Monitoring thermal properties of a composite material used in thermochemical heat storage

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Context and objectives

Conductivity measurement

- in dry conditions
- in wet conditions

Results

- comparison dry/wet conditions
- influence of moisture

Discussion

Conclusions

Context and objectives

SoTherCo project

Solar heating for residential buildings:

- Inter-seasonal storage of solar heat using salts and a reversible reaction
- Thermochemical storage

Funding: European Commission, FP7

Context and objectives

Low grade heat storage

Thermochemical storage offers high energy density

$$S.xH_2O \rightleftharpoons S.(x-y)H_2O + yH_2O$$

(S = salt of divalent metal + sulfate, nitrate or halide)

Major structural changes during use phase

S usually entrapped in a porous matrix like silicagel or activated carbon to stabilize the macroscopic structure:

- Reproducibility of storage cycles
- Heat and water transfer

Context and objectives

Need of numerical data for heat transport models

- Thermal conductivity λ(T,%) for salt-matrix system with voids between the grains
- Influence of the state of hydration of the salt

…for a proper automation of theses systems

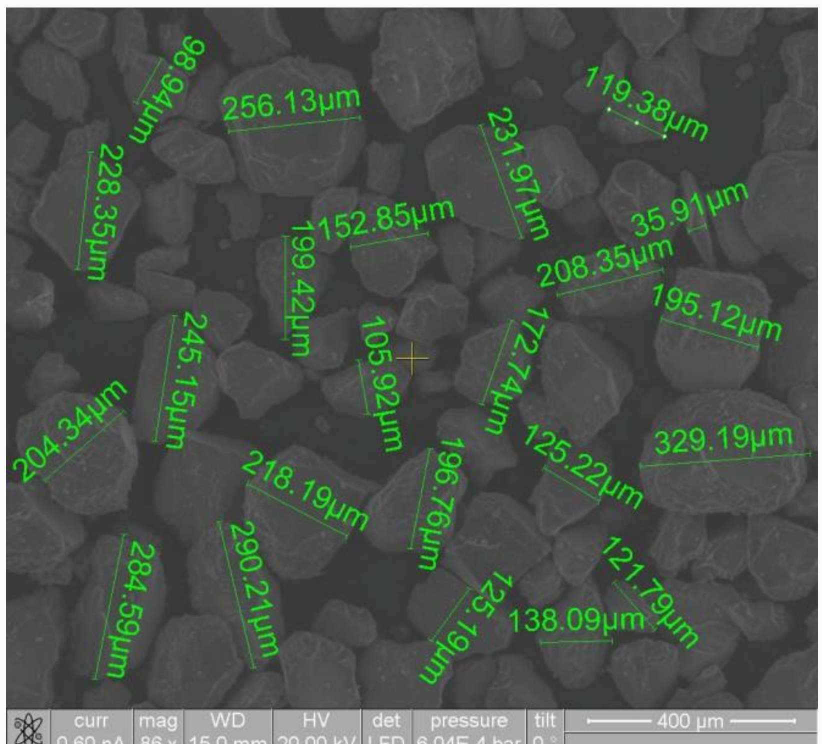
Correlation with mass change?

Is mass transfer more limiting than heat transfer?

Conductivity measurements

Studied material:

- Synthesized at UMONS
- Grains of ~200 µm diameter of composite (salt, inorganic matrix)

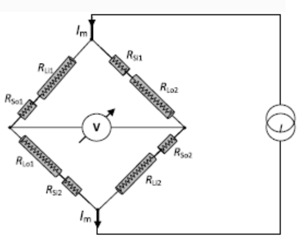


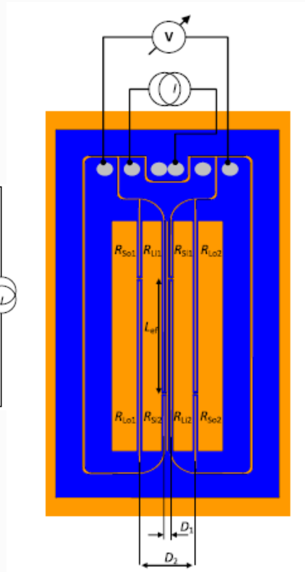
Conductivity measurements

Measurements in dry conditions:

