ASSOCIATION
des CHIMISTES, INGENIEURS et CADRES
des INDUSTRIES AGRICOLES et ALIMENTAIRES

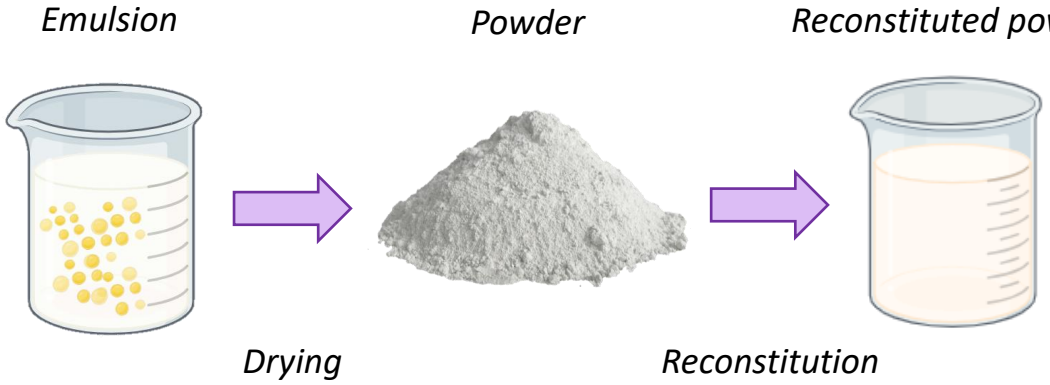
THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

LIBio
Laboratoire d'Ingénierie des Biomolécules

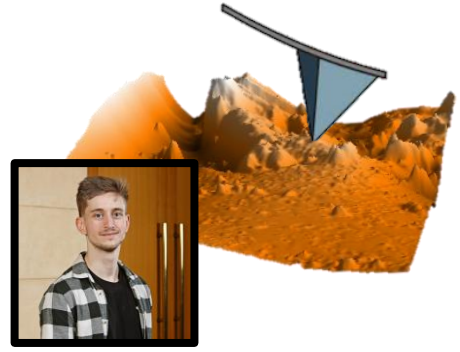
LORRAINE Université d'Excellence

UNIVERSITÉ DE LORRAINE | SIReNa

PRESENTATION PRIX MARCEL LONCIN
19 Mai 2026



Régis BADIN
Post-Doctoral Researcher



regis.badin@univ-lorraine.fr

19.05.2026

Raw material

Bhandari *et al.*, (2013)
Chen & Patel, (2008)
Islam & Langrish (2013)

Spray drying

Freeze drying

Drying processes

Grinding

Attrition

Crushing

Size reduction processes

Baudelaire *et al.*, (2013)
Cuq *et al.*, (2013)
Ratti *et al.*, (2013)

Food powders

Cocoa

Carbohydrates

Plant-based

Coffee

Flour

Spices

Semolina

Milk

Storage

Transport

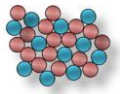
Bhandari et al., (2013)
Schuck, (2013)
Hedegaard & Skibsted, (2013)

Handling

Ease of use

Reconstitution

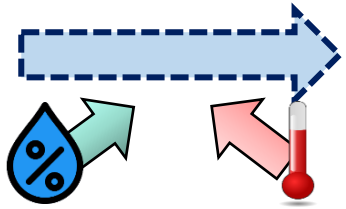
Ronkart *et al.*, (2009); Roos, (2006); Fitzpatrick *et al., (2007*)



Glass transition temperature (Tg)

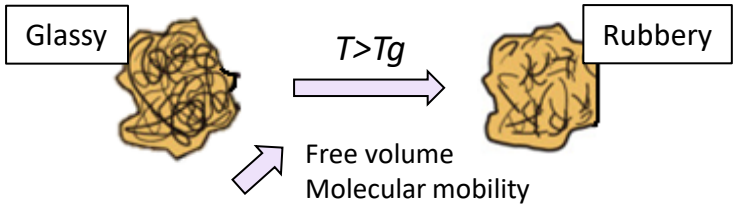
Glassy state → **Rubbery state**

T < Tg ***T > Tg***



Environmental variations

Plasticizing effect of water



(Chen et al., 2022)

Effect of M_w

- Relationship Molecular weight - Tg

$$T_{g,s} = T_{g,s}^{\infty} - \frac{a_{FF}}{M}$$

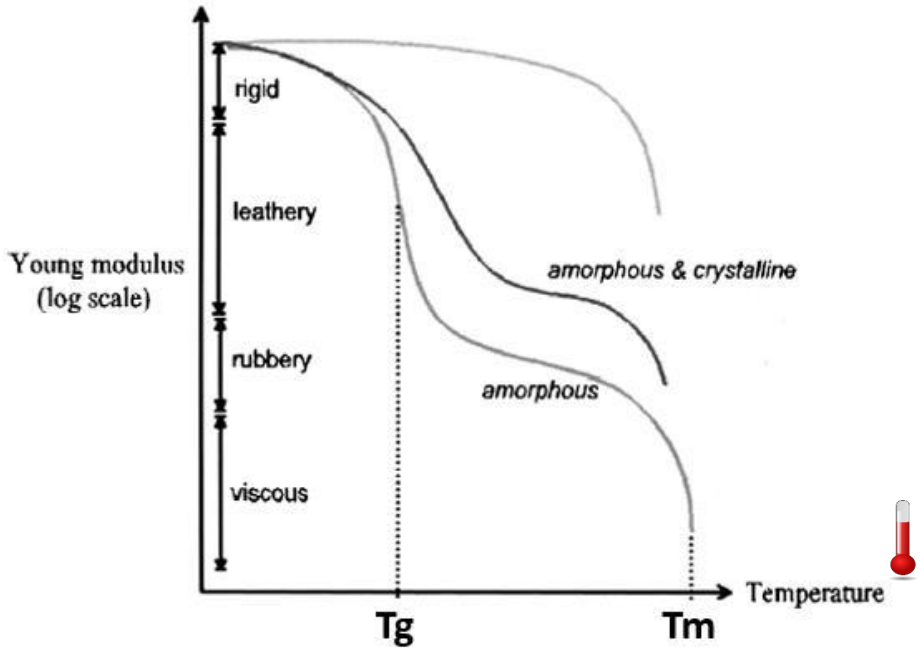
Flory-Fox equation

(Fox & Flory, 1950; Siemons et al., 2022)

High M_w → **Low M_w**

Tg

Palzer, (2007)



Young modulus evolution with temperature

MACROSCALE

PARTICLE

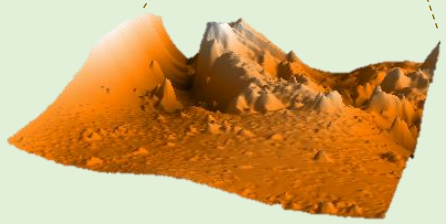
SURFACE

Glassy state

Reconstitution
Fitzpatrick *et al.*, (2017)
Fournaise *et al.*, (2020)

Flowability
Sharma *et al.*, (2012)
Juarez-Enriquez *et al.*, (2022)

Individual particles
"Free-flowing"



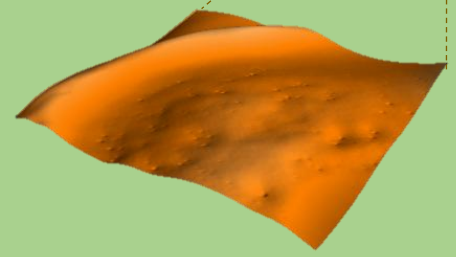
Rubbery state

Reconstitution
Gaudel *et al.*, (2022)
Ong *et al.*, (2017)

Flowability
Dupas *et al.*, (2023)

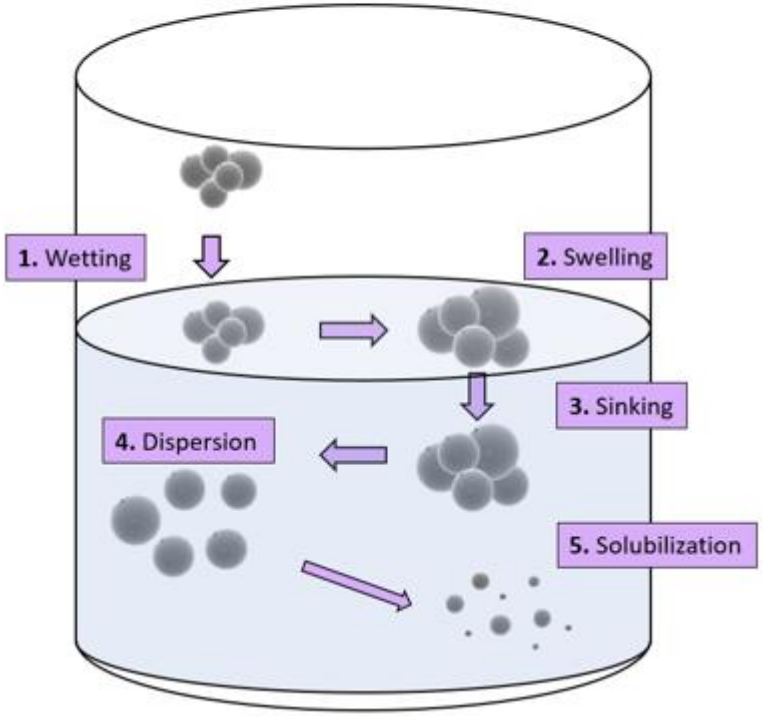
Caked particles
"Cohesive"

?



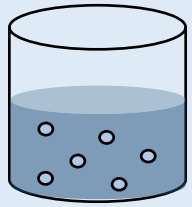
4

Reconstitution steps of a food powder

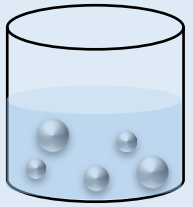


Crowley *et al.*, (2016)
Forny *et al.*, (2011)
Fournaise *et al.*, (2021)

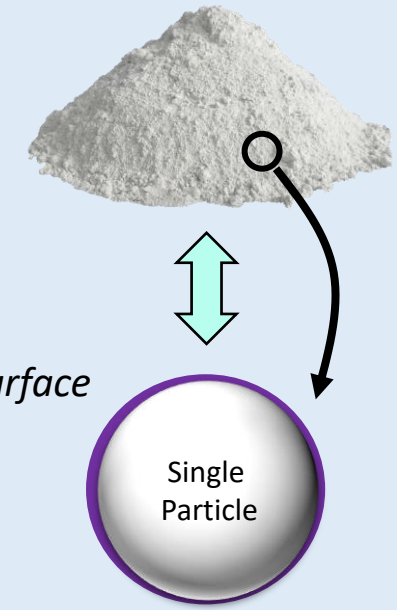
Reconstitution properties

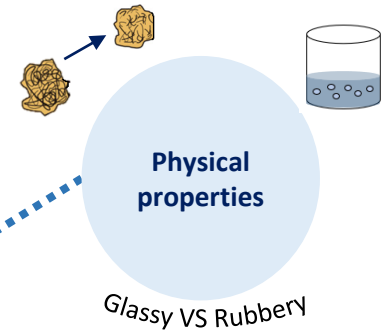


Good reconstitution properties



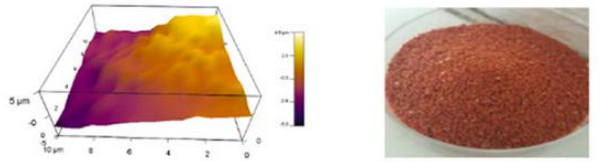
Poor reconstitution properties





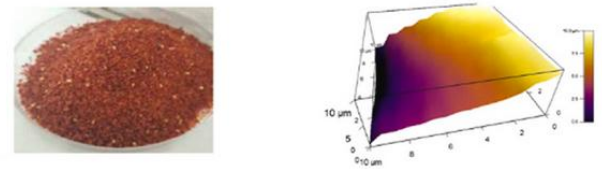
Reconstitution shear rate dependent (Glassy; T<Tg)

$a_w \sim 0$



Reconstitution shear rate independent (Rubbery; T>Tg)

