ADVANCES AND INNOVATIONS IN SOFCs 2
FROM MATERIALS TO SYSTEMS

Water Formation and Permeation in the Central Membrane of a Dual Membrane Fuel Cell

Z. Stoynov, D. Vladikova, D. Levi

AIM :

- **To summarize results for the Central Membrane behavior**

- **To fulfill requirements of the reviewers**

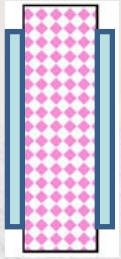
- **To prepare for the final report**

  - ❖ “the most significant progress is required for the development of the CM” (*mid term review*)
  - ❖ “ Intensive use of the HT cell and EIS facilities already developed” (*mid term review recommendation)*
  - ❖ “You are supposed to indicate how the summary of the recommendations have been taken into account” *(Carlos Saraiva Martins)*

AIM & OUTLINES :

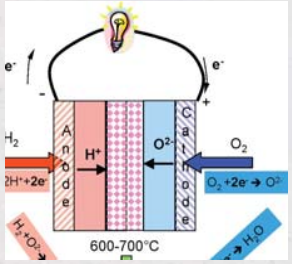
- **CM – new requirements:**
  - High H^+ conductivity
  - High O^{2-} conductivity
  - Optimal porosity for:
    - *Active TPB points for water formation*
    - *Easy water evacuation*

- **CM studies:**
  - Conductivity – EIS
  - Gases permeation
  - Water permittivity



Pt, Ag **Me/BCY+YDC$_{poros}$/Me in H_2 and O_2**

  - Water formation & transport at operating conditions - EIS

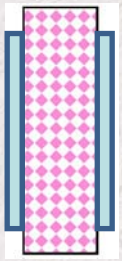


ADVANCESAND INNOVATIONS INSOFCS From Materials to Systems

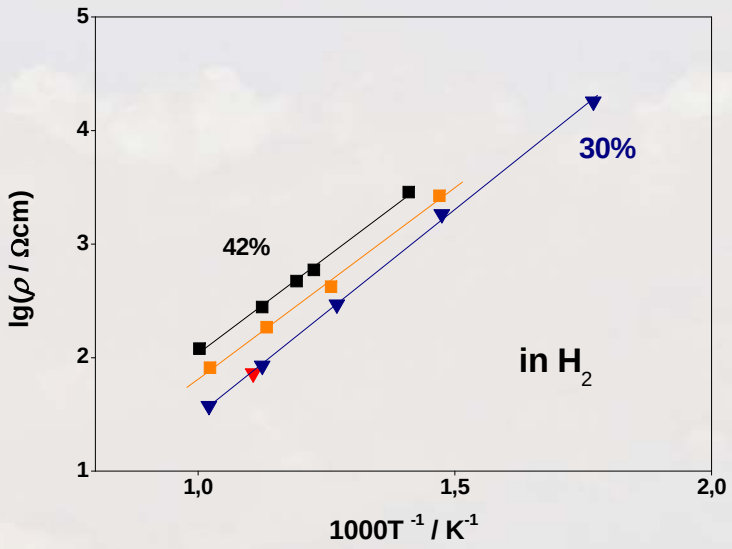
IDEAL Cell

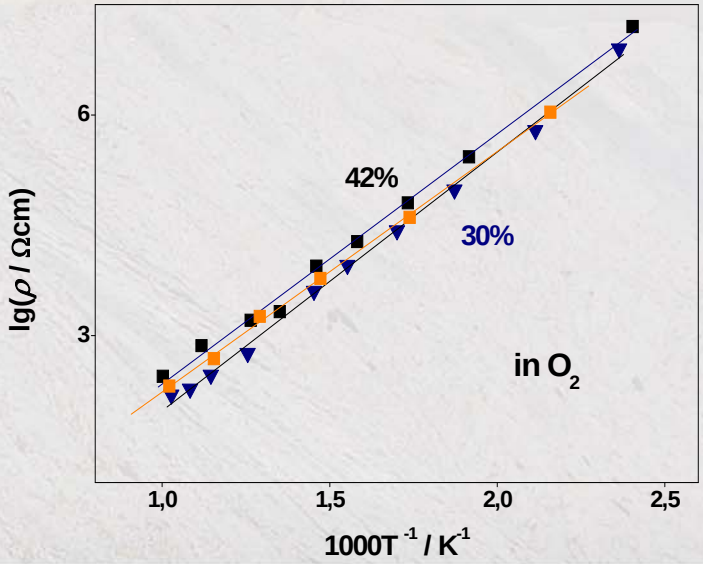
Conductivity Studies

Me/BCY+YDC$_{poros}$/Me



- Relation between porosity and conductivity
- Lack of information for water





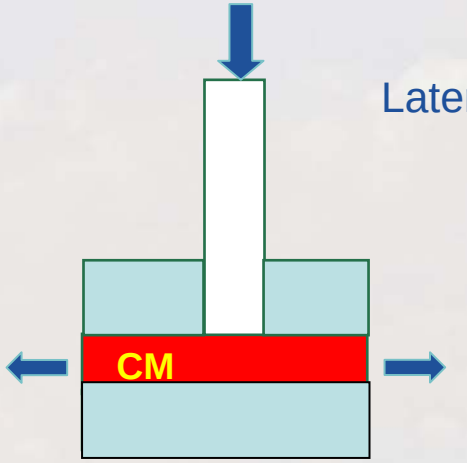
Gases Permeability Measurements and Studies

General Relations

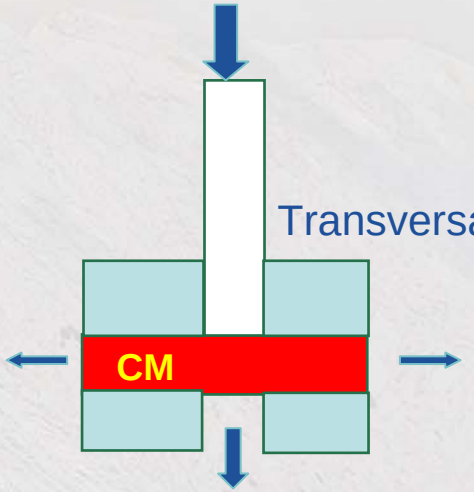
(1) $P = f(q_{flow})$ P [mm H_2O]