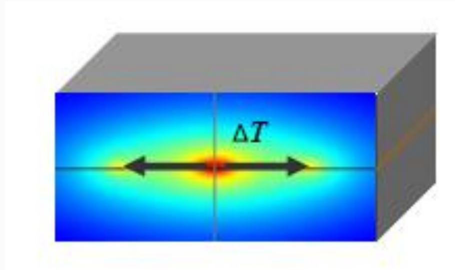
- Preconditioning of composite (dry state)
- Transient Hot Bridge Method (THB)
  - Theory: from transient Thermal Conductivity Phenomenology
  - Measurement: Geometry (→THB sensor), Parameters (→ thermoelectric), THB response

$$\lambda = \frac{\alpha\cdot}{4\cdot\pi\cdot L_{eff}}\cdot\frac{\ln(g)}{d(U_s)_{max}}\cdot\left(\frac{I_m}{2}\right)^2\cdot m_{max} = f_g\cdot f_{el}\cdot\frac{\ln(g).m_{max}}{d(U_S)}$$

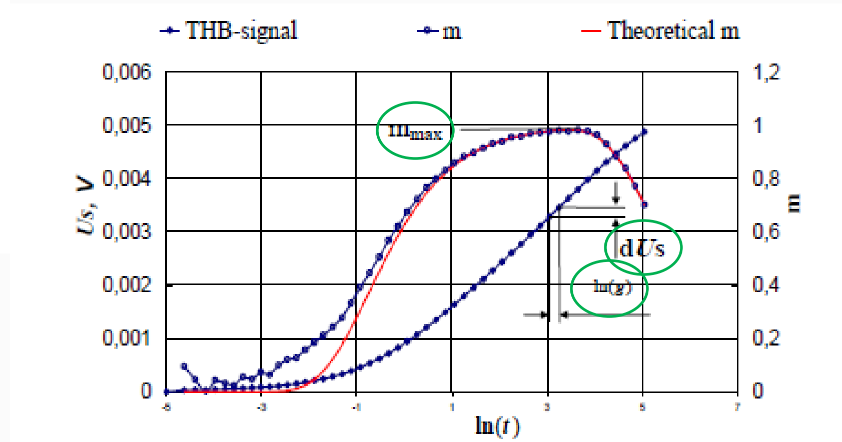




TBH Sensor



Temperature distribution in a sample



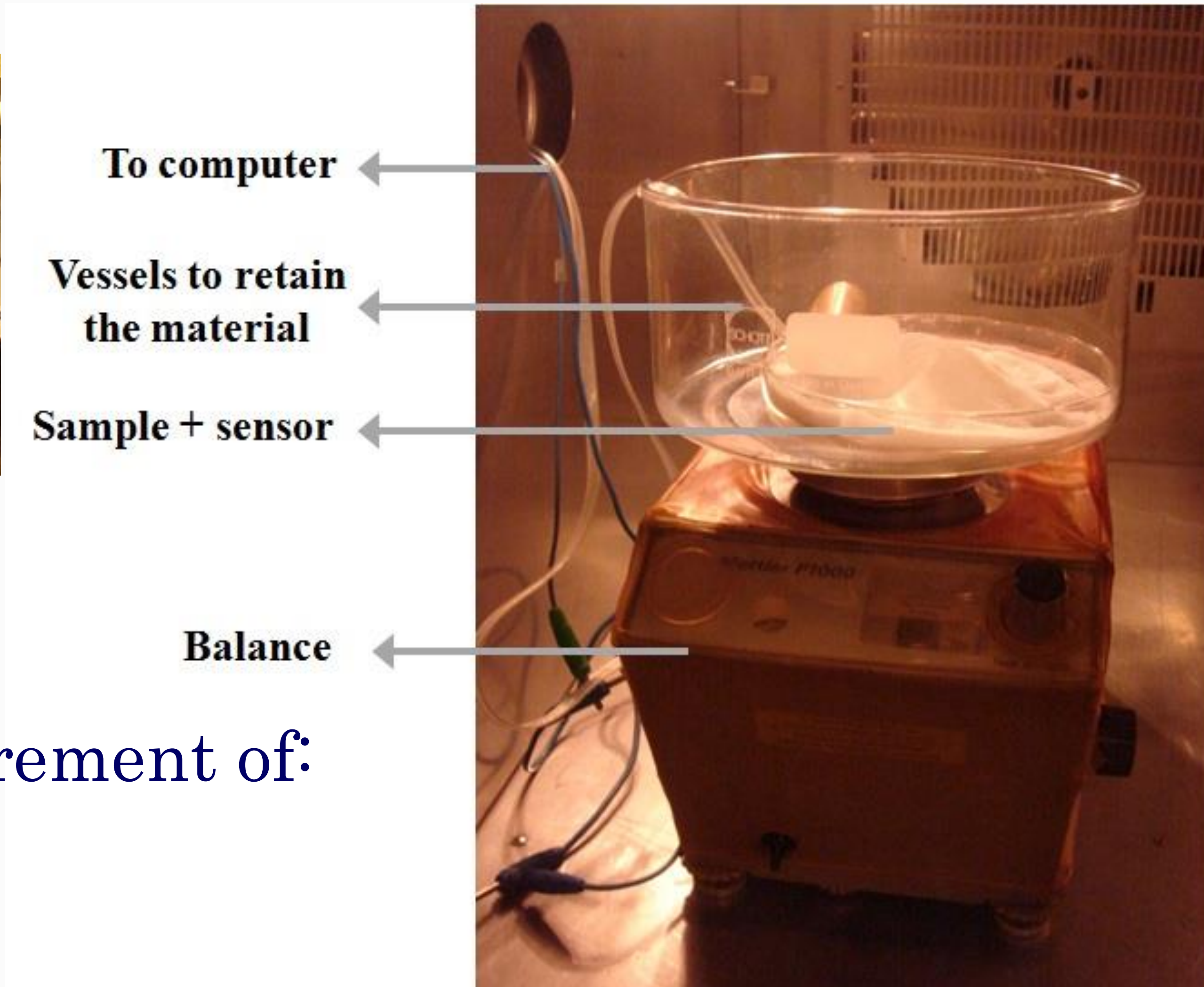
measured TBH response, used to examine λ /W/mK, and a /m²/s