$a_w \sim 0.35$



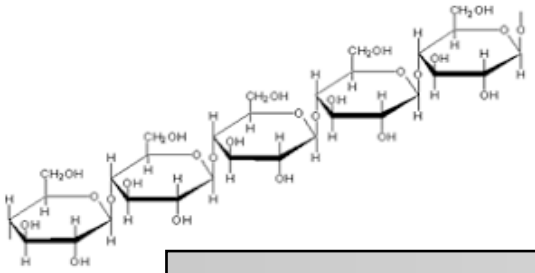
Gaudel *et al.*, (2022)

Maltodextrins

Sports products

Ice creams and candies

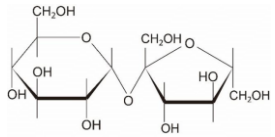
Food powders systems



DE 4-7

DE 12

DE 16.5-19.5



Dextrose Equivalent (DE) value

Low DE

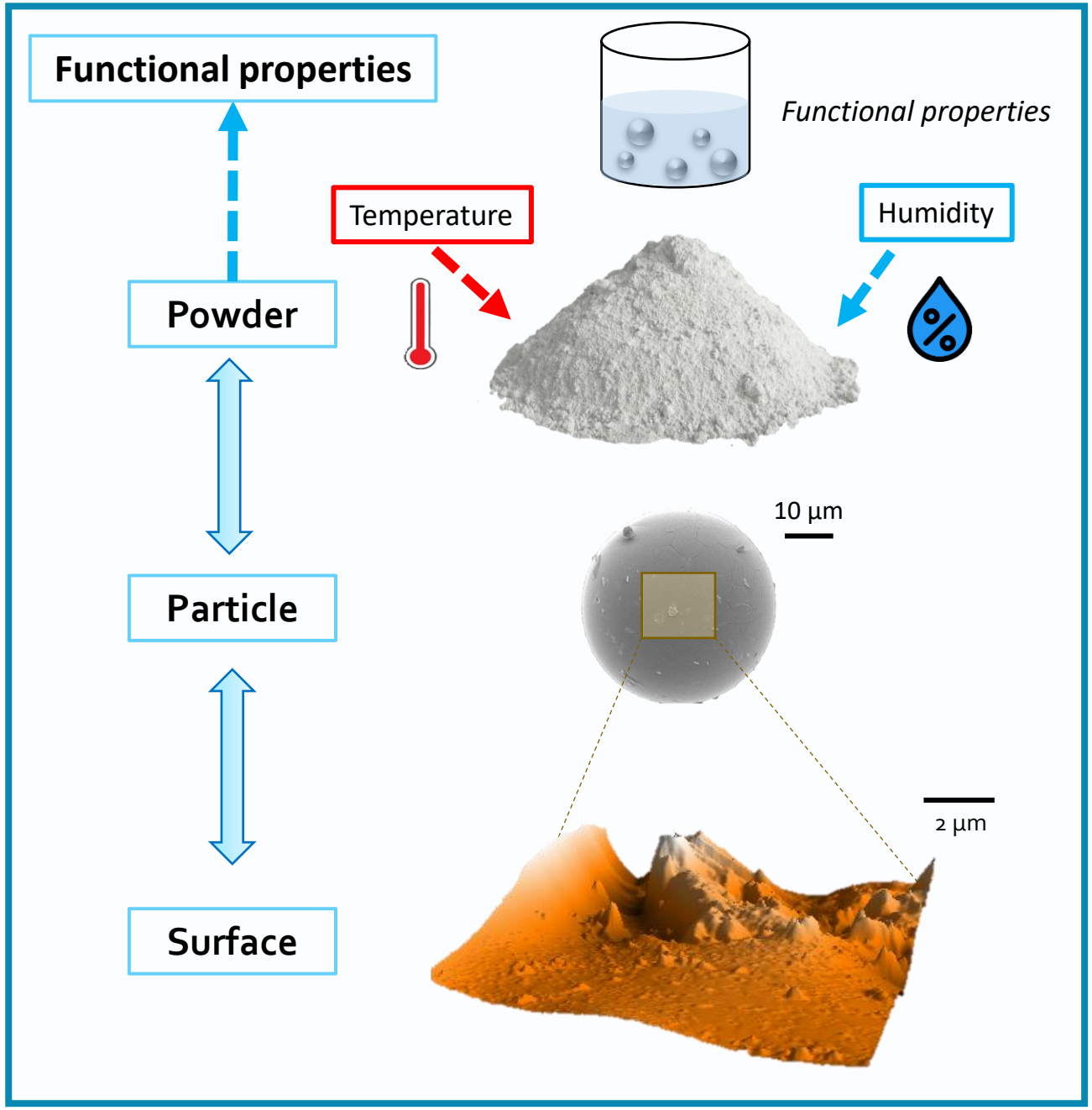
Intermediate DE

High DE

> DE 20 (syrups)

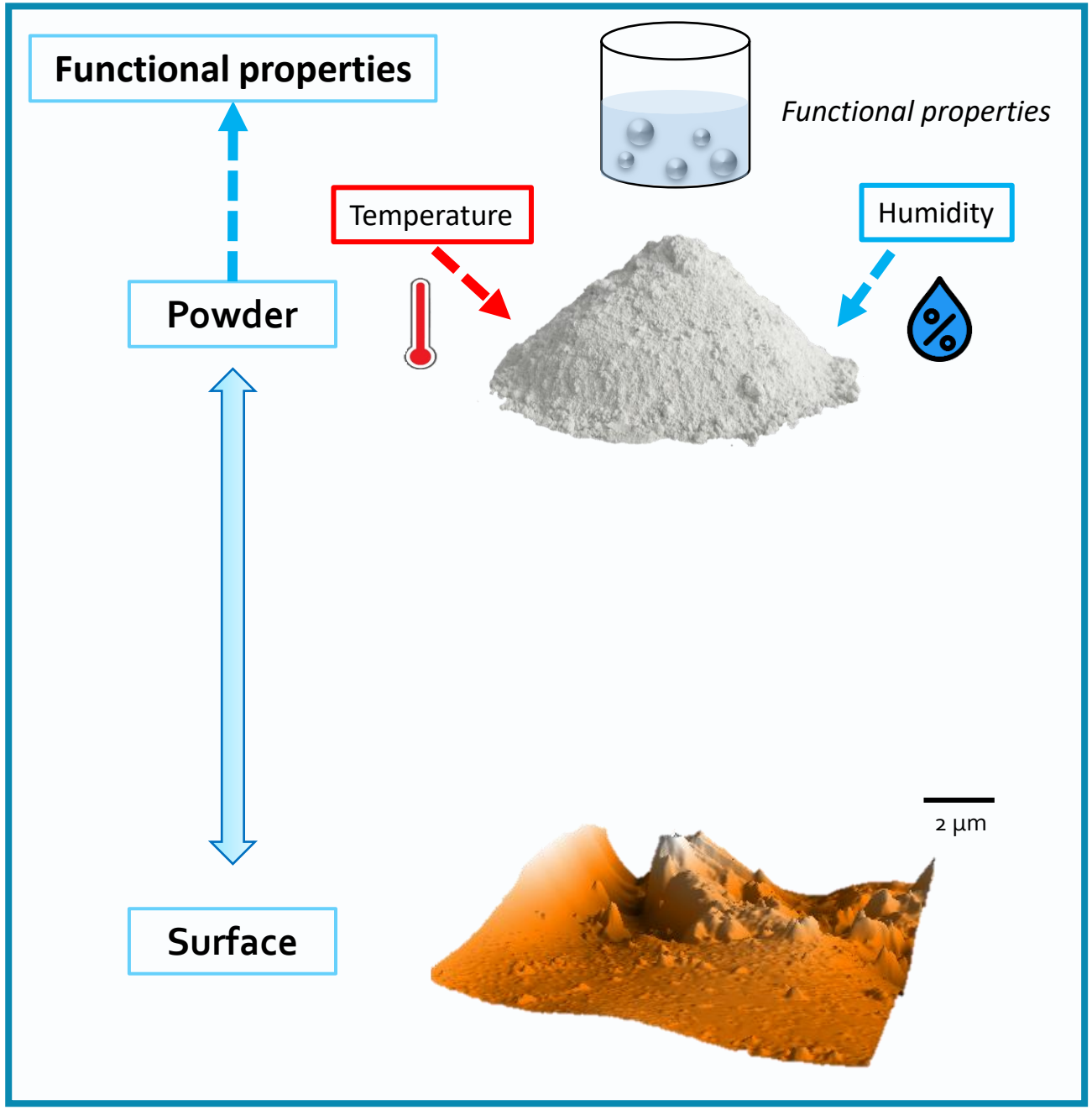
Polymer lenght chain

MULTISCALE STUDY OF GLASS TRANSITION IMPACTS ON MALTODEXTRIN POWDERS PROPERTIES AND FUNCTIONALITIES



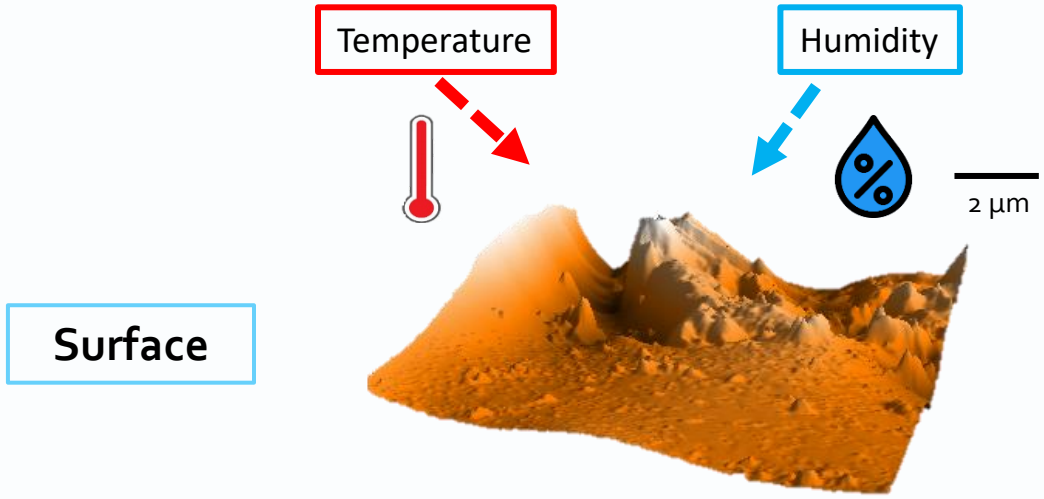
MULTISCALE STUDY OF GLASS TRANSITION IMPACTS ON MALTODEXTRIN POWDERS PROPERTIES AND FUNCTIONALITIES

What are the links between particle surface features and powder reconstitution, at the interplay of glass transition ?



MULTISCALE STUDY OF GLASS TRANSITION IMPACTS ON MALTODEXTRIN POWDERS PROPERTIES AND FUNCTIONALITIES

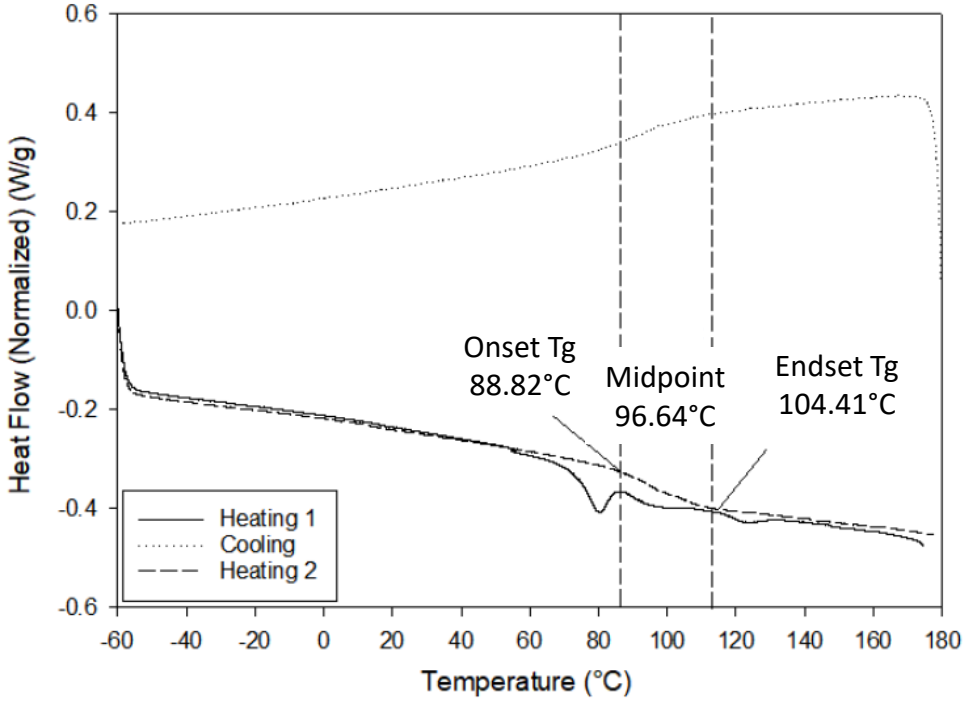
How does single particle surface properties evolve with environmental variations (RH, T°C) and glass transition ?



