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In-situ NMR & MRI characterization of proton exchange membranes for fuel cells

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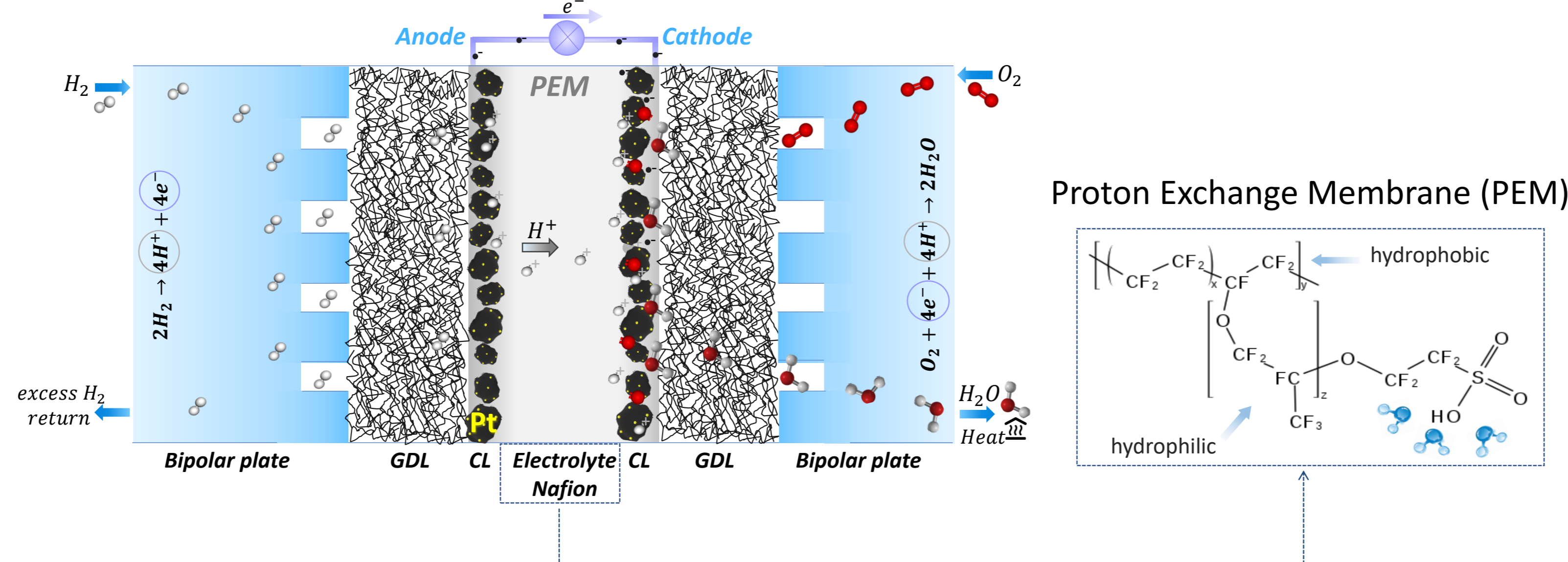
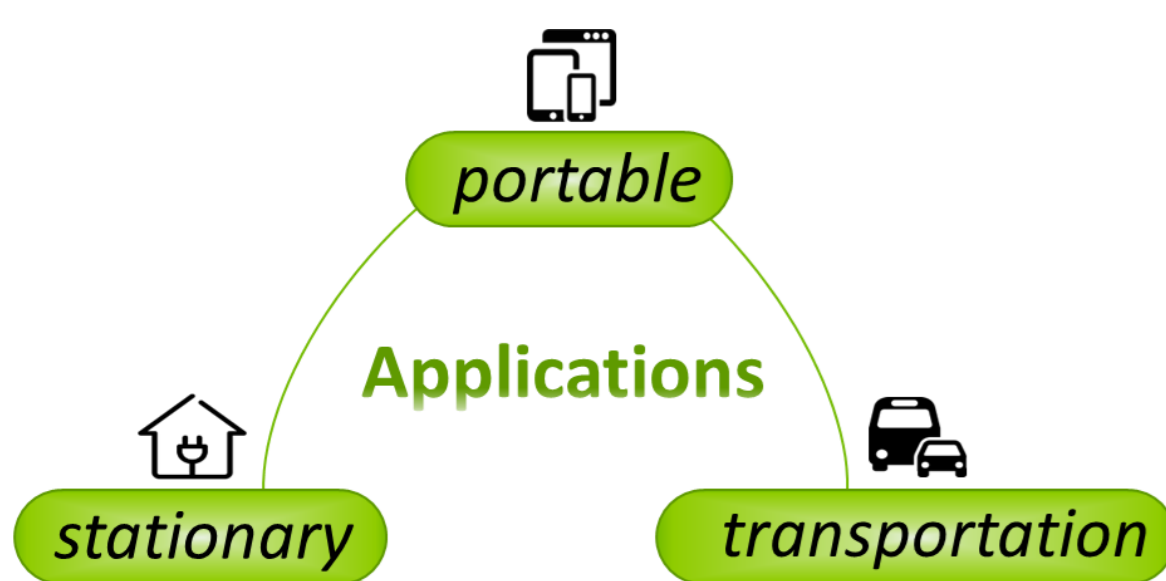
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Introduction