Conductivity measurements

Measurements under controlled atmosphere:

VTRK climate chamber

(Heraeus Vötsh)



In situ measurement of:

- λ(T,%)
- Mass

Conductivity measurements

Measurements under controlled atmosphere:

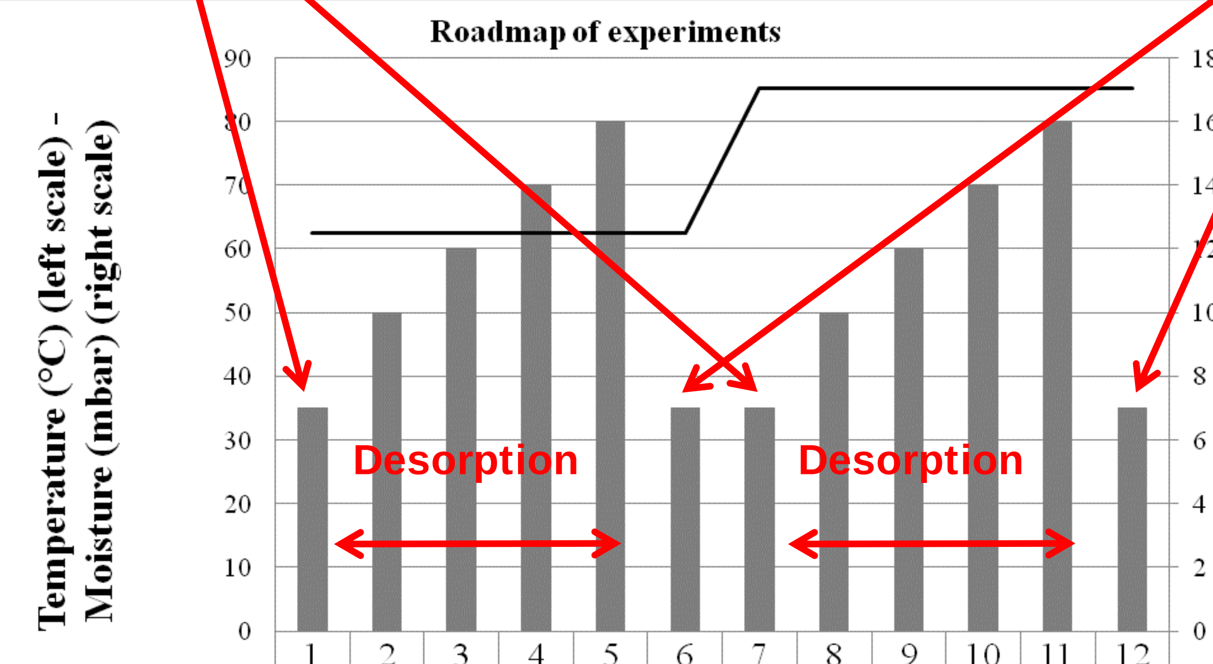
Initial step: preconditioning: hydration

