catalytic Layer (CL)
- Microporous Layer (CPL)
- Gas Diffusion Layer (GDL)
- Bipolar Plates (BP)

[1] Song. KY et al., 2011,doi:10.1016/j.ijhydene.2011.06.095
[2] Kang J et al., 2010, doi:10.1016/j.jhydene.2010.01.071
[3] Ren P et al., 2020, doi:10.1016/j.pecs.2020.100859
[4] Kumagai et al., 2007, doi:10.1016/j.electacta.2007.12.078

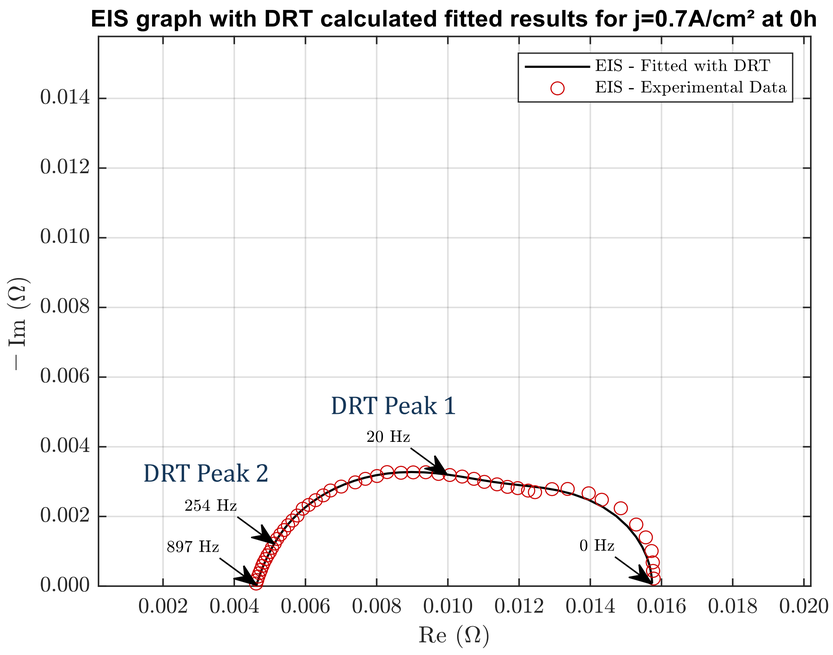
Equivalent Circuit Modeling (ECM)



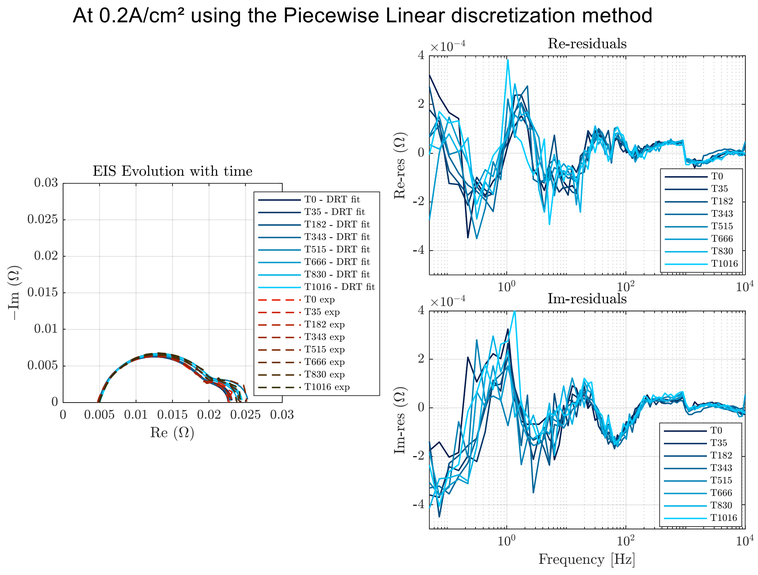
→ **Limitations:** ECM can be **tedious,** have **no physical meaning,** deals with a **single dynamic,** is **not easy** to **automate**