$P = R_p \cdot q_{flow}$

R_p - *permeability resistance*

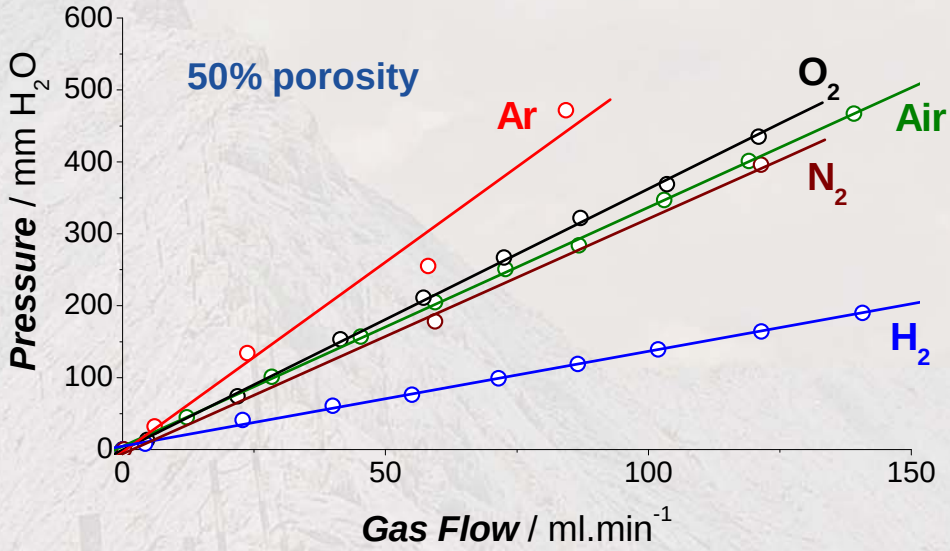


(2) $P = f(t^o C)$ *at constant flow*



Gases Permeability Measurements and Studies

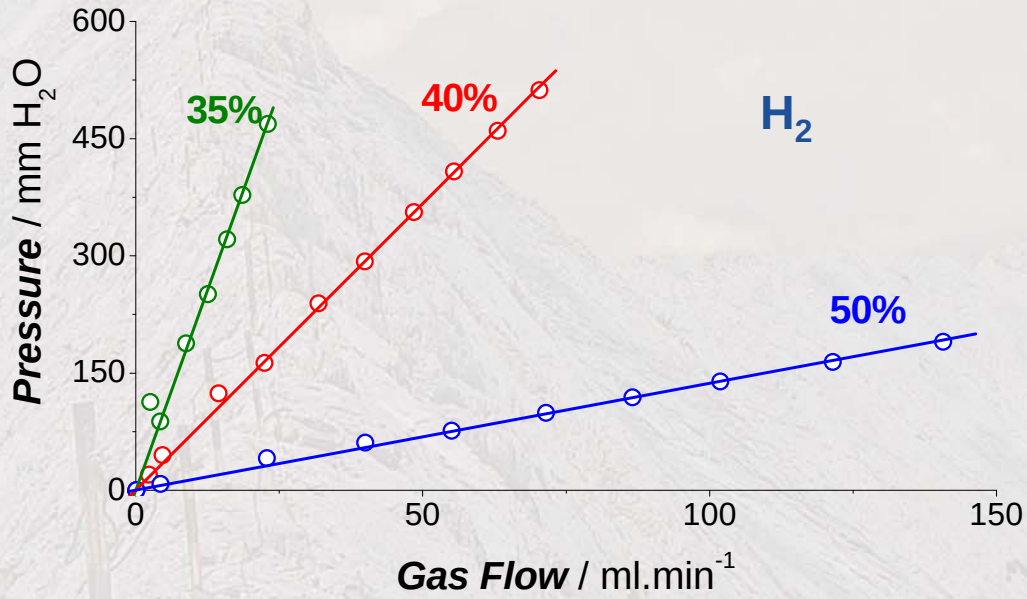
- **Strong correlation between gases molecular weight and permeability**



- **Conclusions for the electrodes porosity:**
  - Different optimal porosity for different gases
  - Gases mixtures feeding??
  - Gas + H_2O??

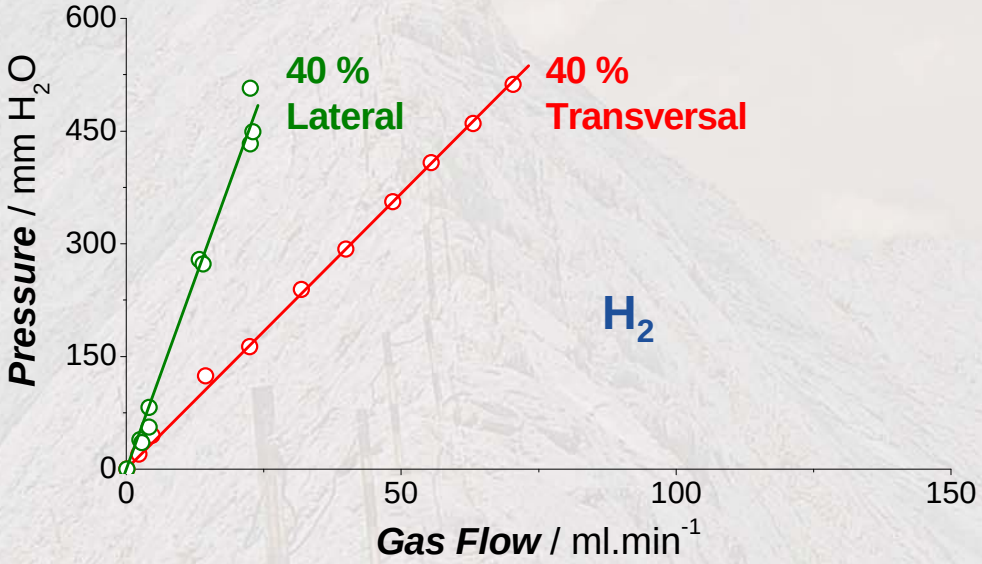
Gases Permeability Measurements and Studies

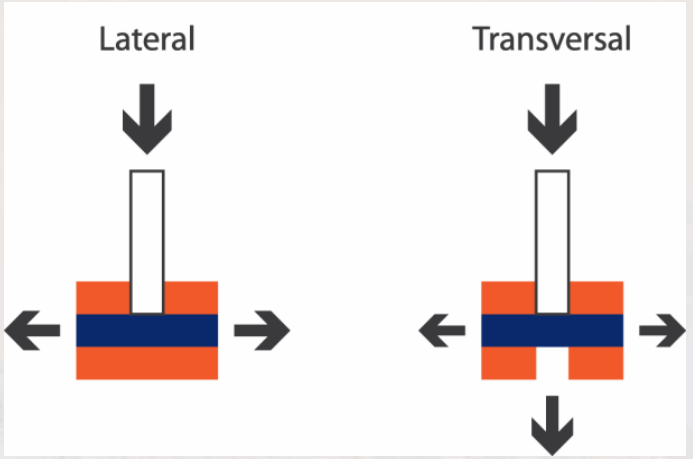
- **Strong correlation between porosity and permeability**



Gases Permeability Measurements and Studies

- **Strong correlation between configuration and permeability**

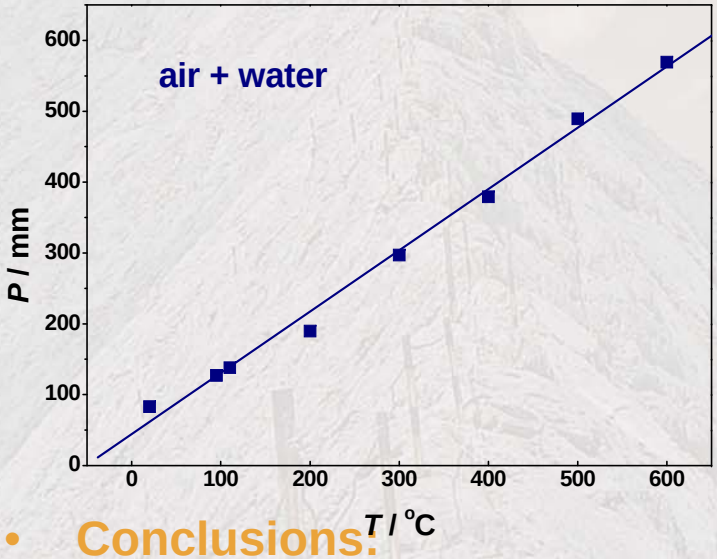


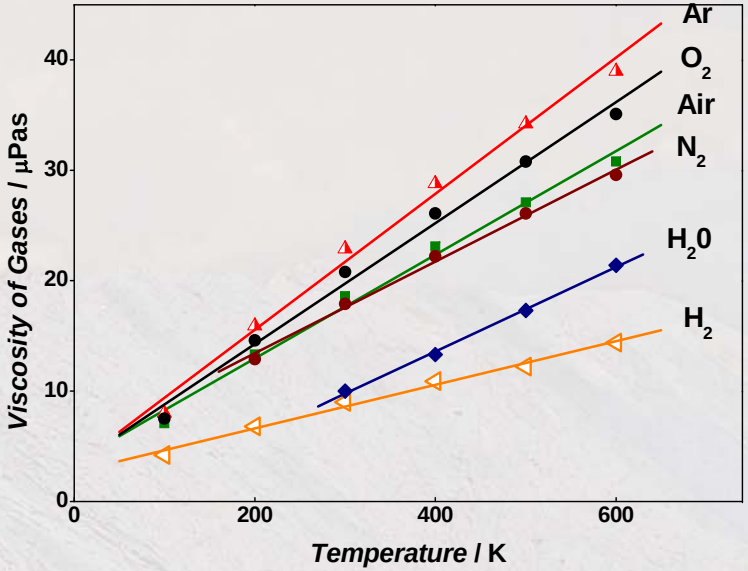


Gases Permeability Measurements and Studies

- **Strong correlation between temperature and permeability**

Handbook of Chemistry and Physics, 85th Edition, David R. Lide (Ed.), CRS Press, 2004-2005, p. 6-201