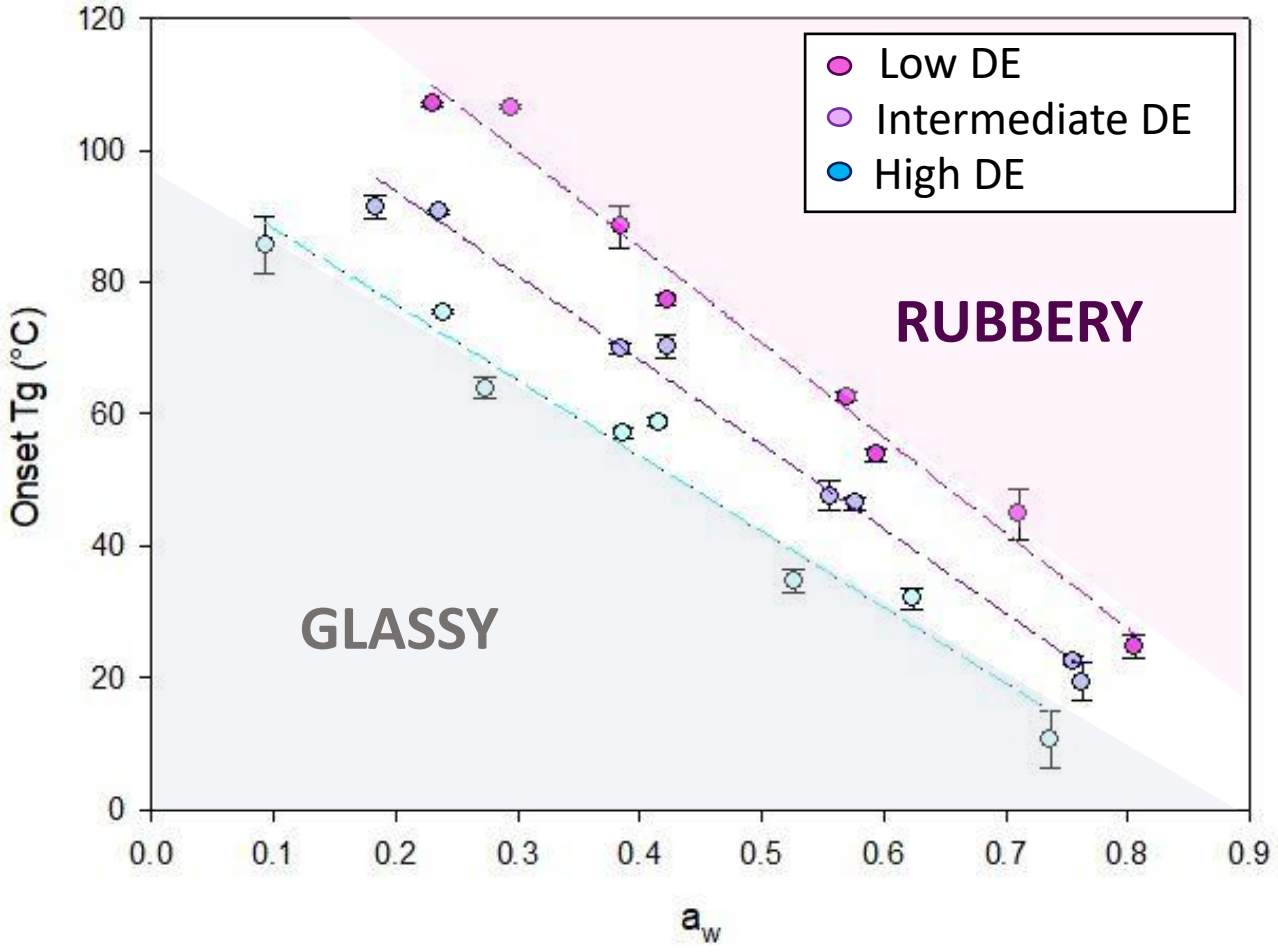
Macroscale

Differential Scanning Calorimetry (DSC)

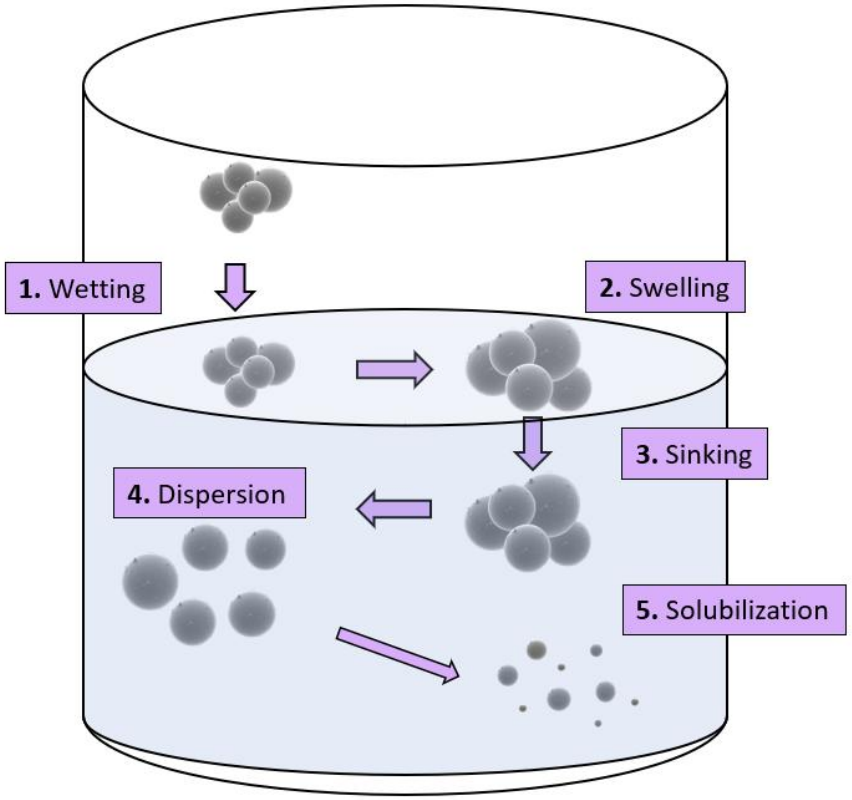
Glass transition temperature (Tg) determination



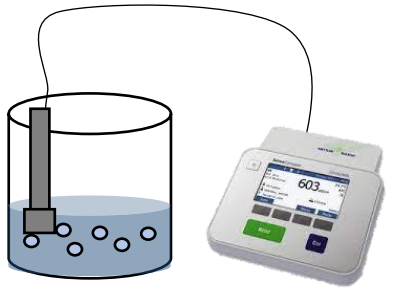
EXPERIMENTAL CONDITIONS ?



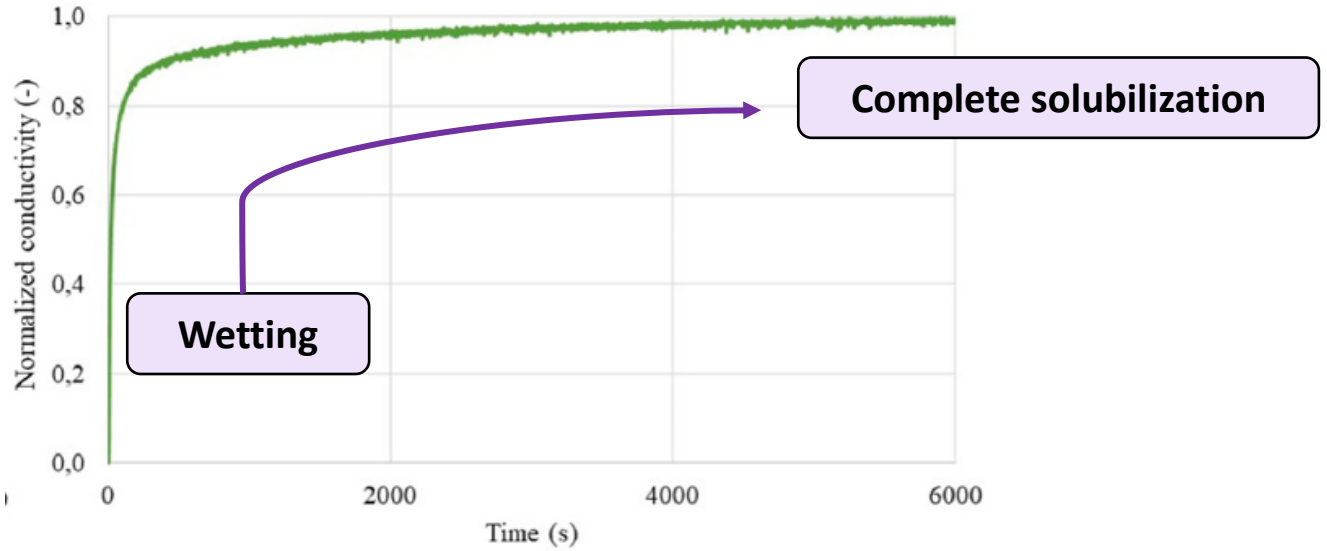
Reconstitution steps of a food powder



Crowley *et al.*, (2016)
Forny *et al.,* (2011)



Mitchell *et al.,* (2015)
Fournaise *et al.*, (2020)