Frequent stirring (slow step)

Final step: rehydration

Consistency check

Frequent stirring (slow step)

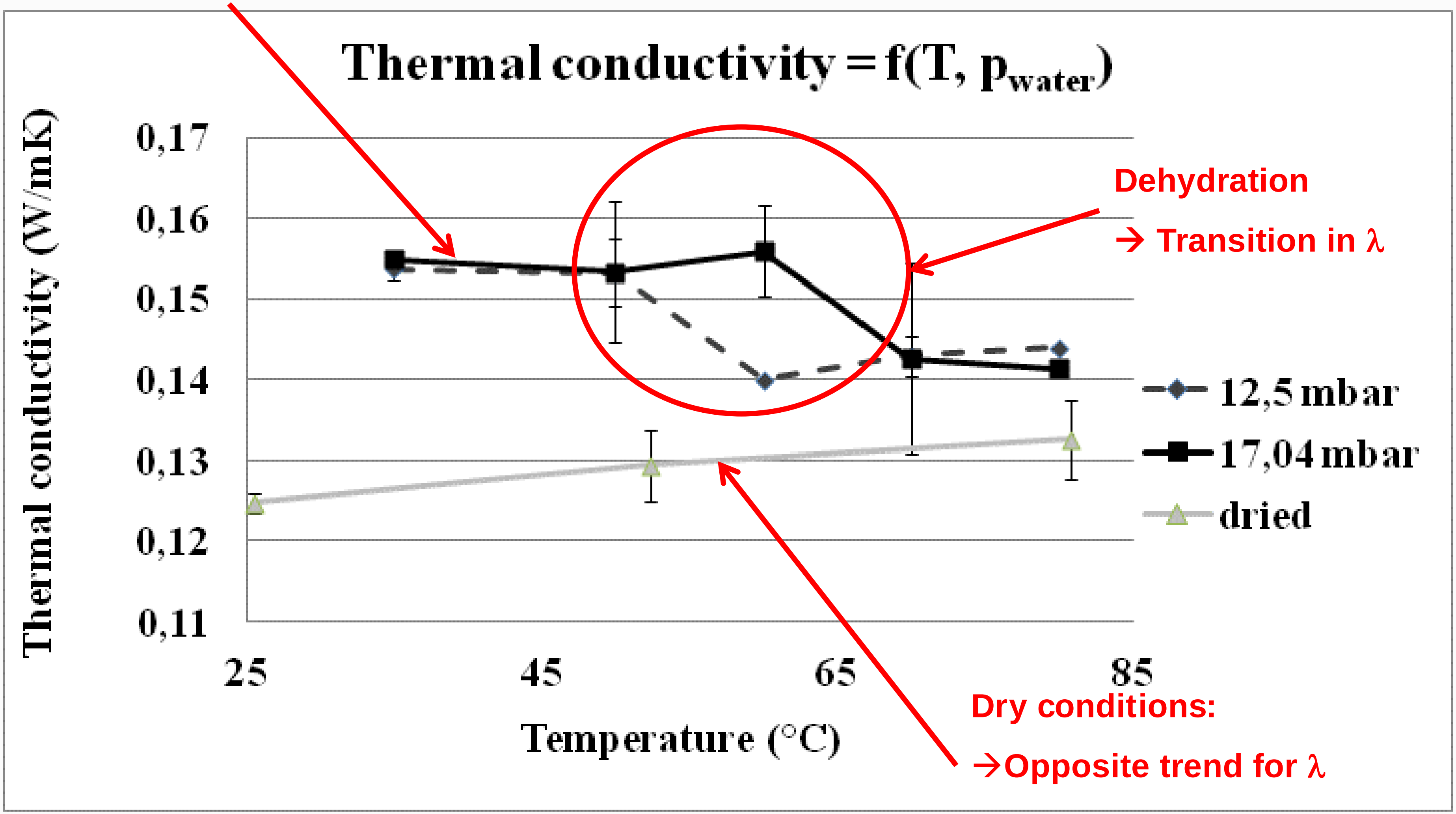


	1	2	3	4	5	6	7	8	9	10	11	12
T (°C)	35	50	60	70	80	35	35	50	60	70	80	35
Moisture (mbar)	12,5	12,5	12,5	12,5	12,5	12,5	17	17	17	17	17	17