Electrochemical Impedance Spectroscopy (EIS)

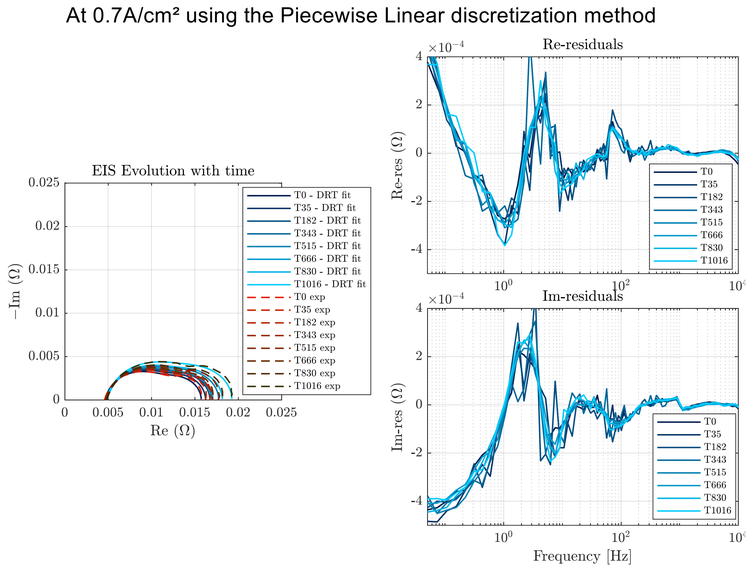
Measure the magnitude and phase response to a sinusoidal current or voltage perturbation



At 0.2A/cm² using the Piecewise Linear discretization method



At 0.7A/cm² using the Piecewise Linear discretization method



→ Fitting the EIS data with DRT is better at lower current densities, higher residuals at low frequencies, evolution of the spectra with time

Distribution of Relaxation Times (DRT)

Study performed on datasets from IEEE PHM 2014 data challenge.