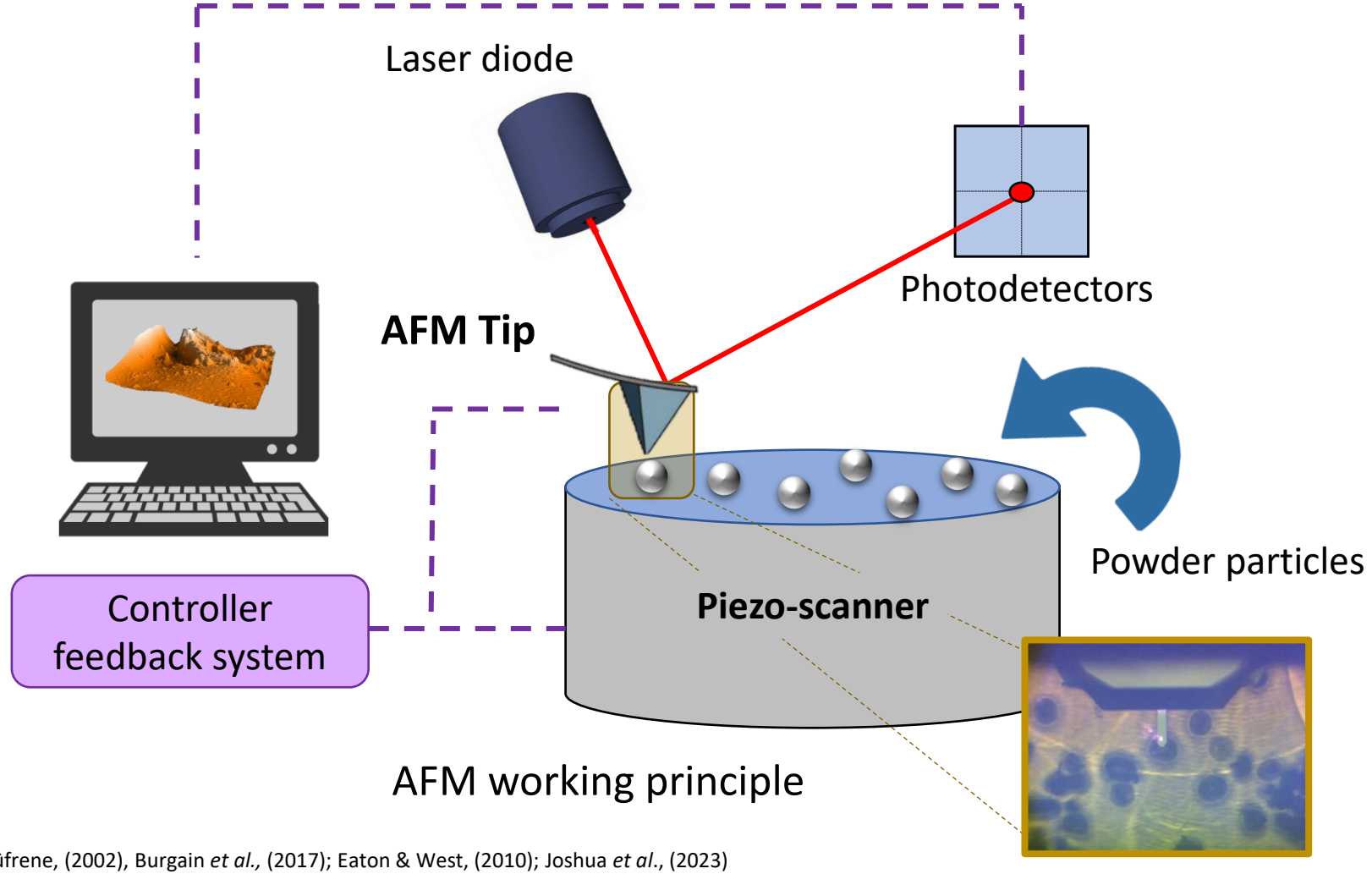


Reconstitution kinetic of a food powder

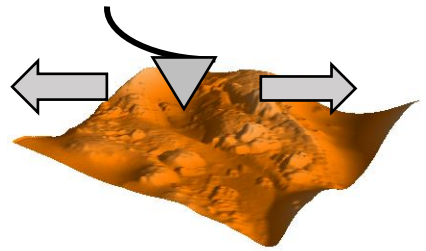
Fournaise *et al.*, (2020)

ATOMIC FORCE MICROSCOPY (AFM)

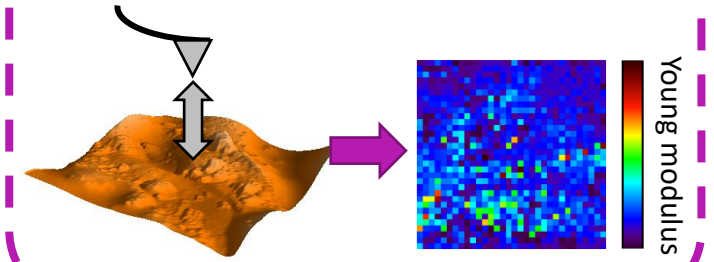
Flex Axiom, Nanosurf



3D Surface topography

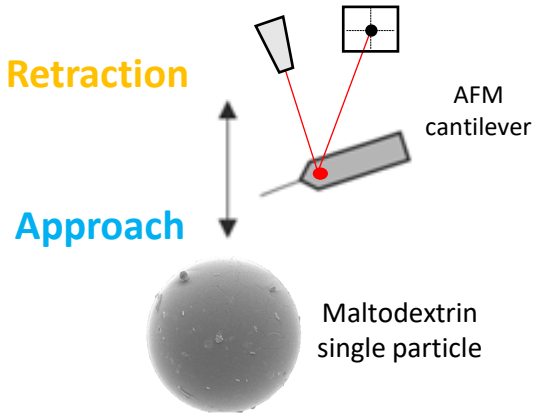


Mechanical properties

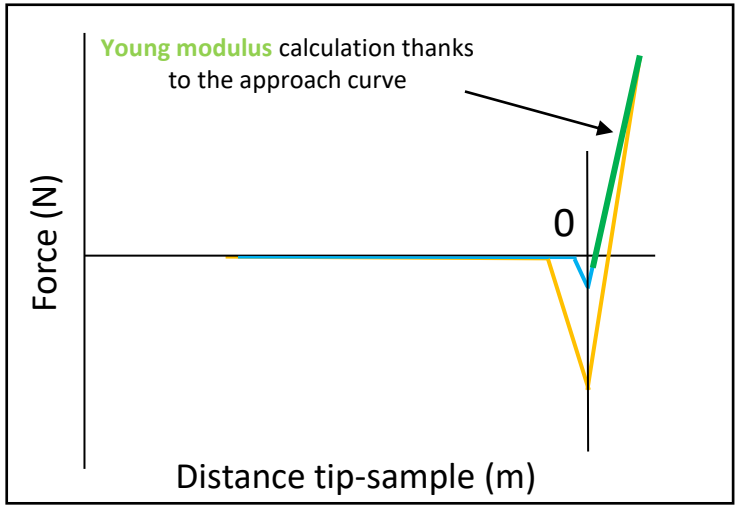


Dûfrene, (2002), Burgain *et al.,* (2017); Eaton & West, (2010); Joshua *et al*., (2023)

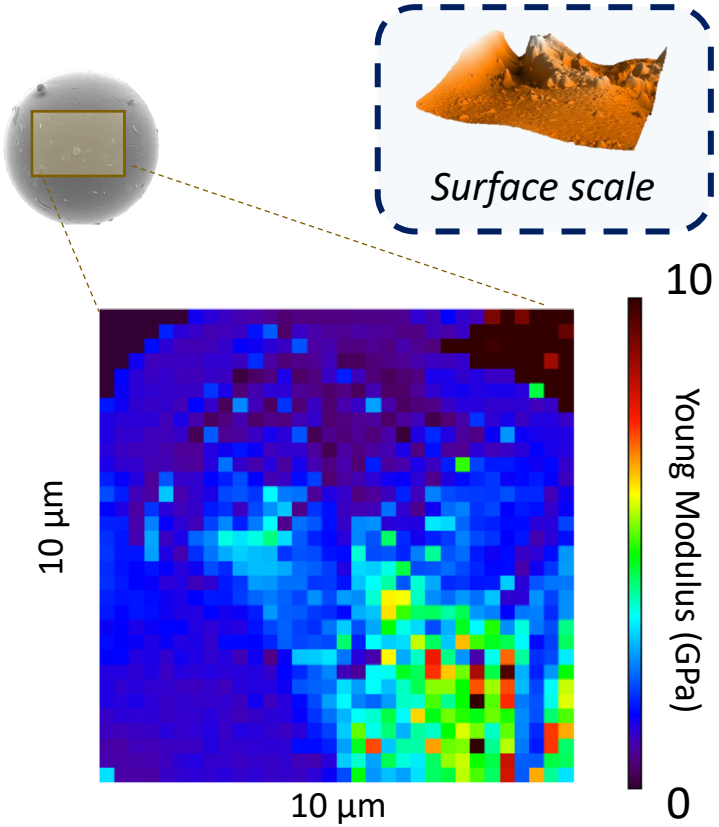
Nanoindentation by AFM
Young modulus characterization



AFM nanoindentation experiment



Force distance curves recording and Young modulus determination



Highly resolutive elasticity mapping (32*32 pixels) for single particles

Calculation of the **Young modulus value** thanks to the **approach curve** and to the choice of an appropriate **model**

$$F = -k_c\, d$$

Hooke's Law

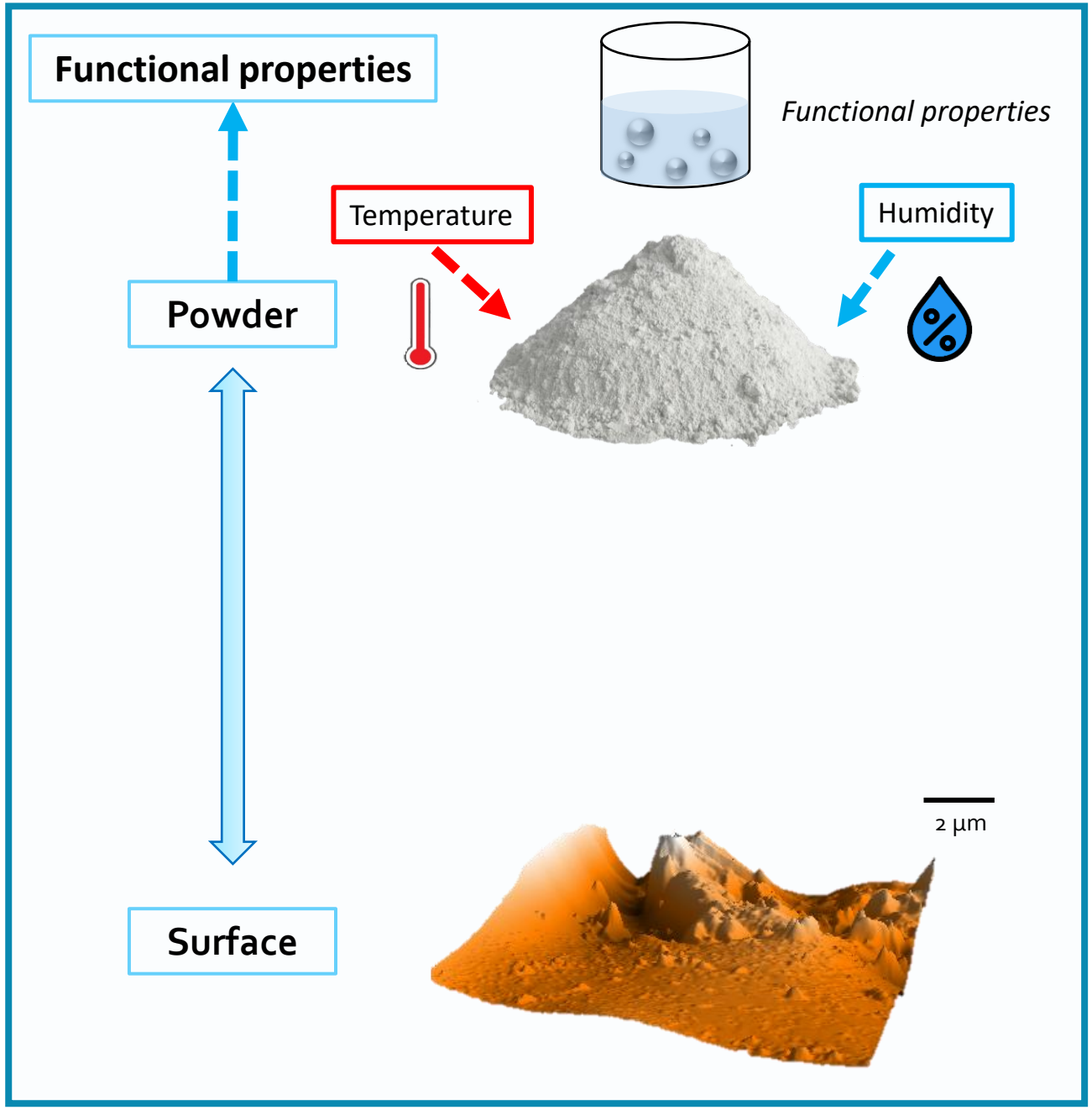
$$F = \frac{2E \tan \alpha}{\pi\,(1 - \nu^2)}\,\delta^2$$

Hertz theory

Hertz, (1882); Cardenas-Perez *et al.*, (2019); Burgain *et al.*, (2016)

MULTISCALE STUDY OF GLASS TRANSITION IMPACTS ON MALTODEXTRIN POWDERS PROPERTIES AND FUNCTIONALITIES

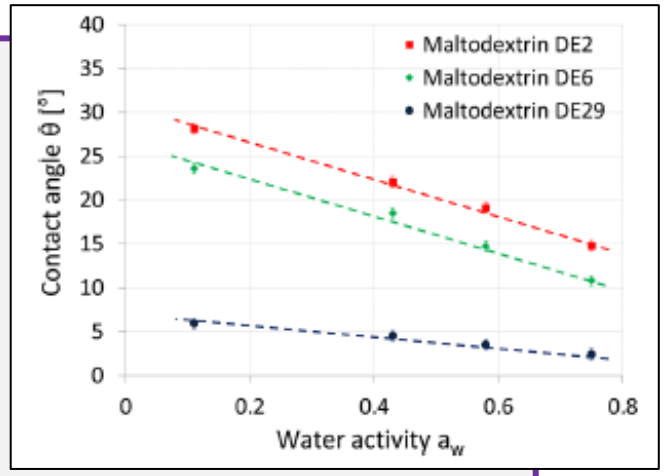
What are the links between particle surface features and powder reconstitution, at the interplay of glass transition ?