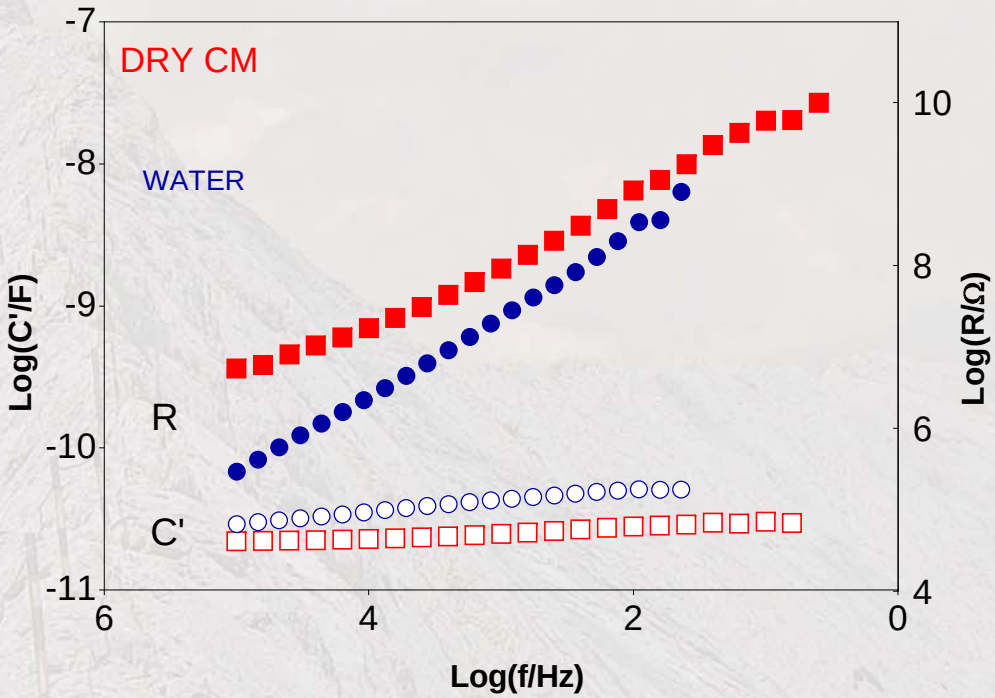


- **Conclusions:**
  - at operating temperatures water will have higher viscosity
  - Optimal porosity (conductivity, permeability, strength) – 35-40%
  - Hypothesis for formation of adsorbed layer

Water Permittivity Measurements

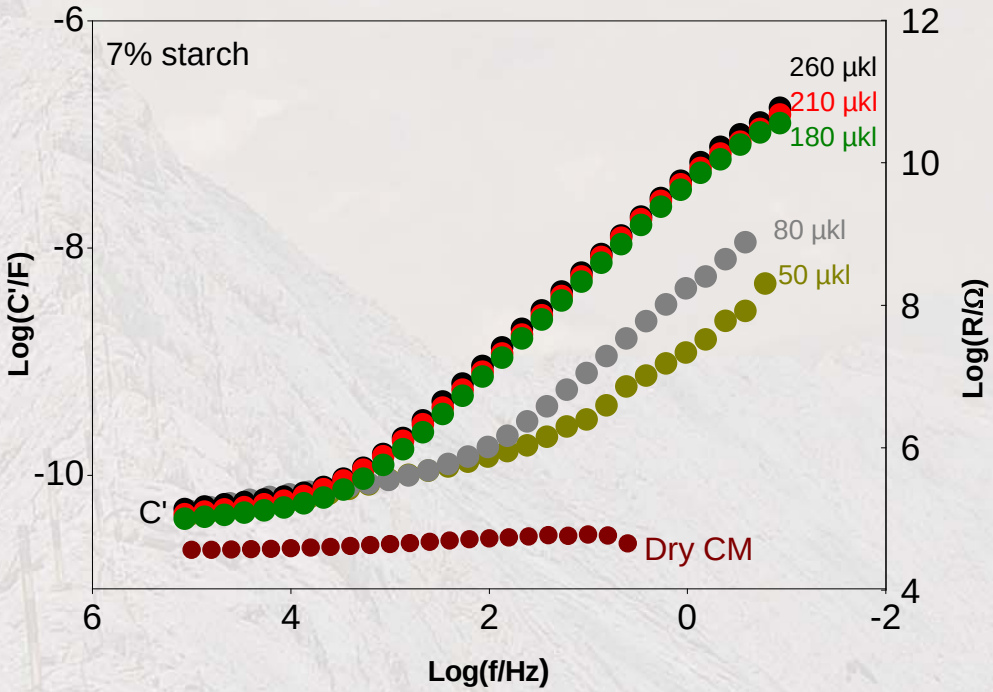
- **Permittivity Measurements (** $\varepsilon = \varepsilon' - j\varepsilon''$ ⟶ $C = C' - jC''$ **)**
  - Central membranes:
    - 50vol.% YDC15 *(Lot 003)* + 50 vol.% BCY15 *(Lot 006)*
    - Different pore former
    - Different quantity of the pore former
    - Sintering 1300°C/ 5h
  - Measurement conditions
    - 1 MHz – 10 mHz
    - A.C. = 1 V
    - lg C` = ***F*** (lg *f*) – *polarization ability*
    - lg (*R* = 1/*ωC``*) = ***F*** (lg *f*) – *losses (dipole reorientation)*