PEMFC efficiency depends on the hydration state of the membrane which permits the proton transportation from the anode to the cathode.

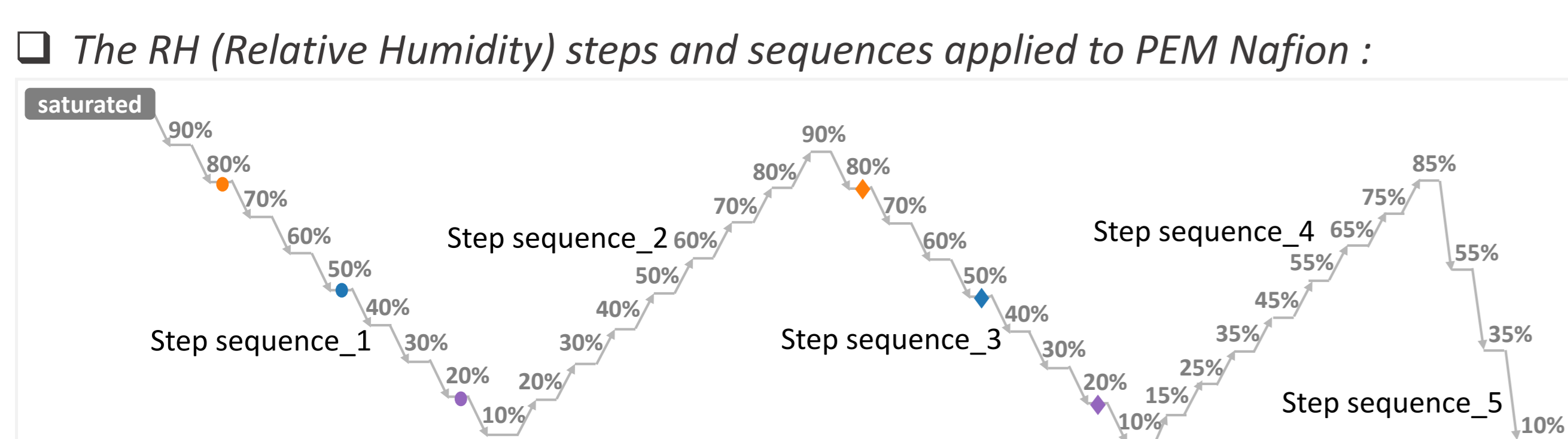
Nuclear Magnetic Resonance & Magnetic Resonance Imaging: non invasive and efficient to measure water properties inside the proton exchange membrane (PEM)

Objectives

This work aim to develop a NMR methodology and adapted experimental set up to investigate the evolution of the PEM properties (water content and distribution, thickness, water flow...) under controlled humidified air for PEM with and without catalyst layer.