Reconstitution kinetics GLASSY vs RUBBERY

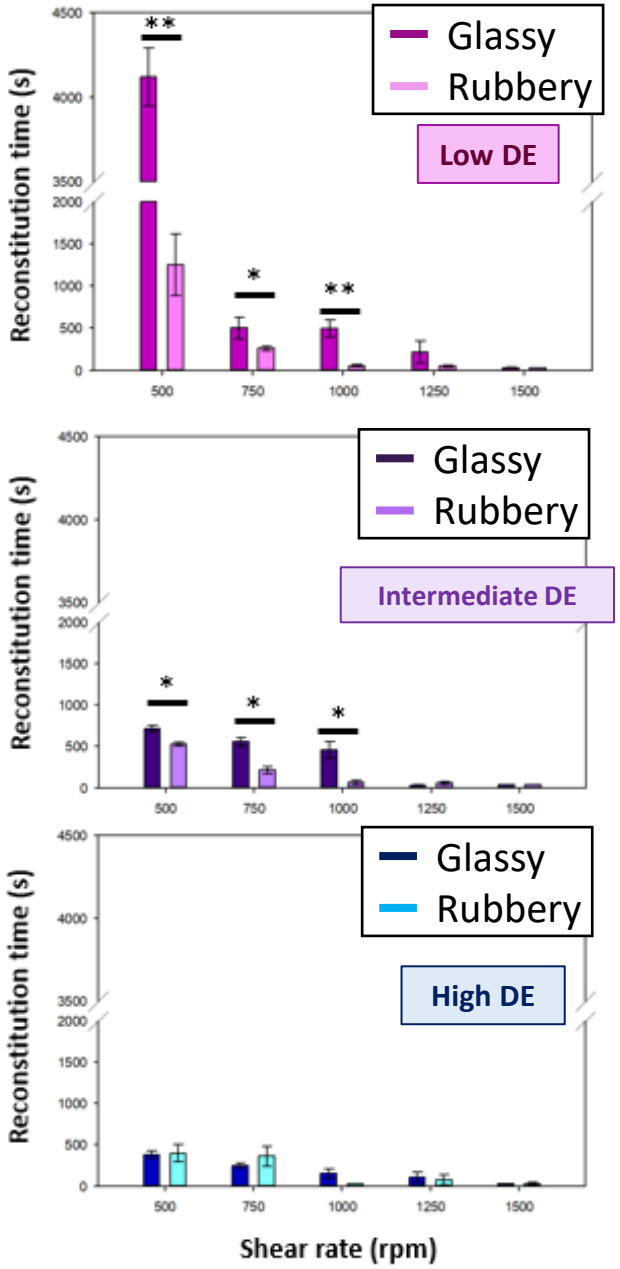
Effect of the DE

Decrease of reconstitution time for ⇗ DE

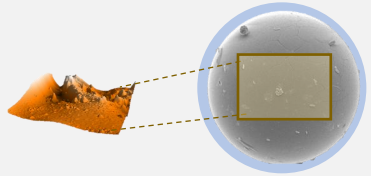


Dupas *et al.*, 2017

Effects of the shear rate



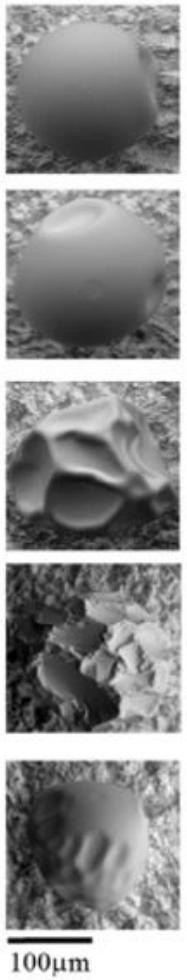
Effects of glass transition



Enhanced wetting step

Surface hydration ?

Surface topography and roughness



Low DE

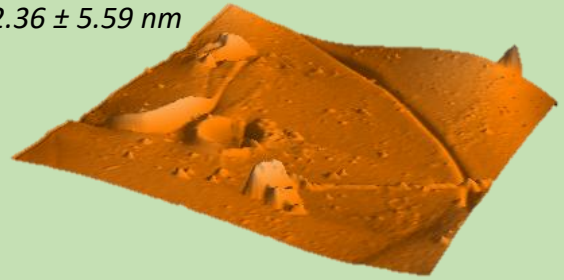
Intermediate DE

High DE

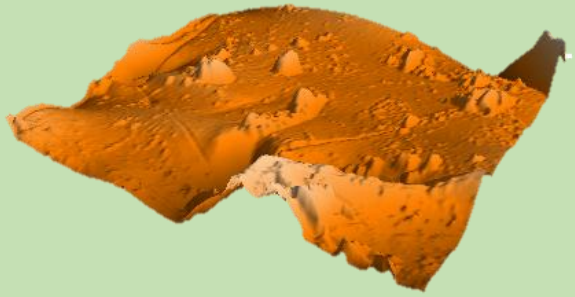
Siemons *et al.*, (2021)