Water Permittivity Measurements

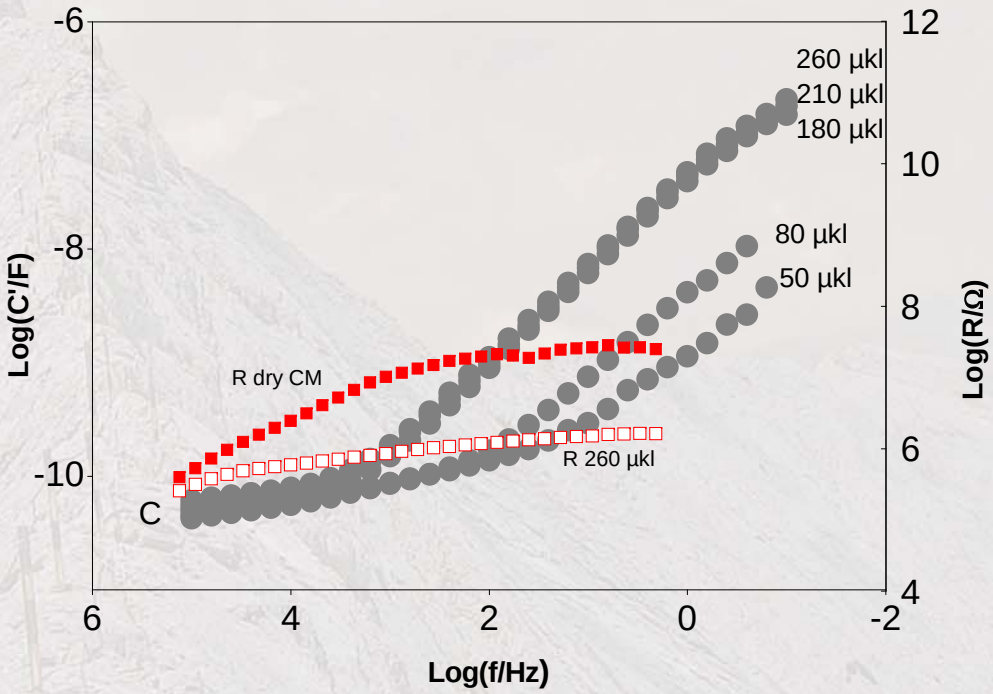


Water Permittivity Measurements

Chemisorption ⟶ organization of dipole film

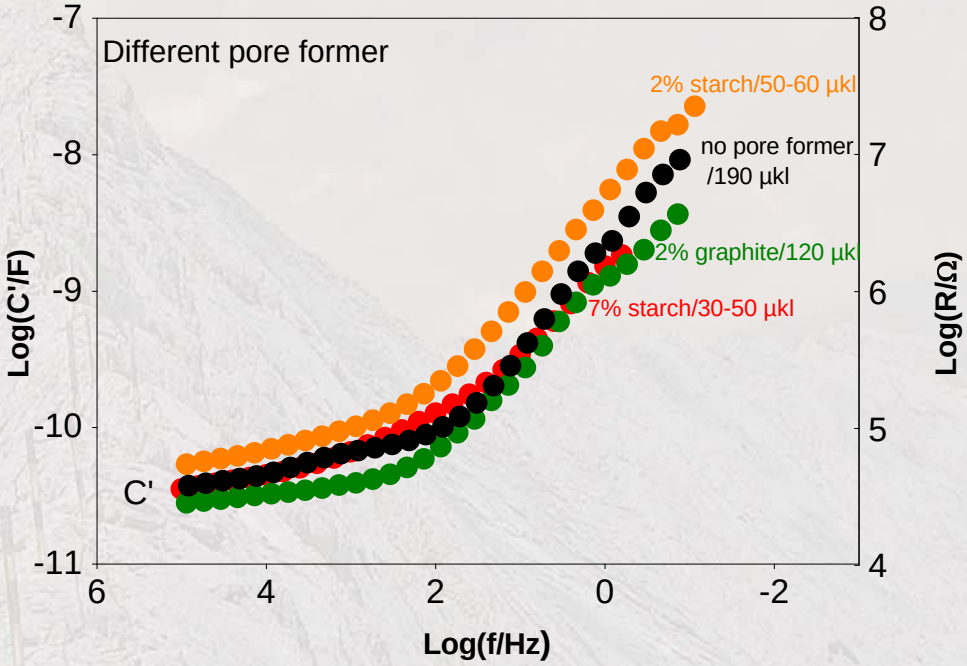


Water Permittivity Measurements



Water Permittivity Measurements

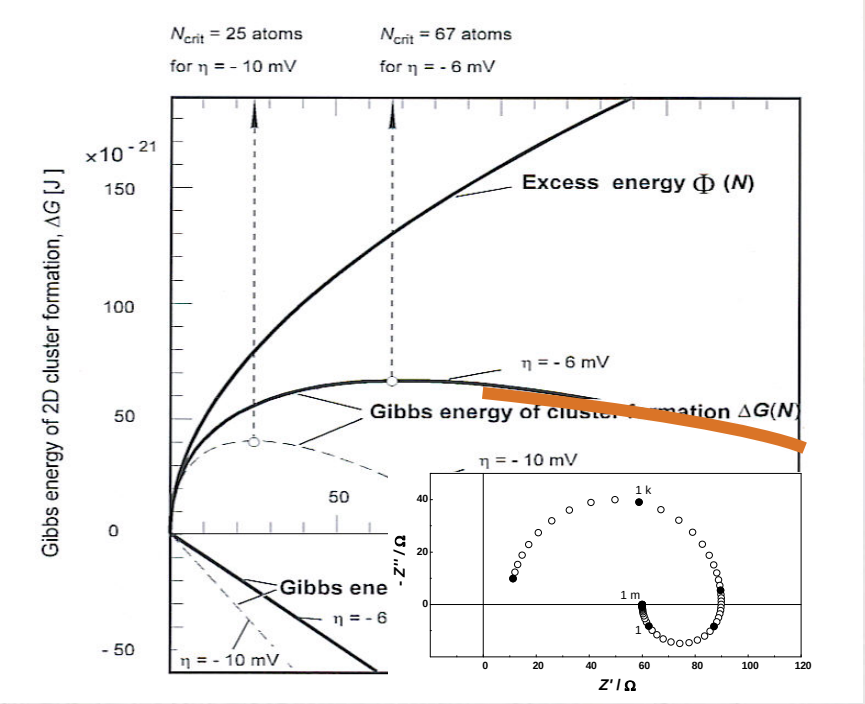
- **Some observations:**
  - Higher porosity – lower water content
  - Different pore former *(different pore geometry)* – different water content



- **What is next:** same measurements at elevated temperatures

Water formation & transport in the CM

- **Studies at operating conditions**
- **Full cell - Impedance**
- **Water formation**
  - **Theoretical background**



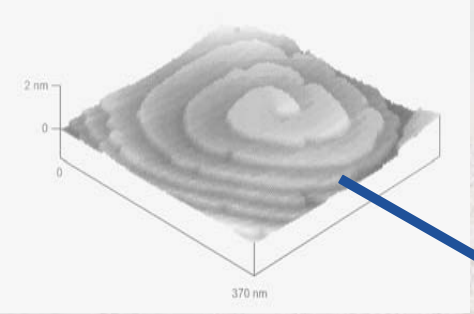
Water formation & transport in the CM

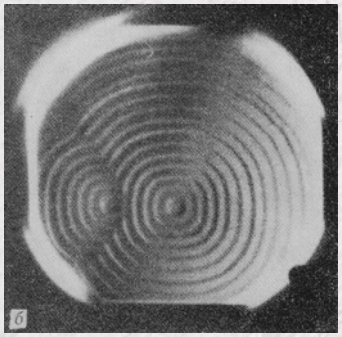
- **Preliminary working hypothesis – analogy with crystal growth**

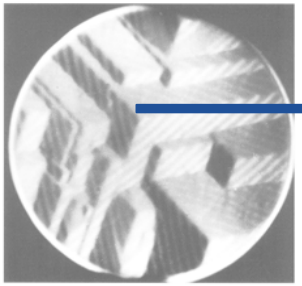
Observability:

- selection of a working point

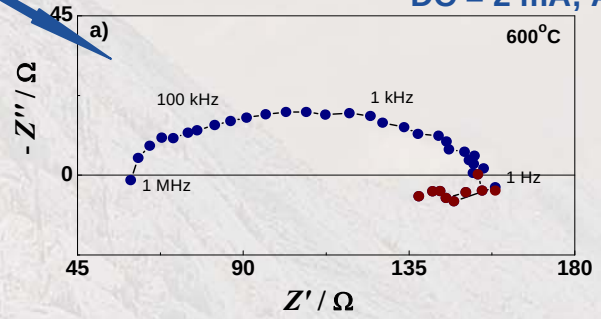
- frequency range

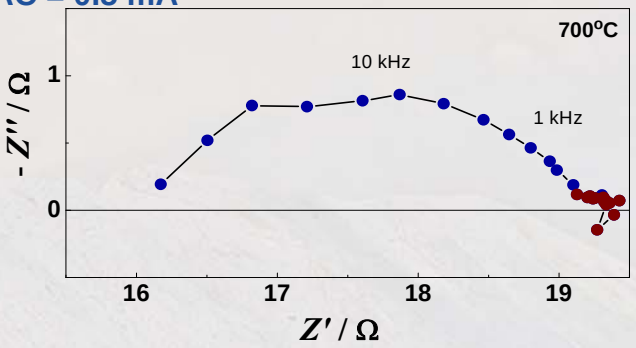


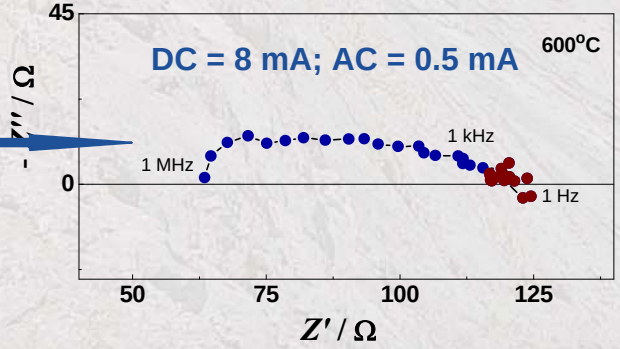


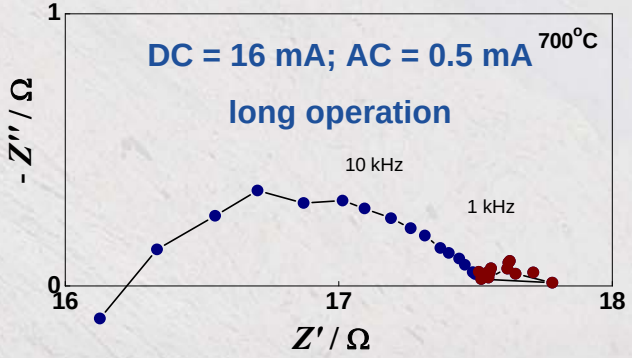


DC = 2 mA; AC = 0.5 mA









ADVANCESAND INNOVATIONS INSOFCS From Materials to Systems

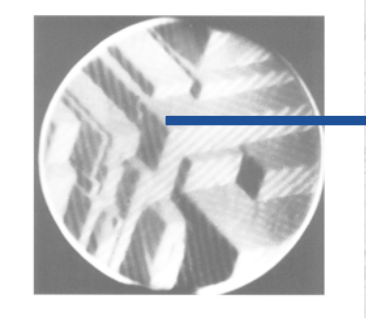
IDEAL Cell

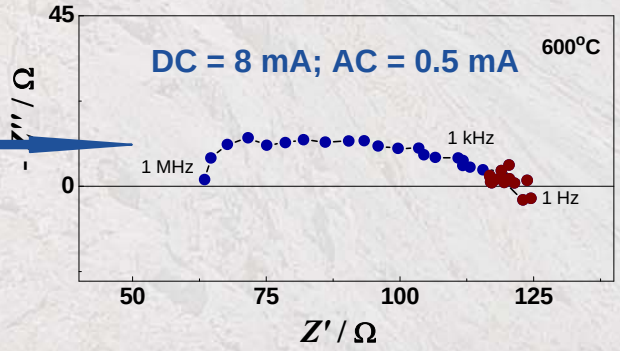
Water formation & transport in the CM

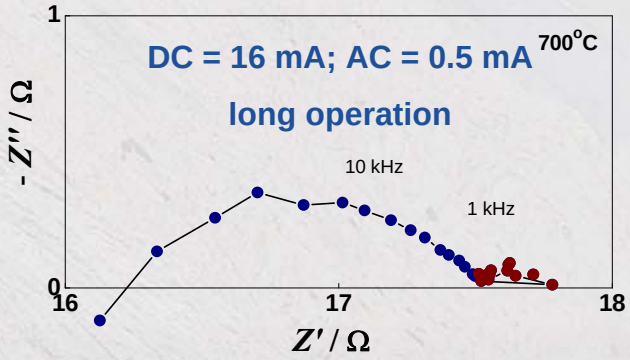
- **Preliminary working hypothesis – analogy with crystal growth**

  Observability:

  - selection of a working point
  - frequency range

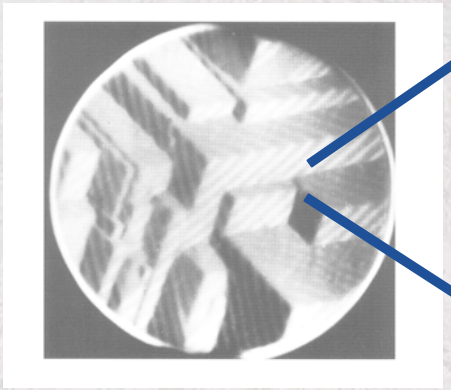


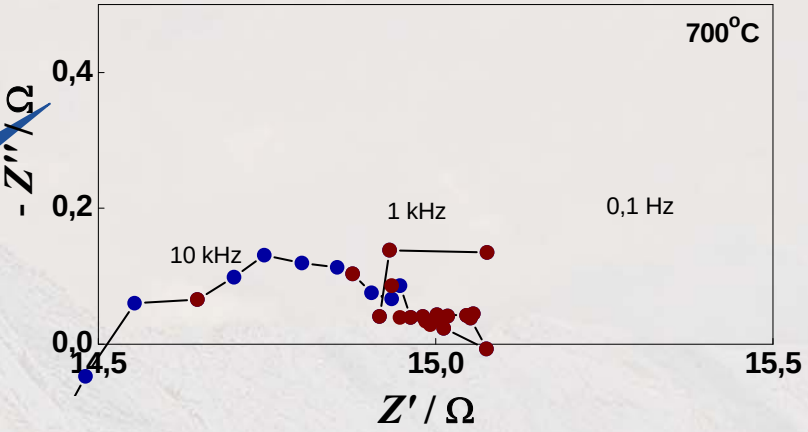


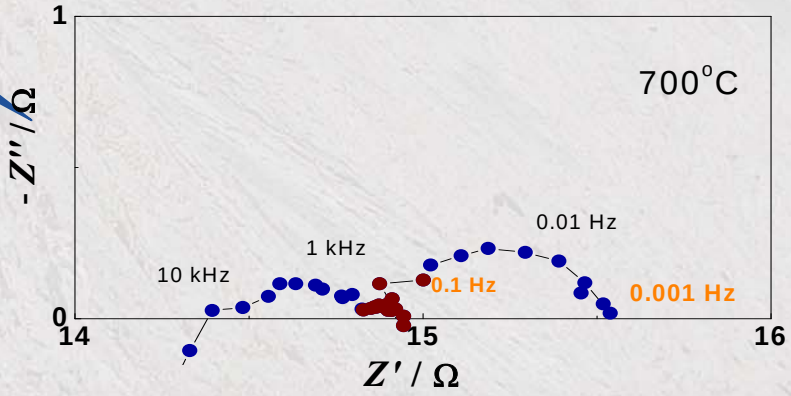


Water formation & transport in the CM

- **Transport through the CM**
- **Observability – increase of the l.f. range (1 MHz – 1 mHz)**