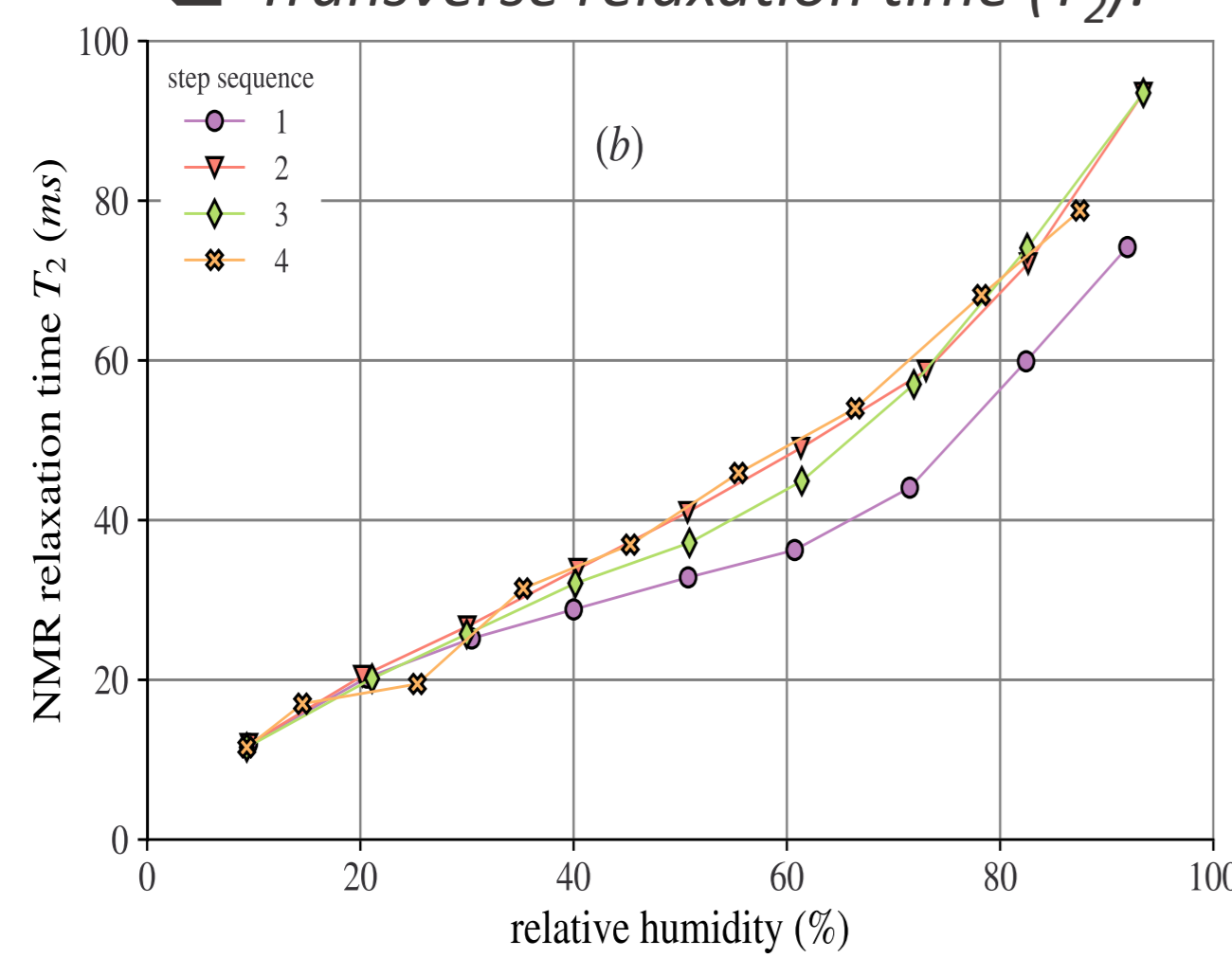
Results

Proton Exchange Membrane Nafion (N1110):