Glassy state

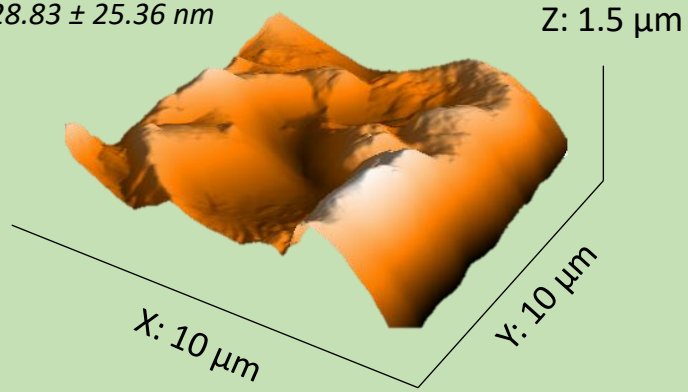
12.36 ± 5.59 nm

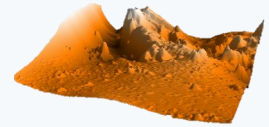


79.09 ± 26.56 nm

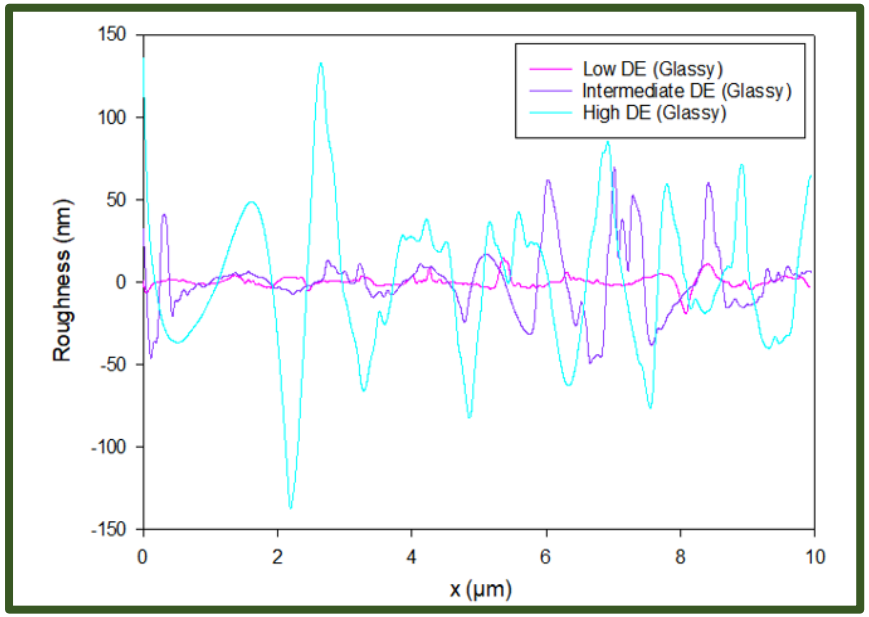


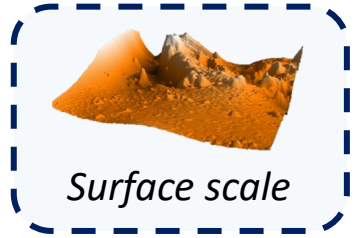
128.83 ± 25.36 nm





Surface scale

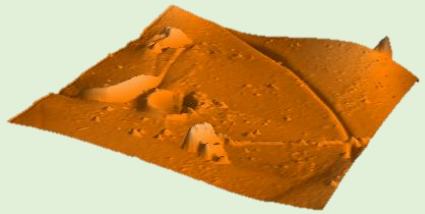




Glassy state

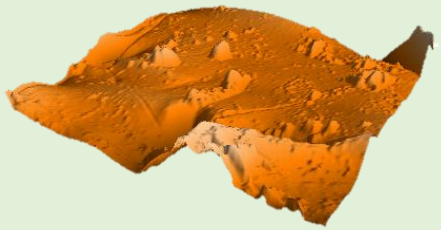
Low DE

12.36 ± 5.59 nm



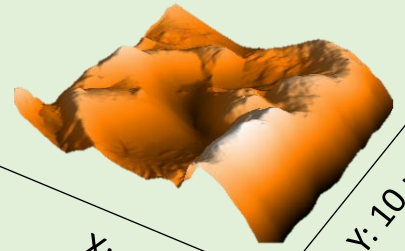
Intermediate DE

79.09 ± 26.56 nm



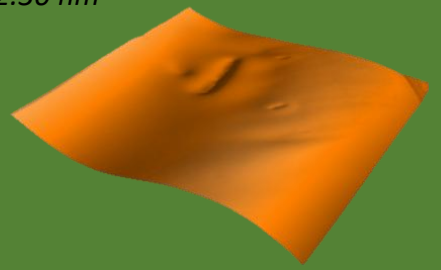
High DE

128.83 ± 25.36 nm

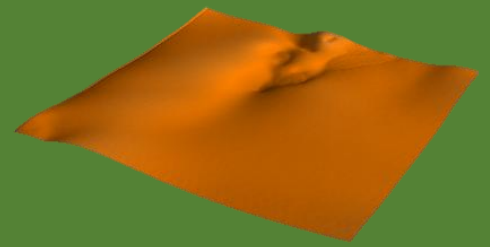


Rubbery state

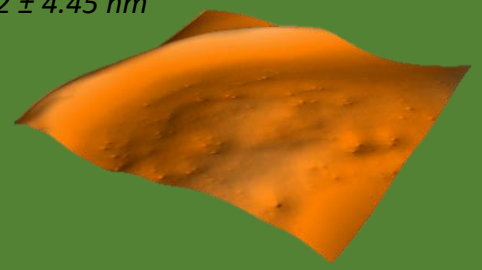
8.70 ± 2.30 nm

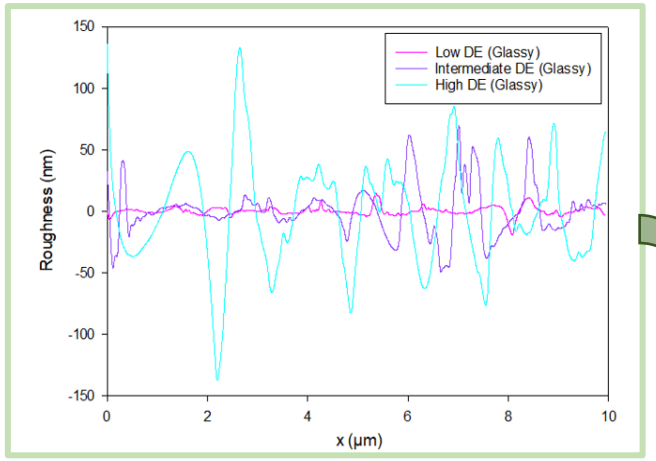


6.19 ± 5.34 nm



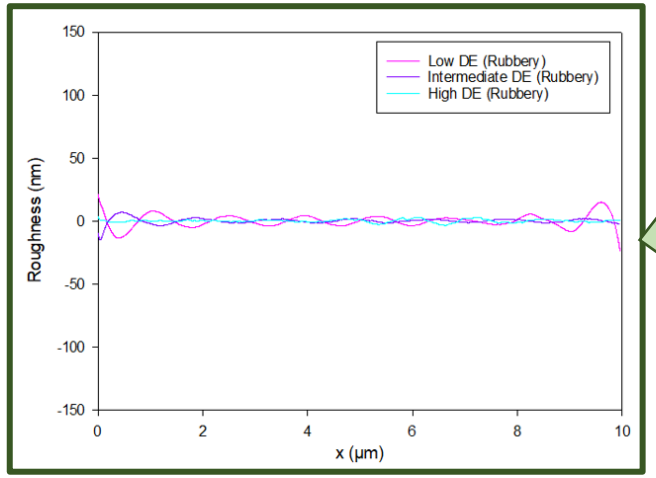
7.82 ± 4.45 nm





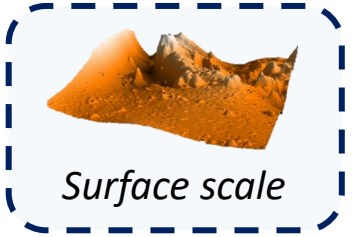
GLASSY

Tg



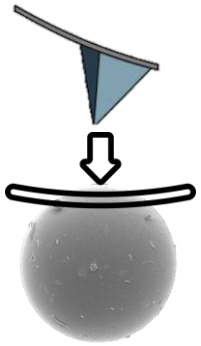
RUBBERY

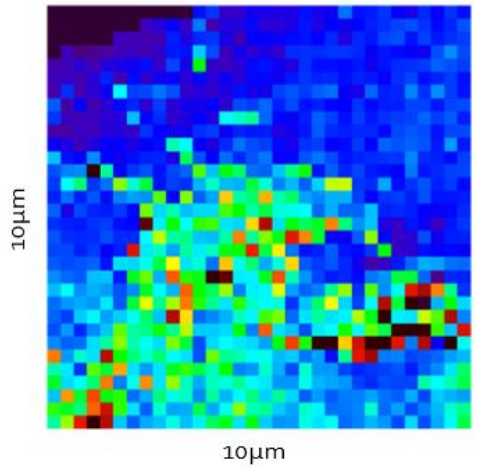
Young modulus

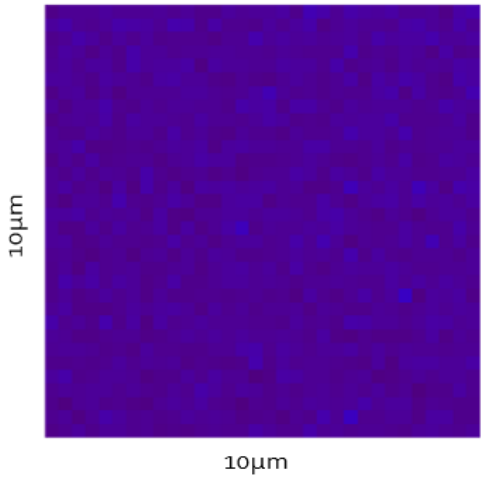


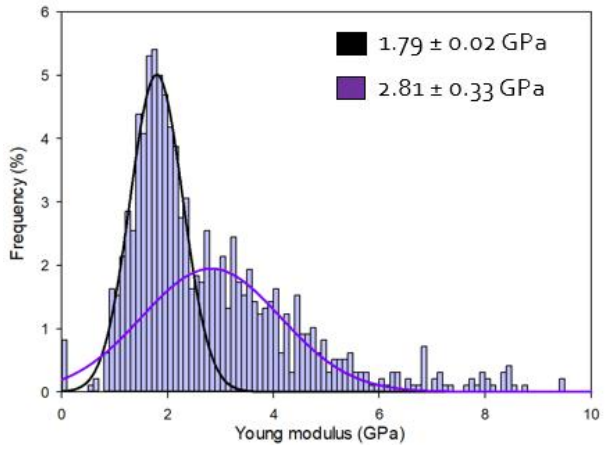
Glassy state → Rubbery state

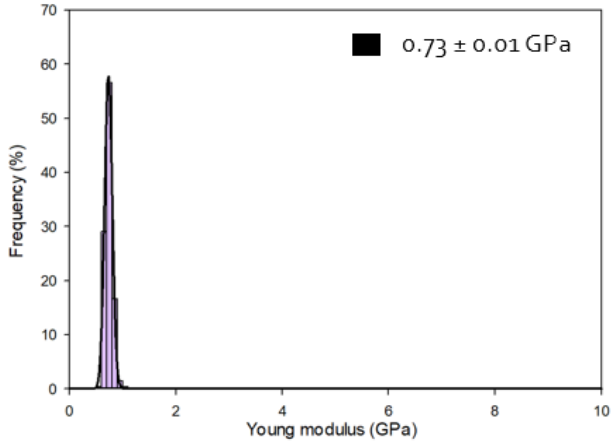
Intermediate DE

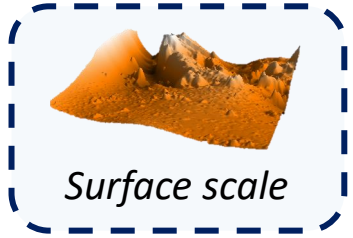










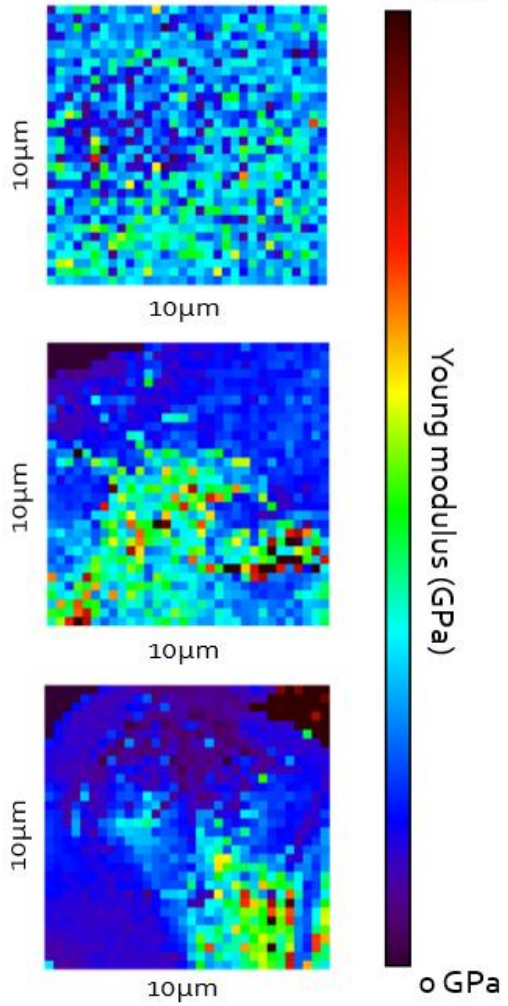


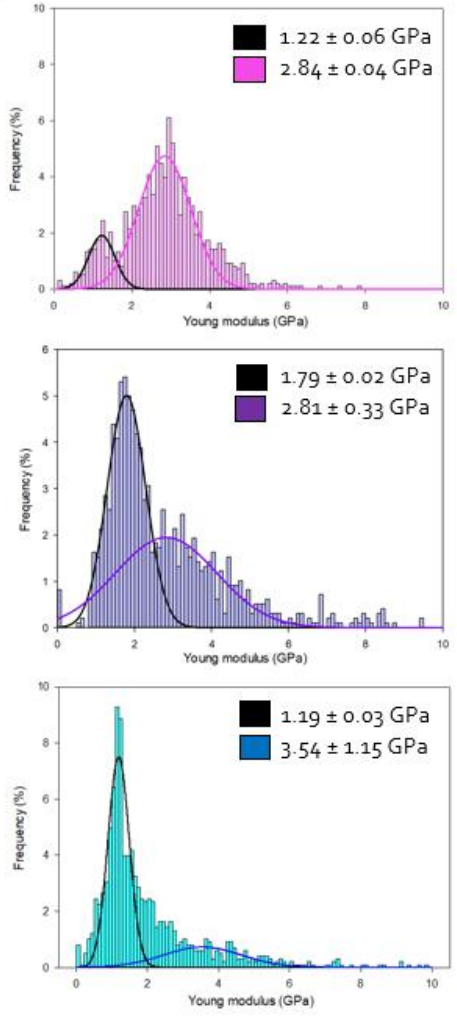
Glassy state → Rubbery state