Results

Comparison dry/wet (after transients)

λ higher in hydrated state



Dehydration

→ Transition in λ

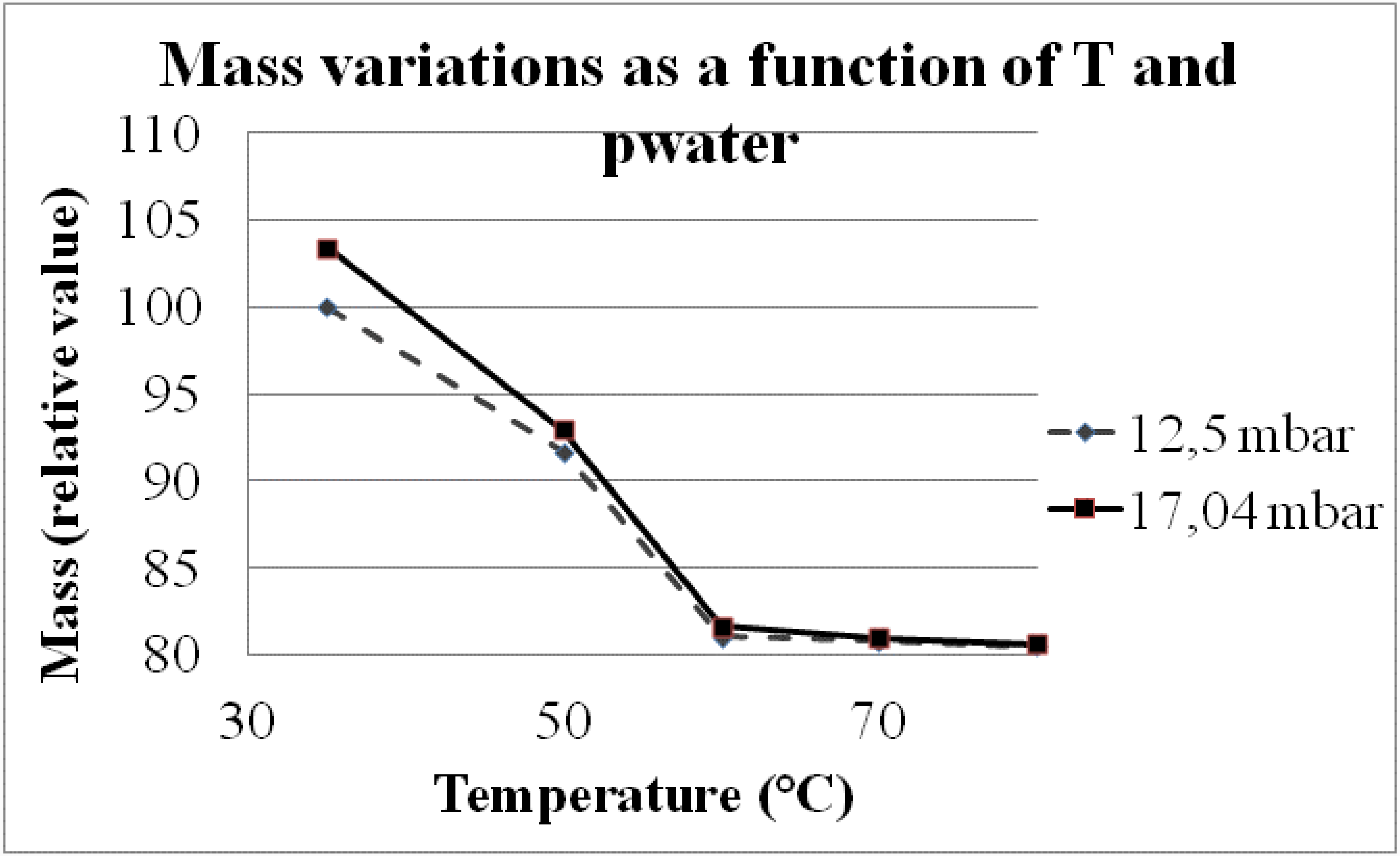
Dry conditions:

→Opposite trend for λ

→ Lower λ

Results

Wet conditions (after transients):