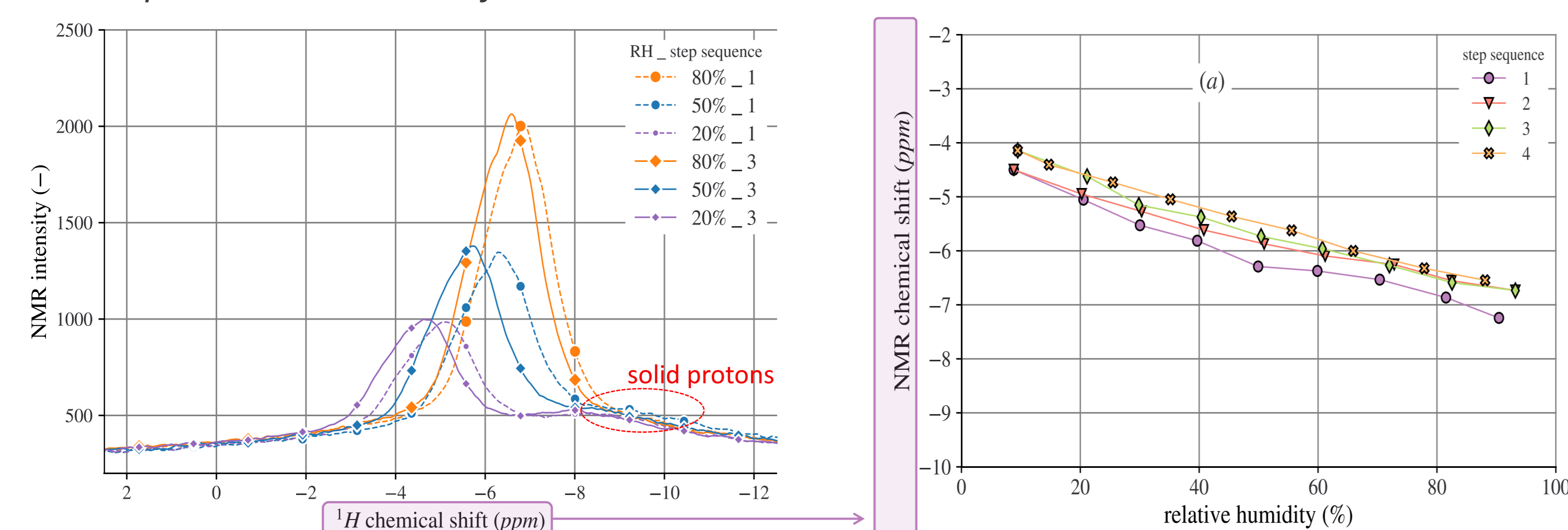


- PEM is submitted to the same RH values on both sides → RH1 = RH2
- Each RH step is maintained for an optimized time (3h) to ensure that stable state is reached.

Transverse relaxation time (T_2):



1H spectra & chemical shift:

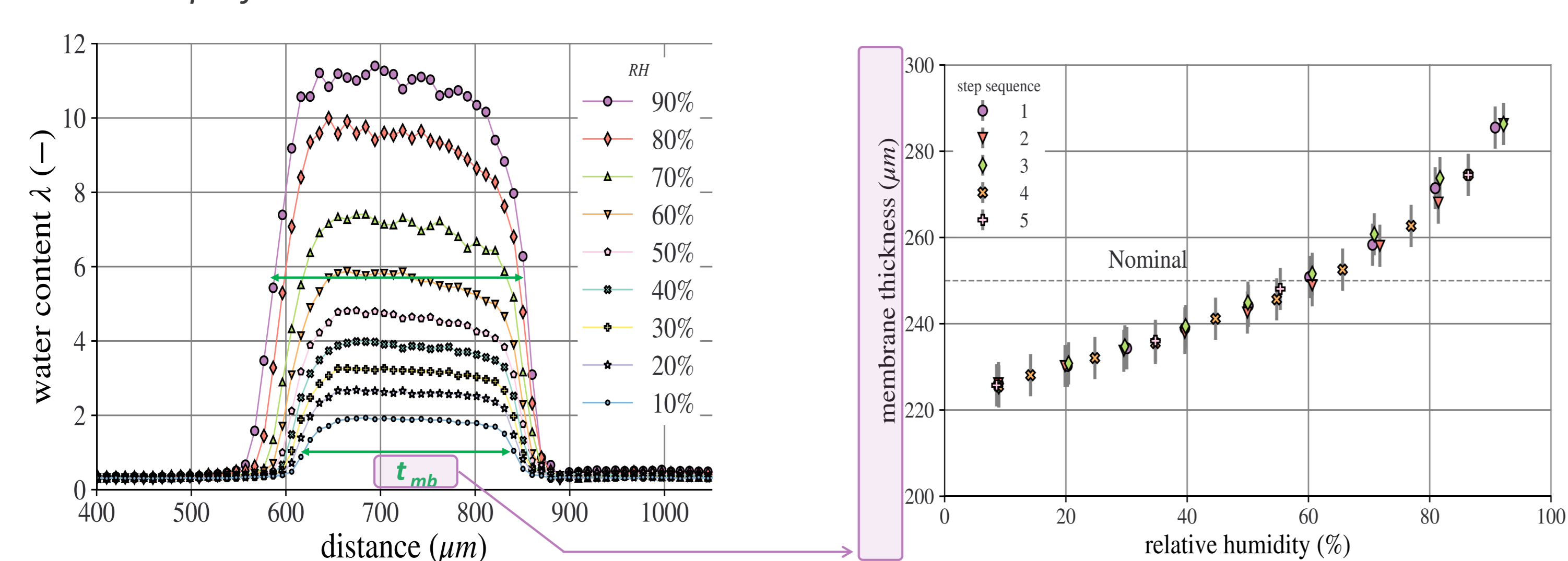


- RH \nearrow \Rightarrow $n_{H_2O} \nearrow \Rightarrow \delta \searrow$
- \Rightarrow water less confined
- $\Rightarrow e^-$ density around H^+ \nearrow