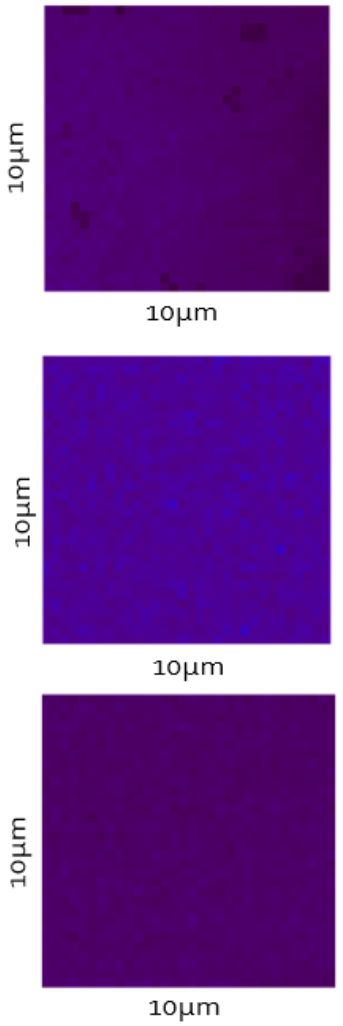
Low DE

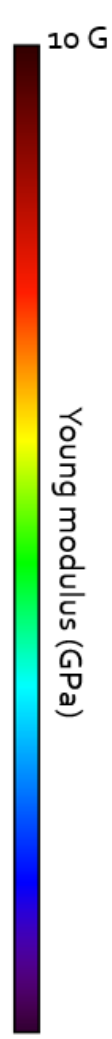
Intermediate DE

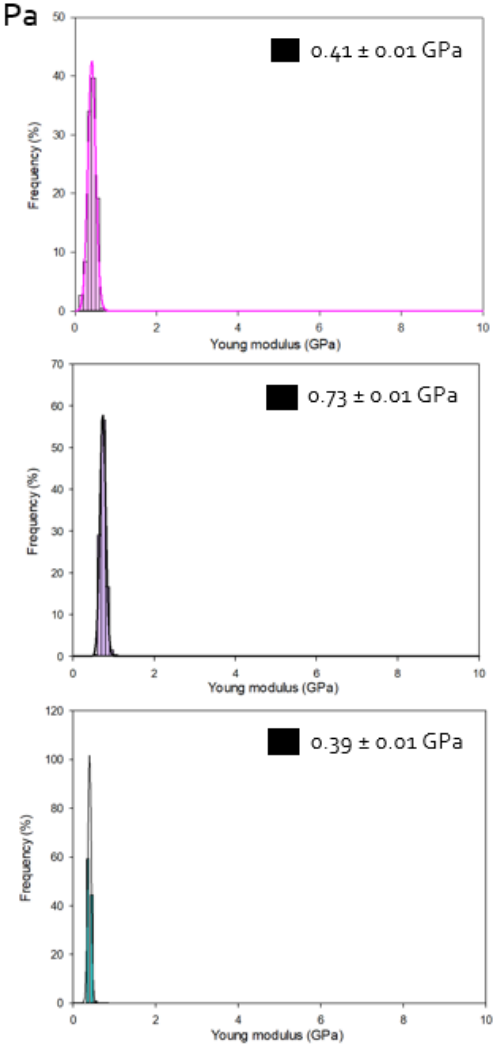
High DE

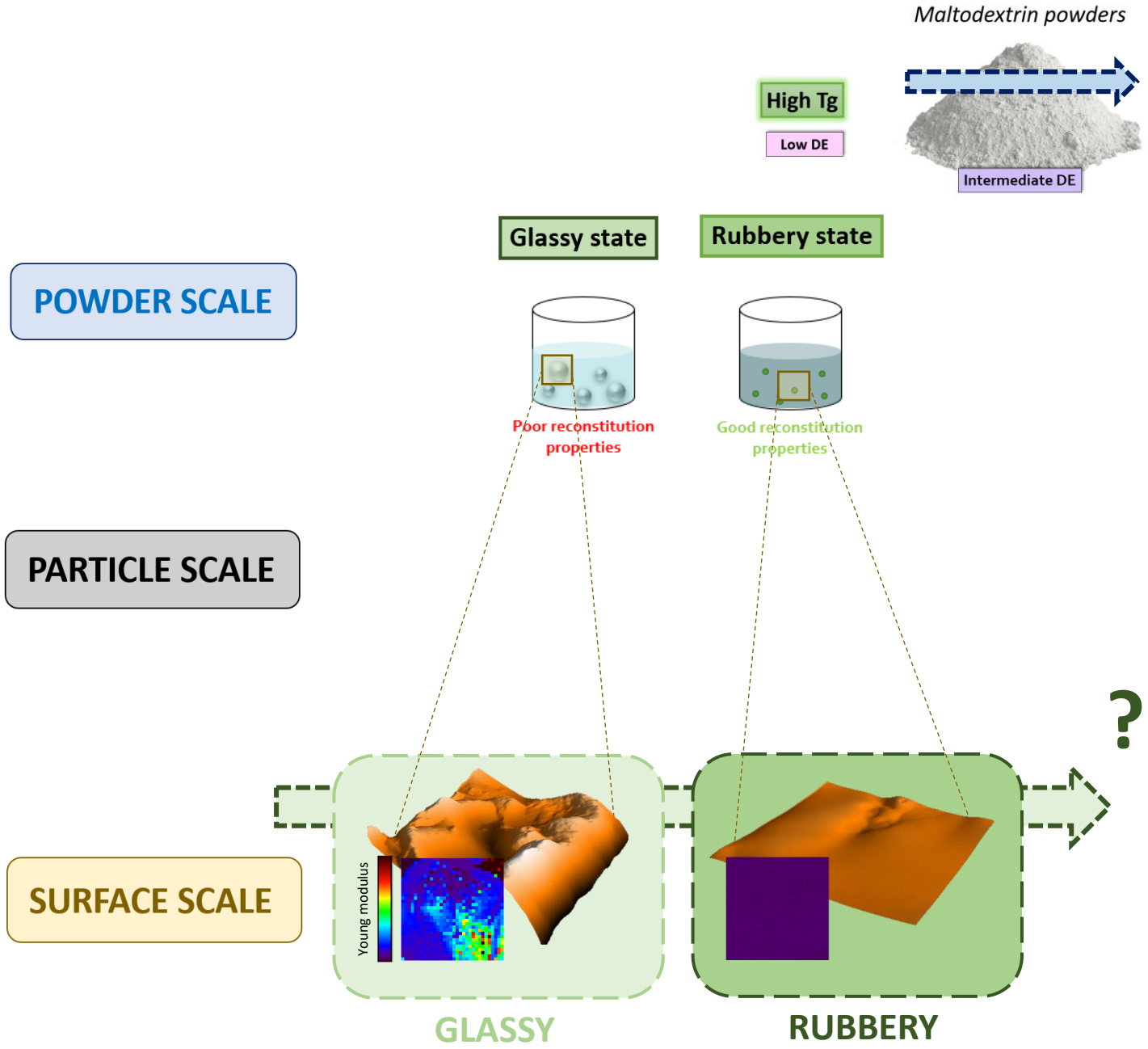












QUESTION 1

What are the links between particle surface features and powder reconstitution, at the interplay of glass transition ?

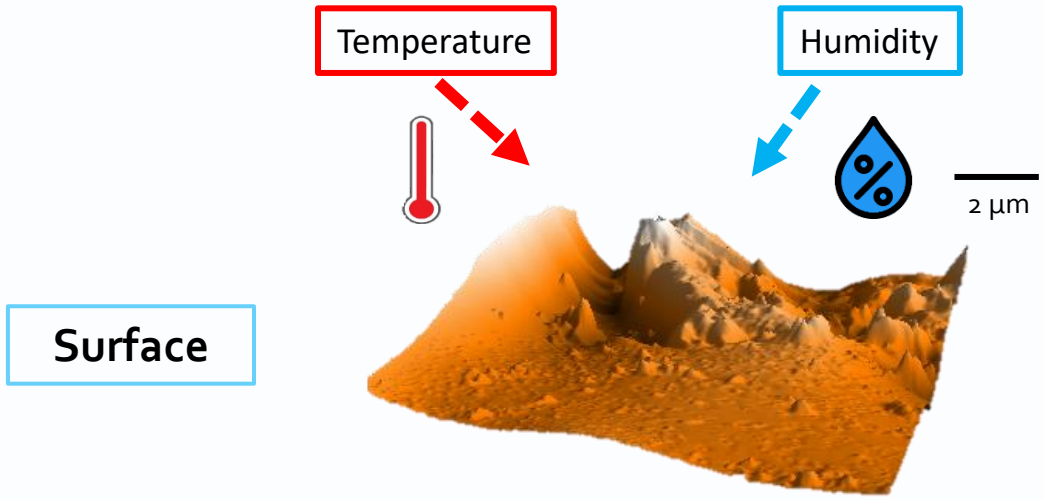
Food Hydrocolloids
Volume 132, November 2022, 107853
ELSEVIER

Probing maltodextrins surface properties by atomic force microscopy: Interplay of glass transition and reconstitution properties

Regis Badin [a], Jennifer Burgain [a], Stephane Desobry [a], Bhesh Bhandari [b], Sangeeta Prakash [b], Claire Gaiani [a c]

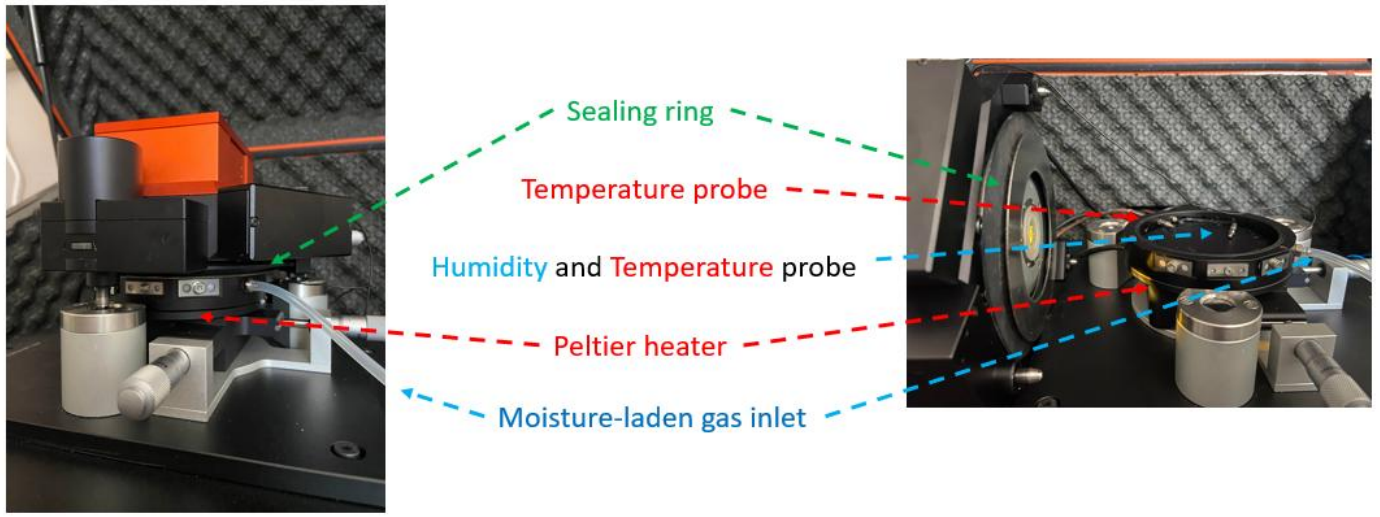
MULTISCALE STUDY OF GLASS TRANSITION IMPACTS ON MALTODEXTRIN POWDERS PROPERTIES AND FUNCTIONALITIES

How does single particle surface properties evolve with environmental variations (RH, T°C) and glass transition ?

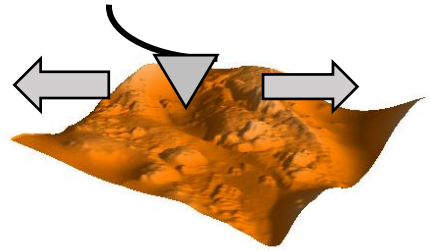


Environmental AFM
In situ properties of single particles

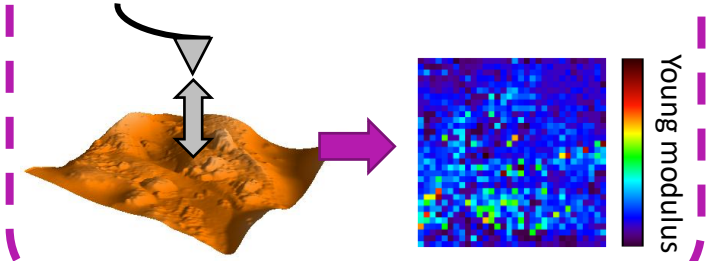
Flex Axiom, Nanosurf



3D Surface topography and roughness



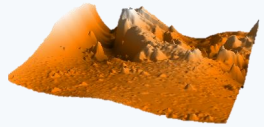
Mechanical properties



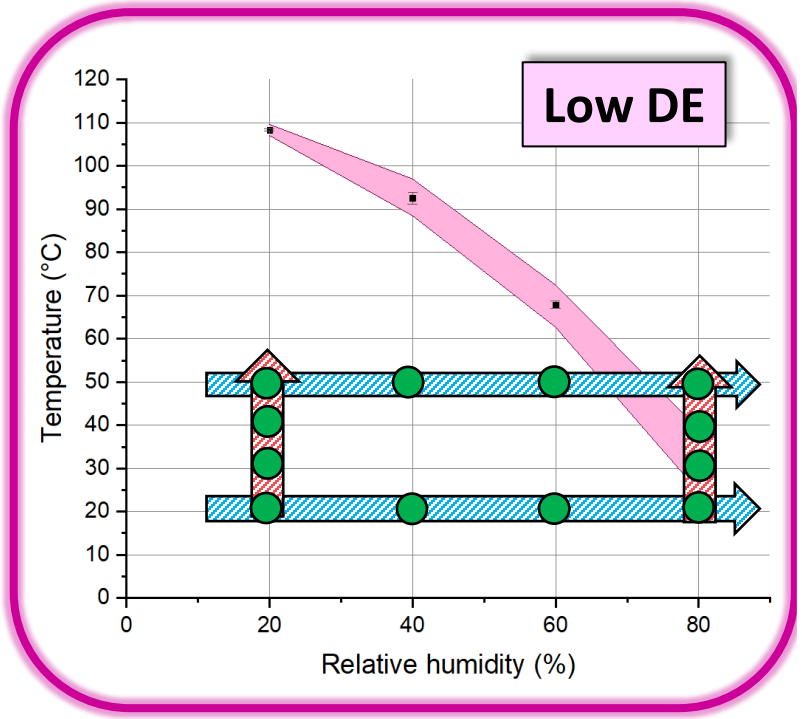
EXPERIMENTAL CONDITIONS ?