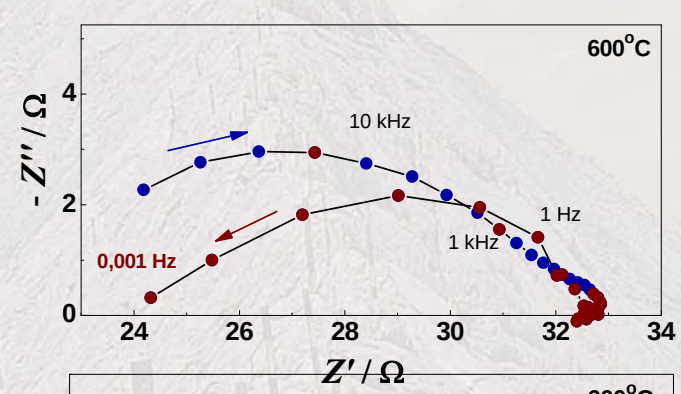


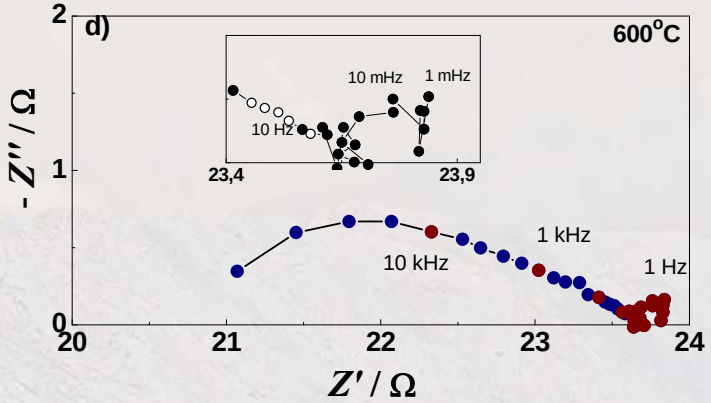


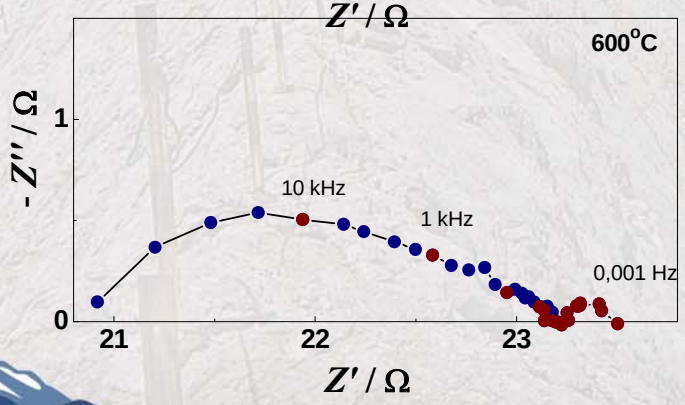


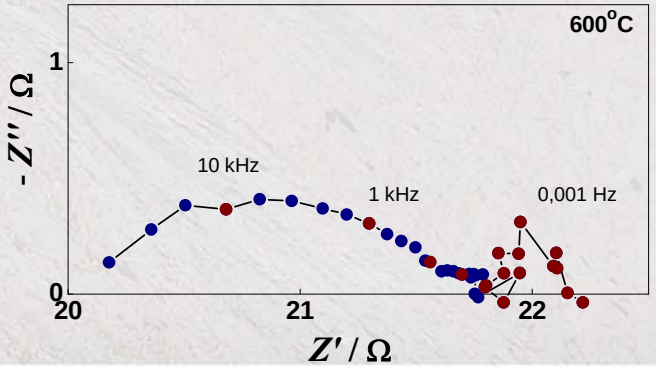
Water formation & transport in the CM

- **Transport through the CM**
- **Observability –** increase of the l.f. range (1 MHz – 1 mHz)
- **Systematic survey :** DC = 16 mA; AC = 0,5 mA









ADVANCESAND INNOVATIONS INSOFCS From Materials to Systems

IDEAL Cell

Water formation & transport in the CM

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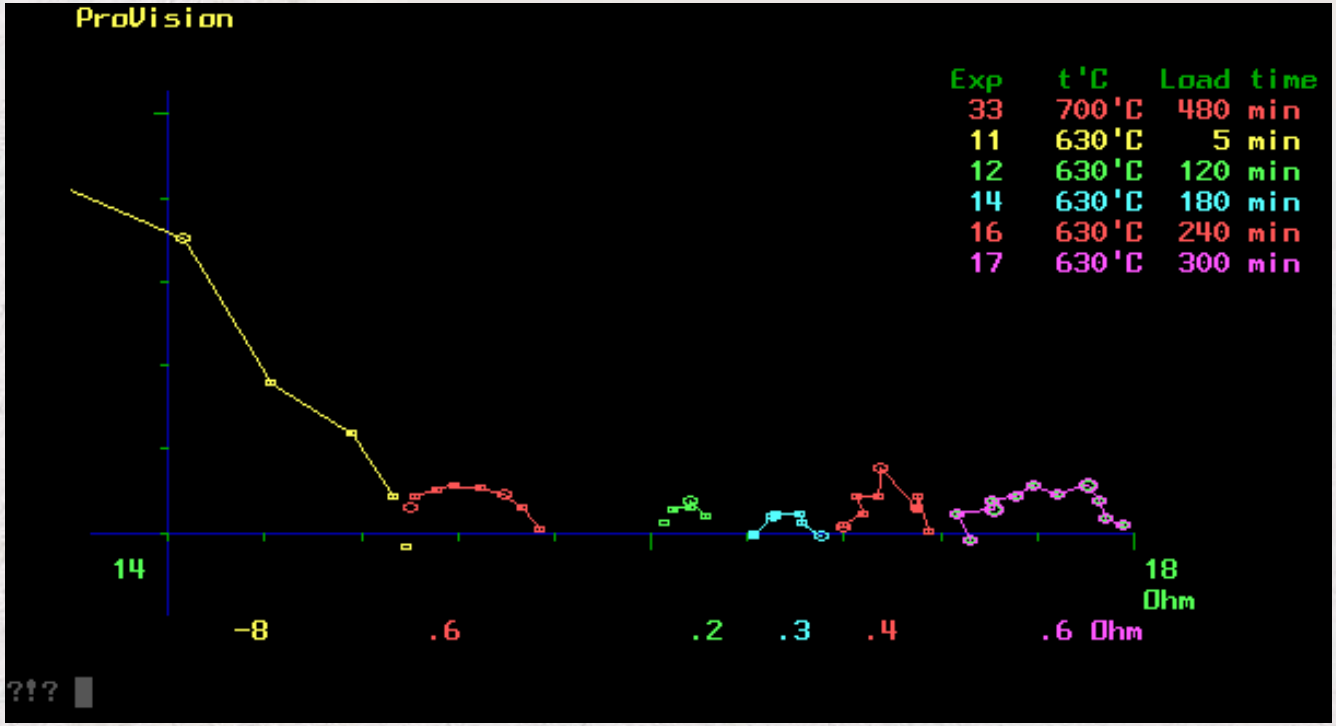
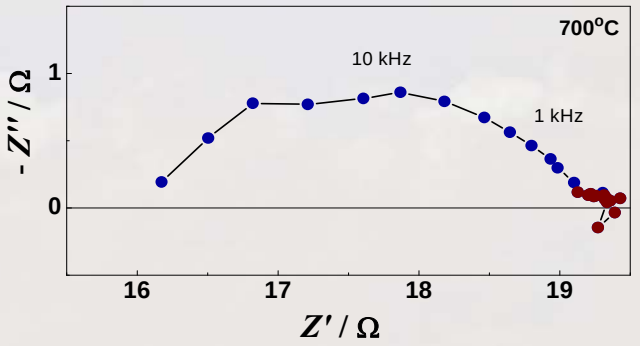
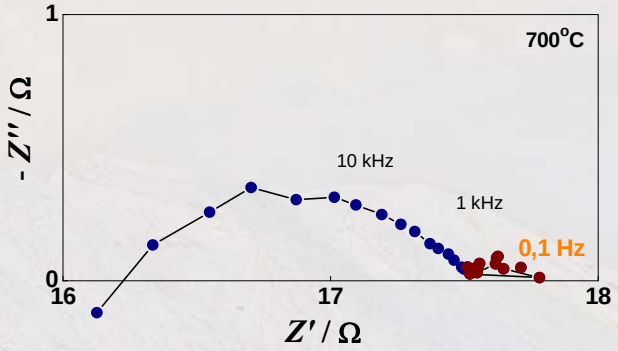