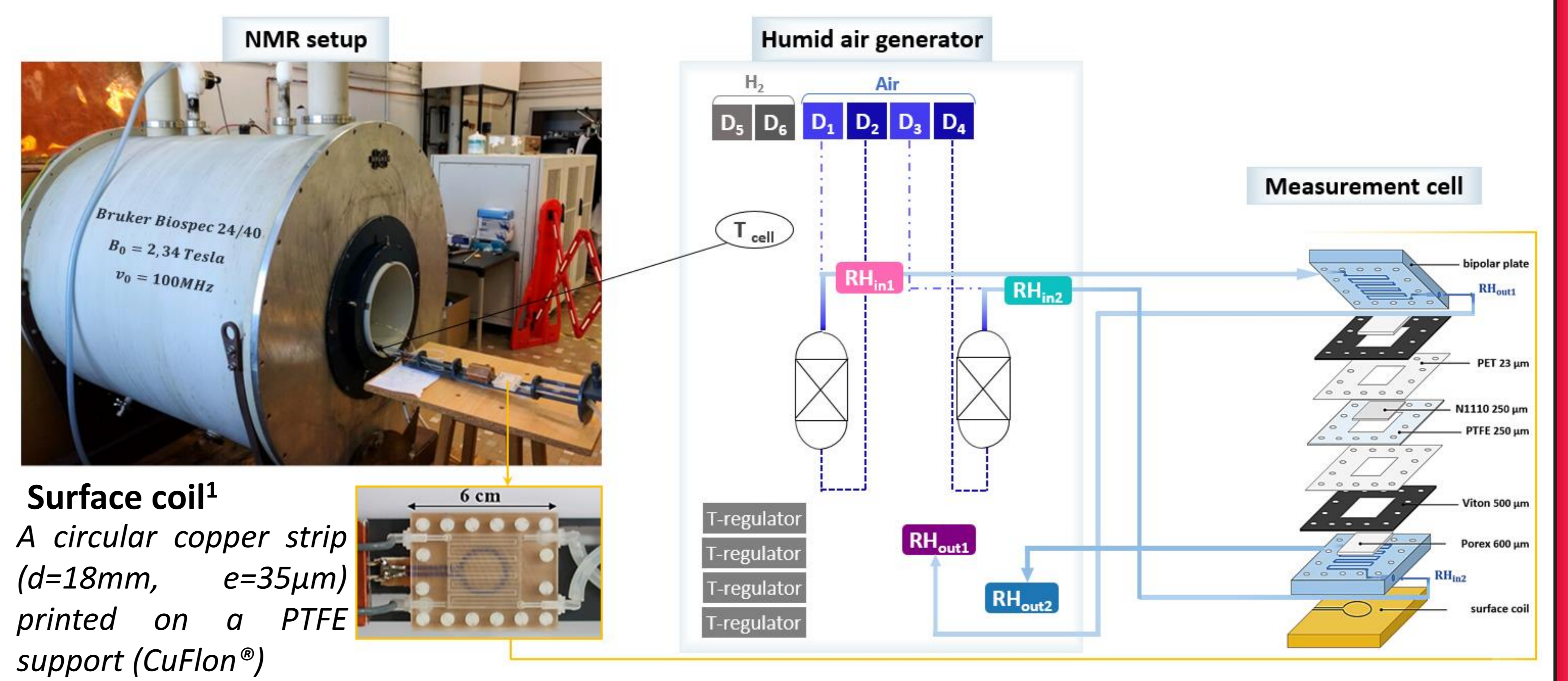
The chemical shift is not just depending on the water content but also on the history steps to which the membrane is subjected

- When the polymer is:
 - soaked in $H_2O_{(l)}$, a swelling pressure is created by the water adsorption & stretches the polymer chain structure
 - subjected to $H_2O_{(v)}$, an additional pressure is released by the membrane/vapor interface where the structure is different from the bulk.