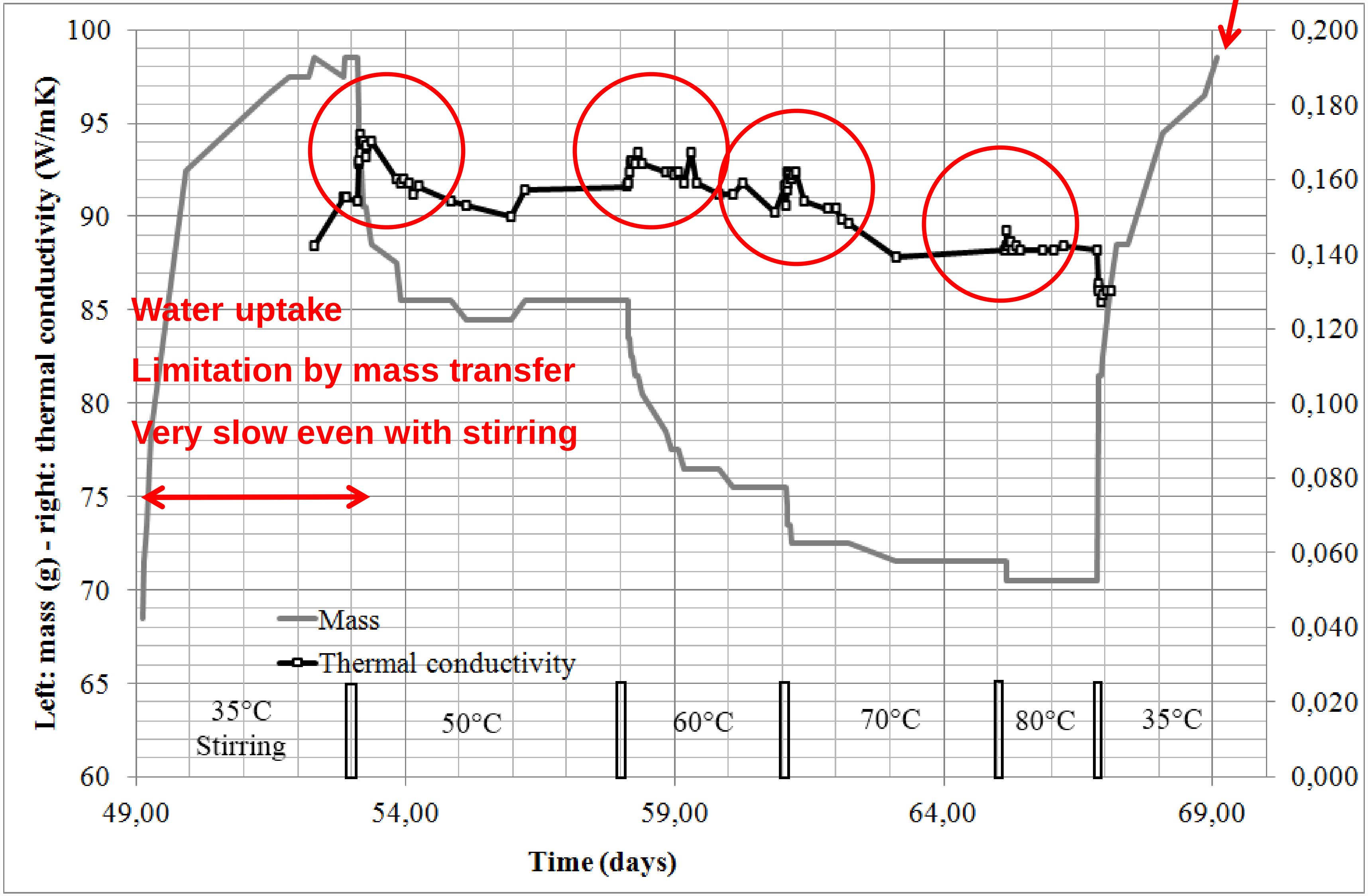
ULB

Results

SOTHERCO

Wet atmosphere: m and λ transients

Reversibility

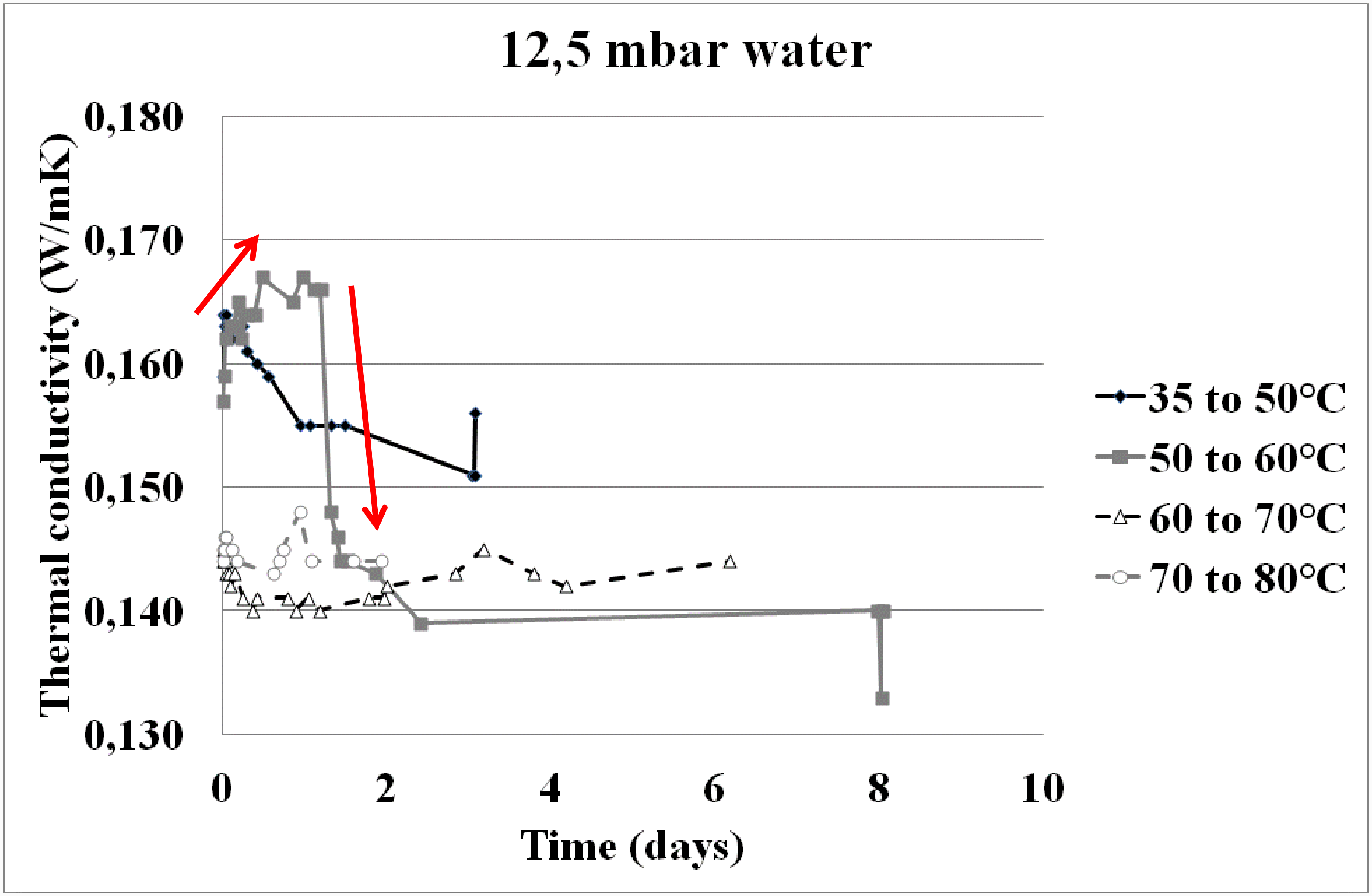


ULB

Results

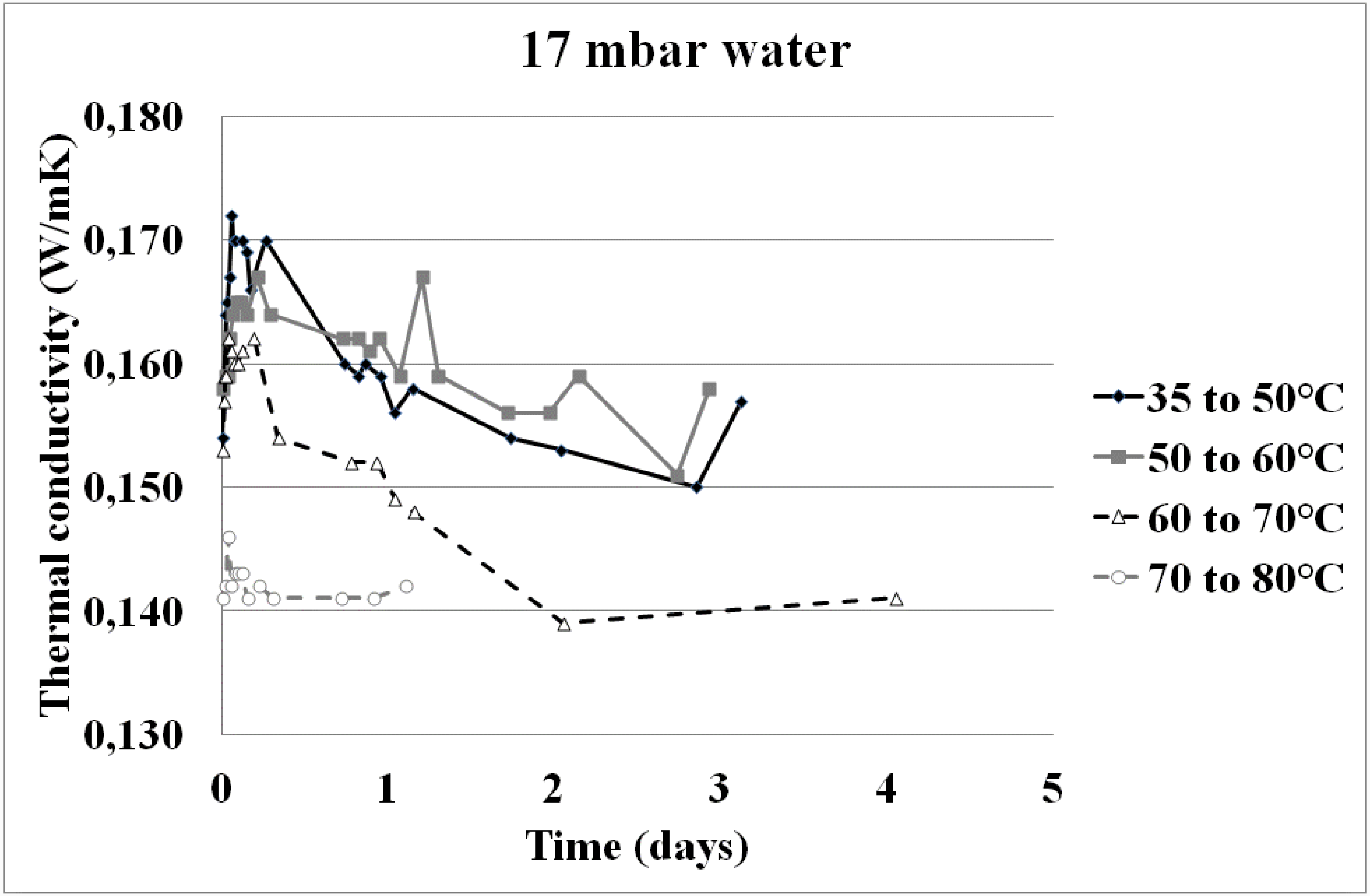
SOTHERCO

Wet atmosphere: m and λ transients



Results

Wet atmosphere: m and λ transients



Discussion

Loss of molecules of H_2O when:

- T increases
- p_{water} decreases

Transition mostly occurs at 35-60°C

Dry material: λ increases with T: typical for ceramics

Wet conditions: λ decreases with T:

- H_2O desorption → more voids
- Different hydrates have different intrinsic λ
- Change in convection processes

Discussion

At 80°C: very little difference between dry and wet experiences: same proportion of H_2O in the salt?

λ during transients: to be interpreted carefully:

- THB method assumes no heat source or sink
- Assumption violated because of water desorption
- % moisture measured by the chamber not representative of % moisture inside the bed

For adapted solutions, see for instance:

Koci J. et al., Proc.Thermophysics, Podkylava, 2013, 55-71

Discussion

Need of modelling work:

- Existing models focus on the amount of water inside the pores
- Convection around grains neglected
- Conduction at contact points between grains

Conclusions

Experience to assess $\lambda(T,\%)$

Slight increase of $\lambda(T)$ in dry composite

Pronounced decrease of $\lambda(T)$ in wet composite at dehydration

$\lambda_{wet}(T) > \lambda_{dry}(T)$

Water release generates complex transients

$0.12 < \lambda < 0.17$ $W.m^{-1}.K^{-1}$

Mass transfer at adsorption is a more important limitation for real life application

Conclusions

Perspectives:

- Assessing convection phenomena between the grains
- Assessing conduction in the presence of a endo/exothermic reaction
- Mass transfer limitation to be solved in real-life conditions

Thank you for your attention

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