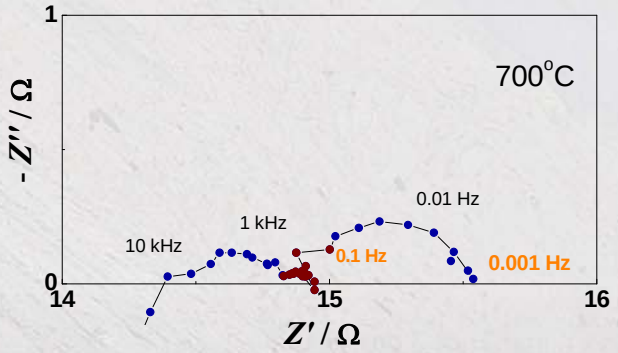
Water formation & transport in the CM

- **Supposed processes**
  - Formation, spontaneous growth of water clusters & overlapping
  - Chemisorption – formation of semi-liquid layer with dipoles orientation (easier incorporation)
  - 3-D growth of the film, penetration and evacuation





- **THE BIGGEST contribution in R comes from the electrolytes (including the CM)**
  - Approach for improvement: cell design (geometry)
    - Thin layers
    - Shorter pathway for the water
    - Le Chatelier



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IDEAL Cell

Acknowledgements:

- **Katarino Workshop 1**
  - Zdravko & Alain
  - Anthony Chesnaud
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- **The Institution that supports our work:**
  - European Community Seventh Framework Program funding under GA 213389 “IDEAL Cell”

Thank you

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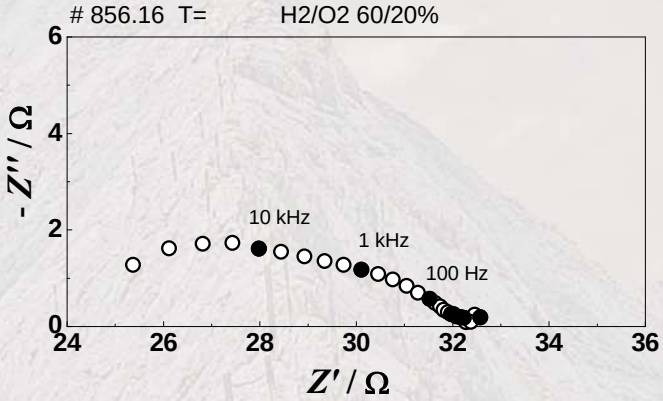
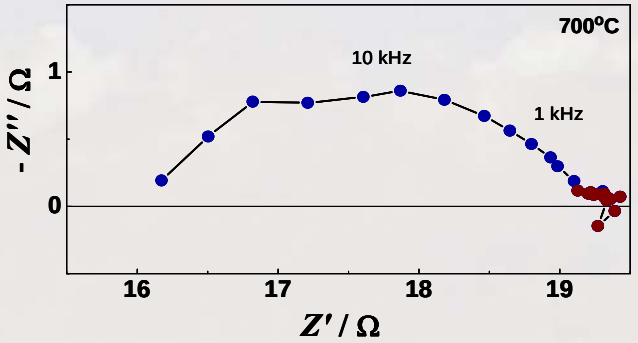
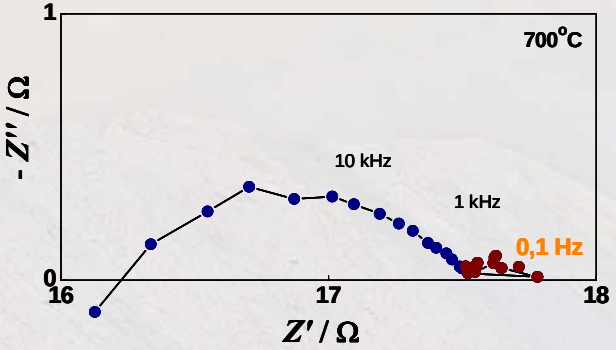
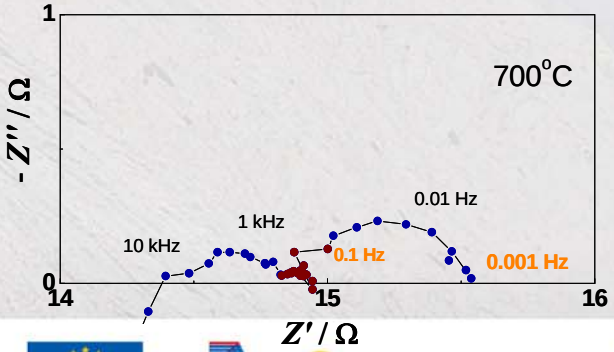
IDEAL Cell









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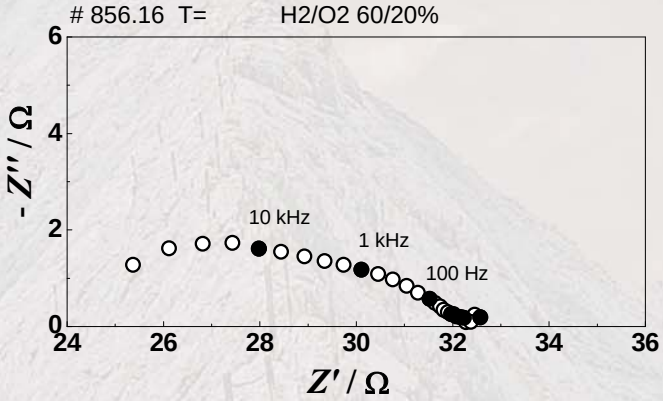
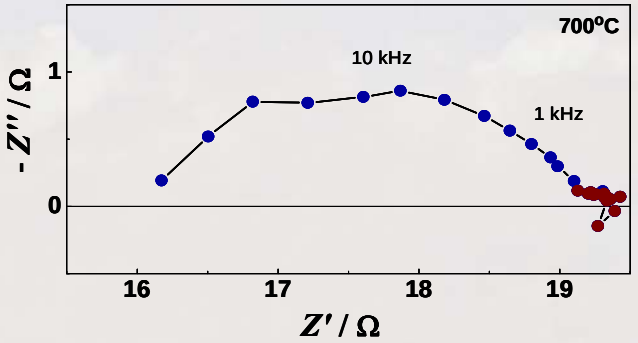
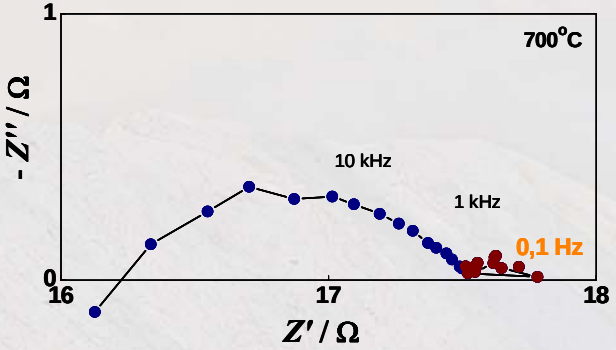
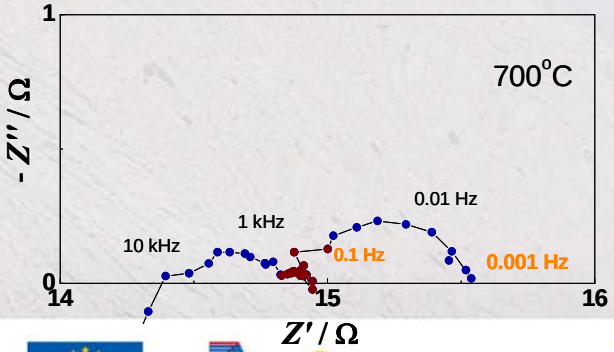
IDEAL Cell