Water profiles & membrane thickness:

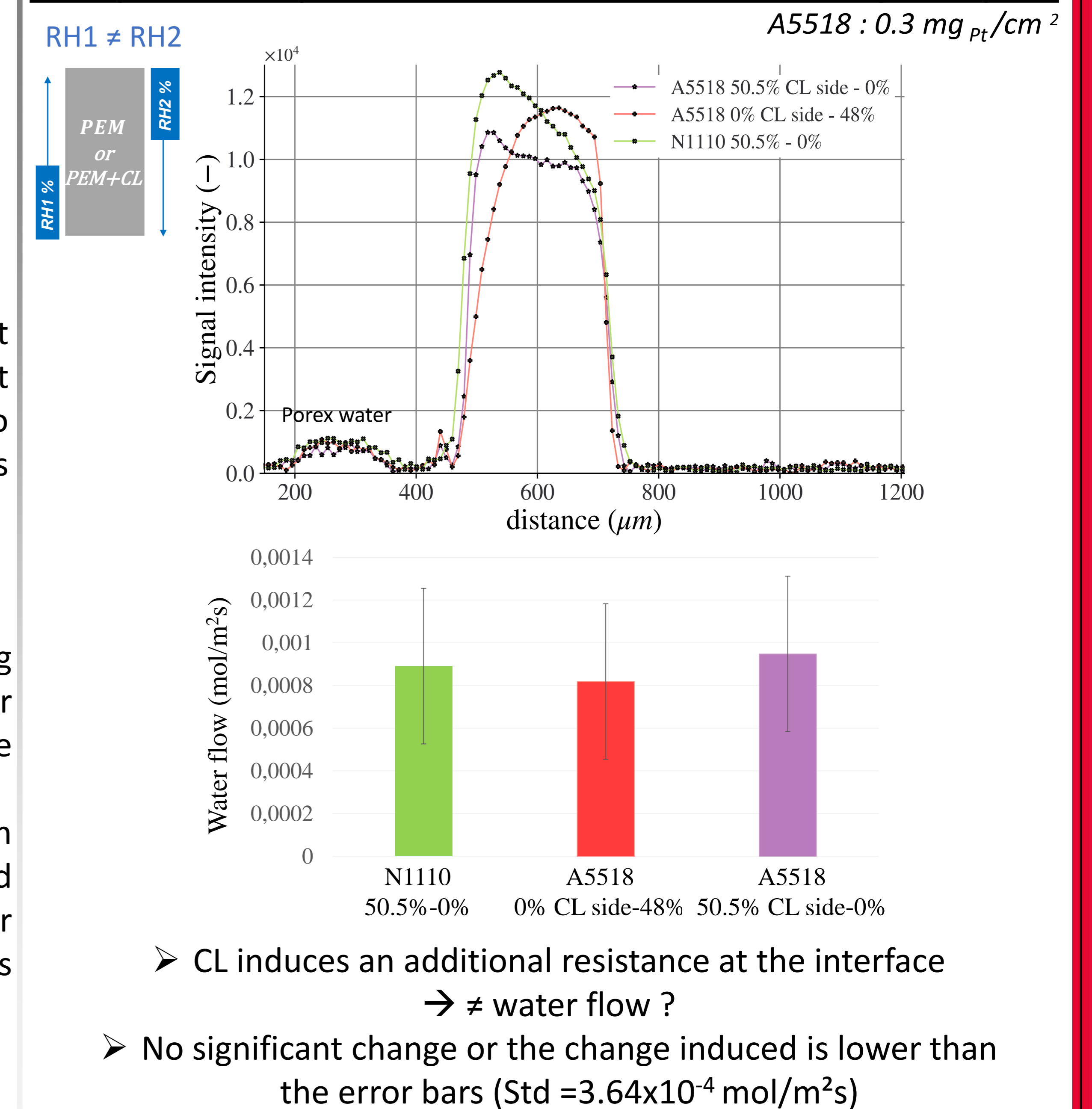


Experimental setup



Surface coil¹
A circular copper strip ($d=18mm$, $e=35\mu m$) printed on a PTFE support (CuFlon[®])

Comparison of N1110 with & without catalyst layer:



Conclusion

- A NMR experimental methodology was developed to allow the precise measurement of the NMR membrane's properties variation with RH sequences.
- The measurement of water flow through membrane in the case of N1110 with and without catalyst layer did not show significant differences → no resistance induced by membrane/catalyst interface or difference lower than error bars ?

References

[1] : Klein, M., Perrin, J. C., Leclerc, S., Guendouz, L., Dillet, J., & Lottin, O. (2013). Spatially and temporally resolved measurement of water distribution in Nafion using NMR imaging. ECS Transactions, 58(1), 283.

Acknowledgement

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