$$Z(\omega) = R_0 + R_{pol}\sum_{k=1}^{N}\frac{g_k}{1 + j\omega\tau_k}$$

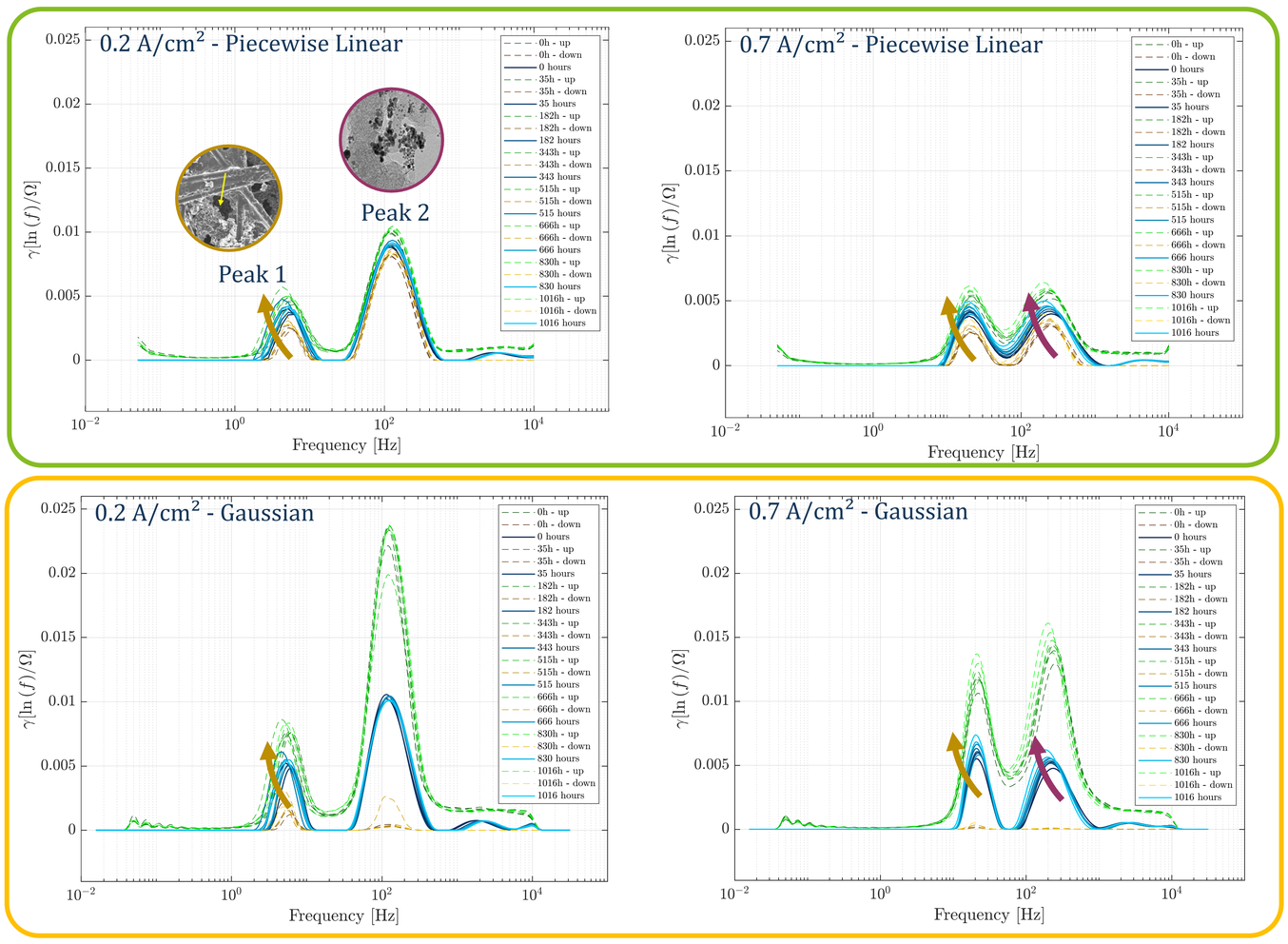
→ **Advantages:** clear time constants identification, automated and optimized, confidence interval

Sensitivity study to the discretization methods of the DRTtool

	CI	NbP	Fit	FR	ExeT
At 0.2 A·cm⁻²					
G	Large	4	Very Good	Extended	Medium
C2M	Large	4	Very Good	Extended	Medium
C4M	Medium	3	Good	Extended	Medium
IQa	Large	4	Very Good	Extended	Slow
PL	Small	3	Very good	Real	Very fast
At 0.45 A·cm⁻²					
G	Large	4	Good	Extended	Medium
C2M	Large	4	Good	Extended	Medium
C4M	Medium	3	Good	Extended	Medium
IQa	Large	4	Good	Extended	Slow
PL	Small	3	Good	Real	Very fast
At 0.7 A·cm⁻²					
G	Large	4	Very Good	Extended	Medium
C2M	Large	4	Very Good	Extended	Medium
C4M	Medium	3	Good	Extended	Medium
IQa	Large	3	Good	Extended	Slow
PL	Small	2	Very Good	Real	Very fast

G: Gaussian, C2M, C² Matérn, M: C⁴ Matérn, IQa : Inverse Quadratic, PL: Piecewise Linear
CI: Confidence Interval, NbP: Number of Peaks, FR: Frequency Range, ExeT: Execution Time

Ageing



→ Shift in amplitude and in frequency with respect to time and current densities

Hypothesis : Phenomena are slowed down

→ Peak 1: flooding increases and gas diffusion decreases

→ Peak 2 : as the electrochemical surface area (ECSA) is reduced, kinetics are too

Conclusions and Perspectives

- Promising results in identifying the contribution of ageing phenomena on PEMFC stack
- Planned ageing tests to apply the method to new datasets
- Further exploit the DRT and EIS to extract parameters to propose an ageing model

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