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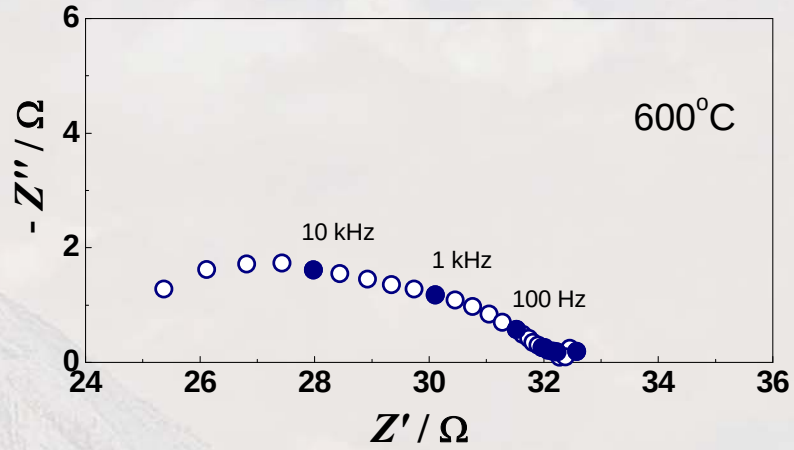
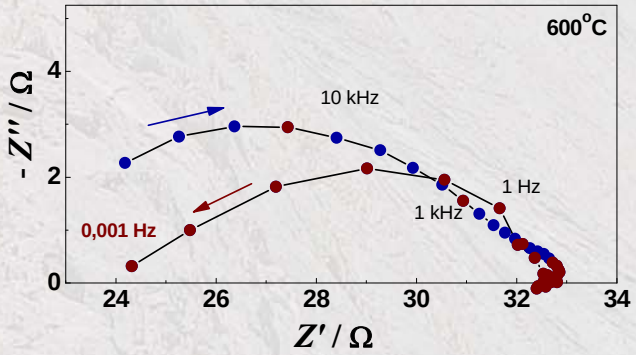
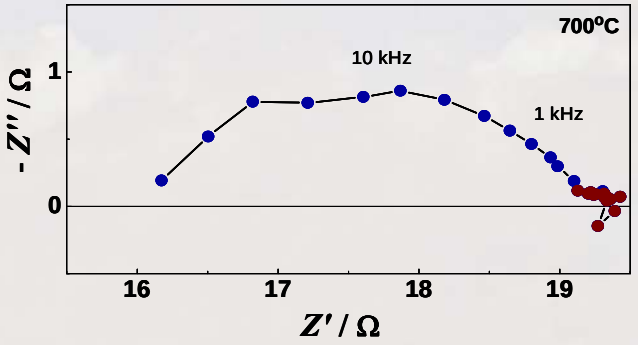
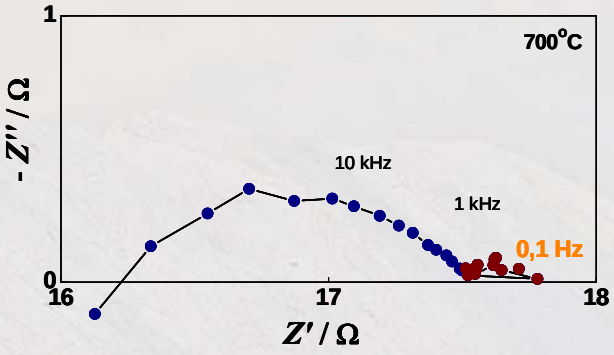
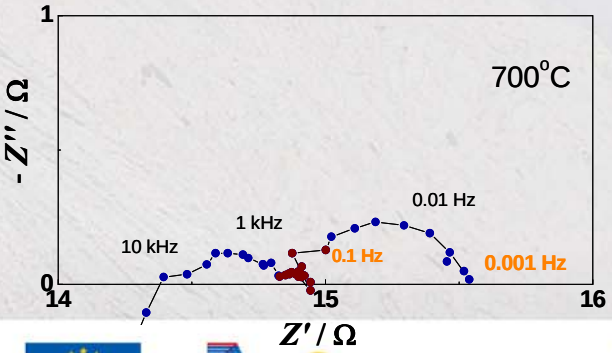
IDEAL Cell


600°C
10 kHz
1 kHz
100 Hz
- Z'' / Ω
Z' / Ω
0
2
4
6
24
26
28
30
32
34
36


600°C
10 kHz
1 Hz
1 kHz
0,001 Hz
- Z'' / Ω
Z' / Ω
0
2
4
24
26
28
30
32
34





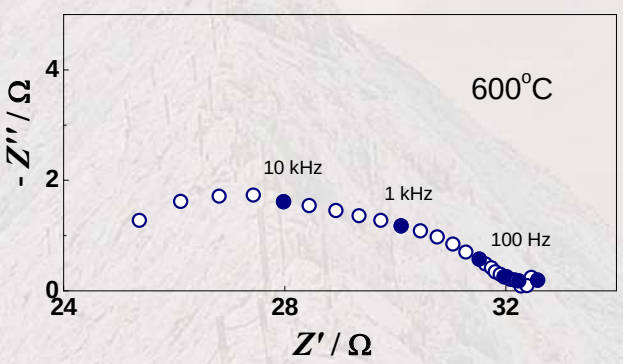


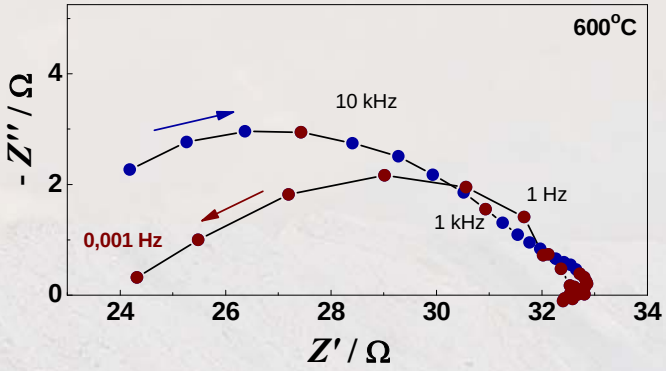
ADVANCESAND INNOVATIONS INSOFCS From Materials to Systems

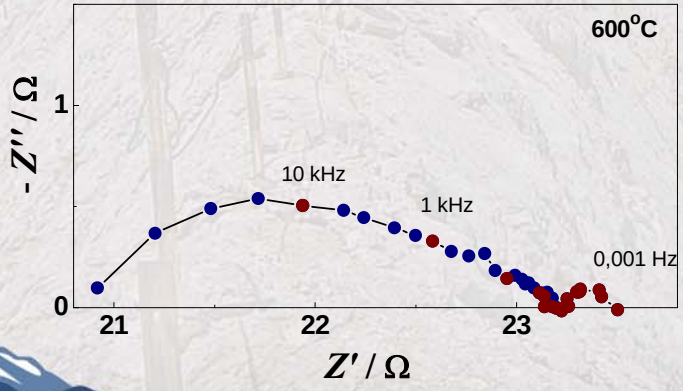
IDEAL Cell

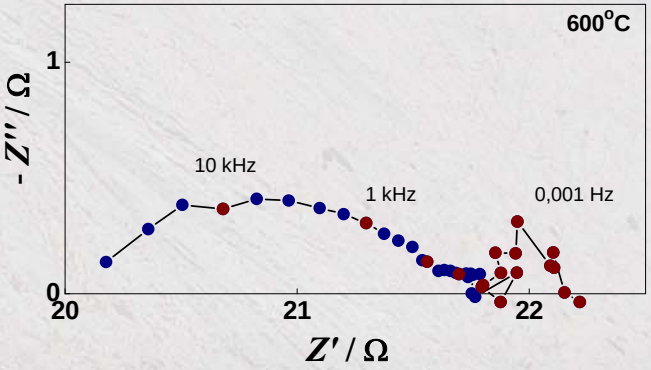
Water formation & transport in the CM

- **Transport through the CM**
- **Observability – increase of the l.f. range** (1 MHz – 1 mHz)
- **Systematic survey :** DC = 16 mA; AC = 0,5 mA









ADVANCESAND INNOVATIONS INSOFCS From Materials to Systems

IDEAL Cell