Glassy state — **Rubbery state**

Environmental AFM
In situ properties of single particles



Surface scale



Glassy state

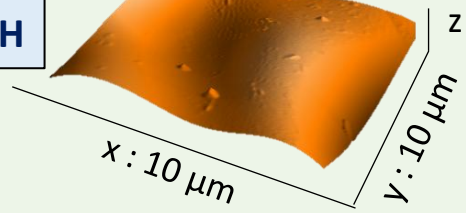
20°C

20 % RH — 140.53 ± 43.30 nm

40 % RH — 132.58 ± 52.97 nm

60 % RH — 140.05 ± 47.98 nm

80 % RH — 132.81 ± 43.46 nm



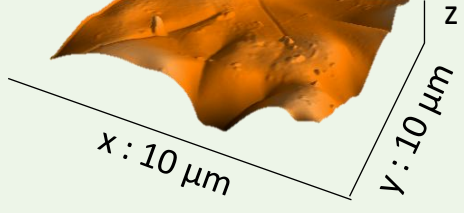
20% RH

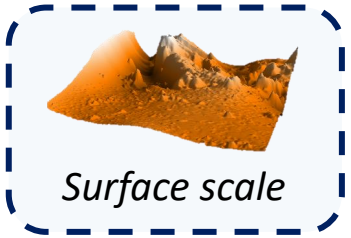
20°C — 47.37 ± 8.28 nm

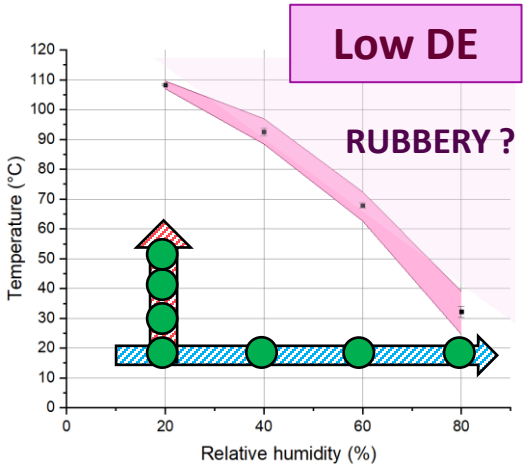
30°C — 47.42 ± 14.71 nm

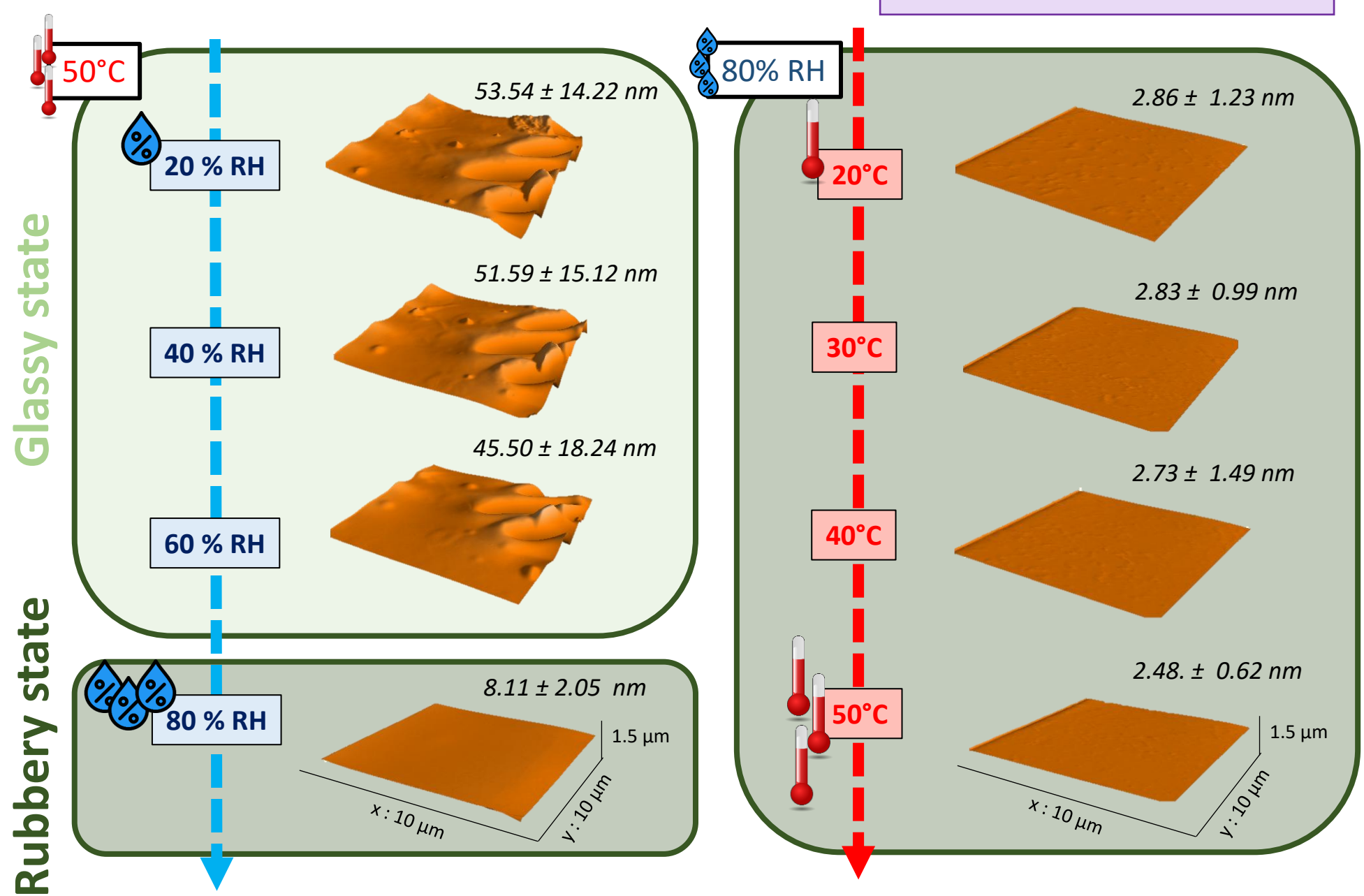
40°C — 50.26 ± 9.32 nm

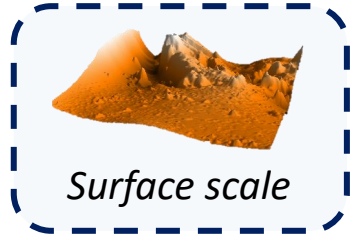
50°C — 49.18 ± 7.34 nm

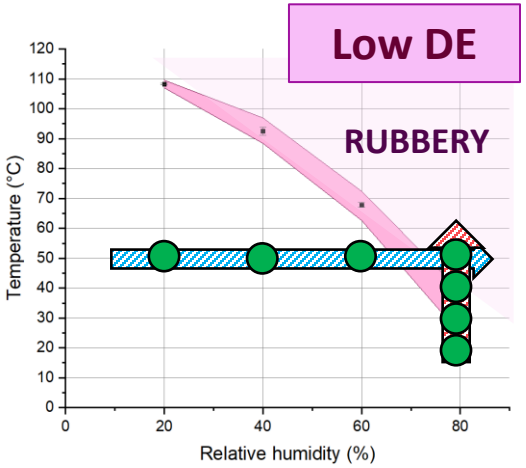


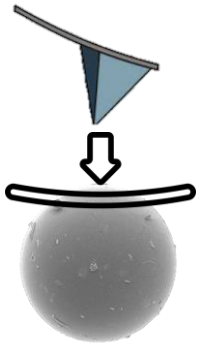




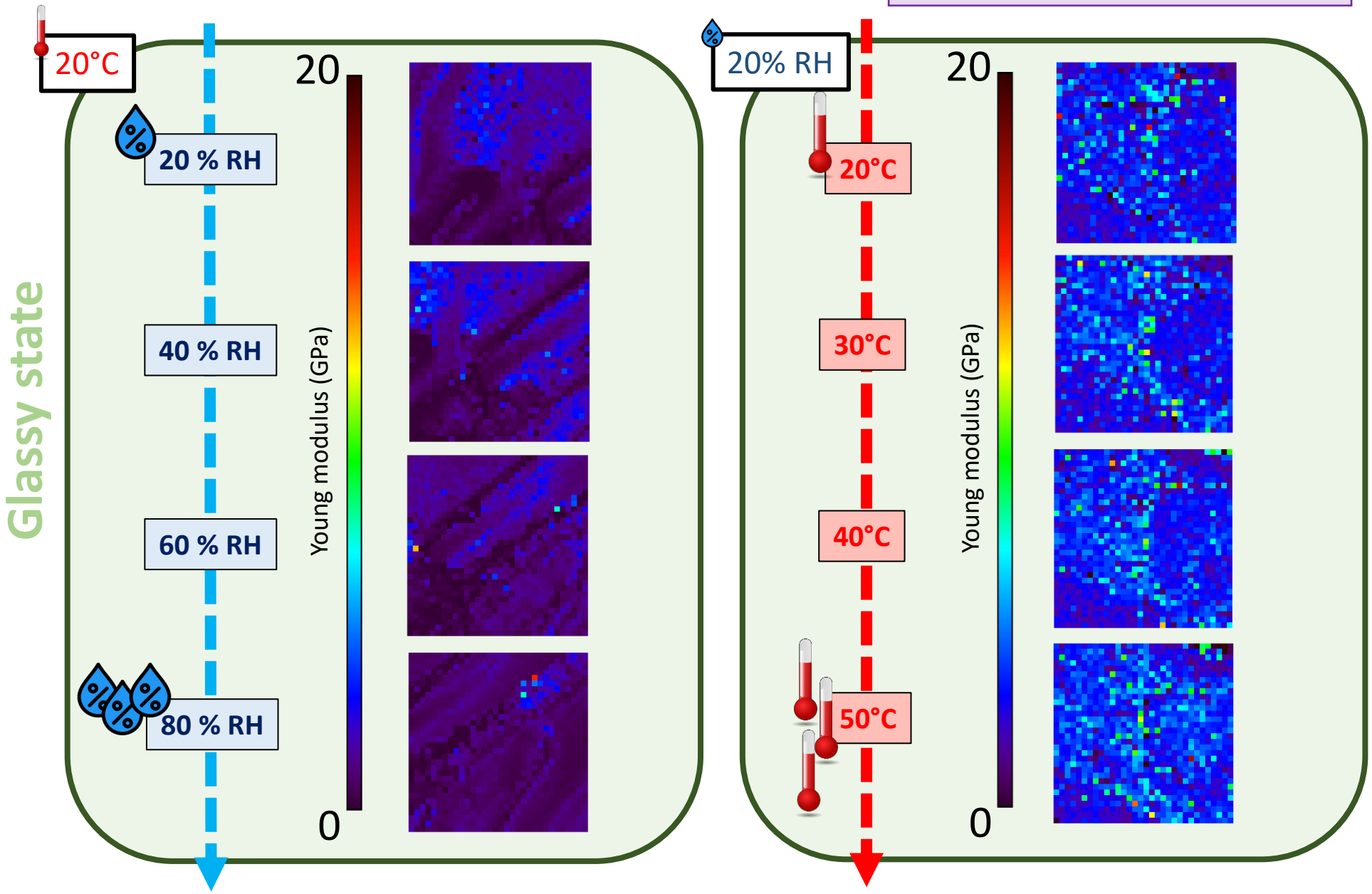


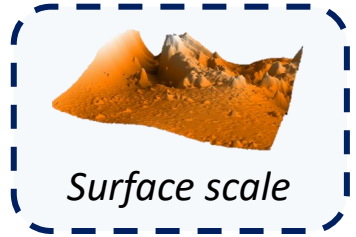


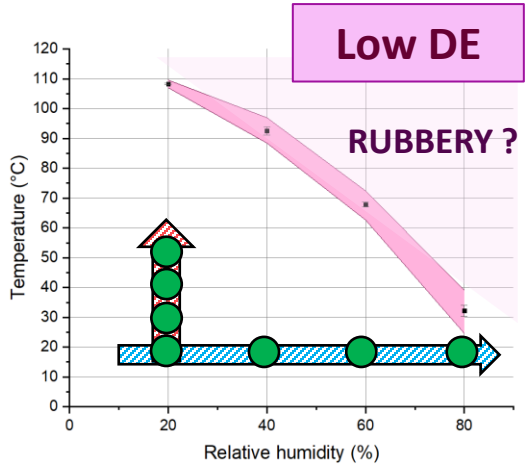


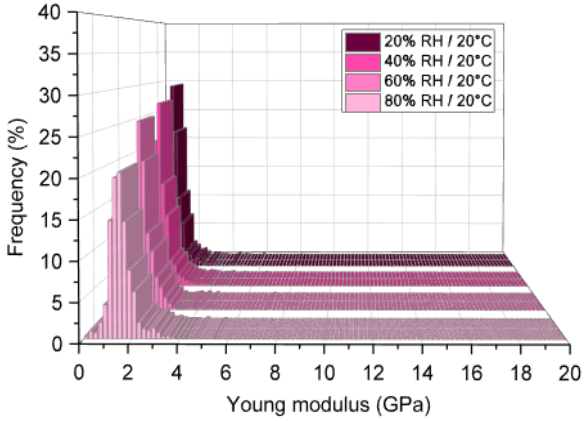


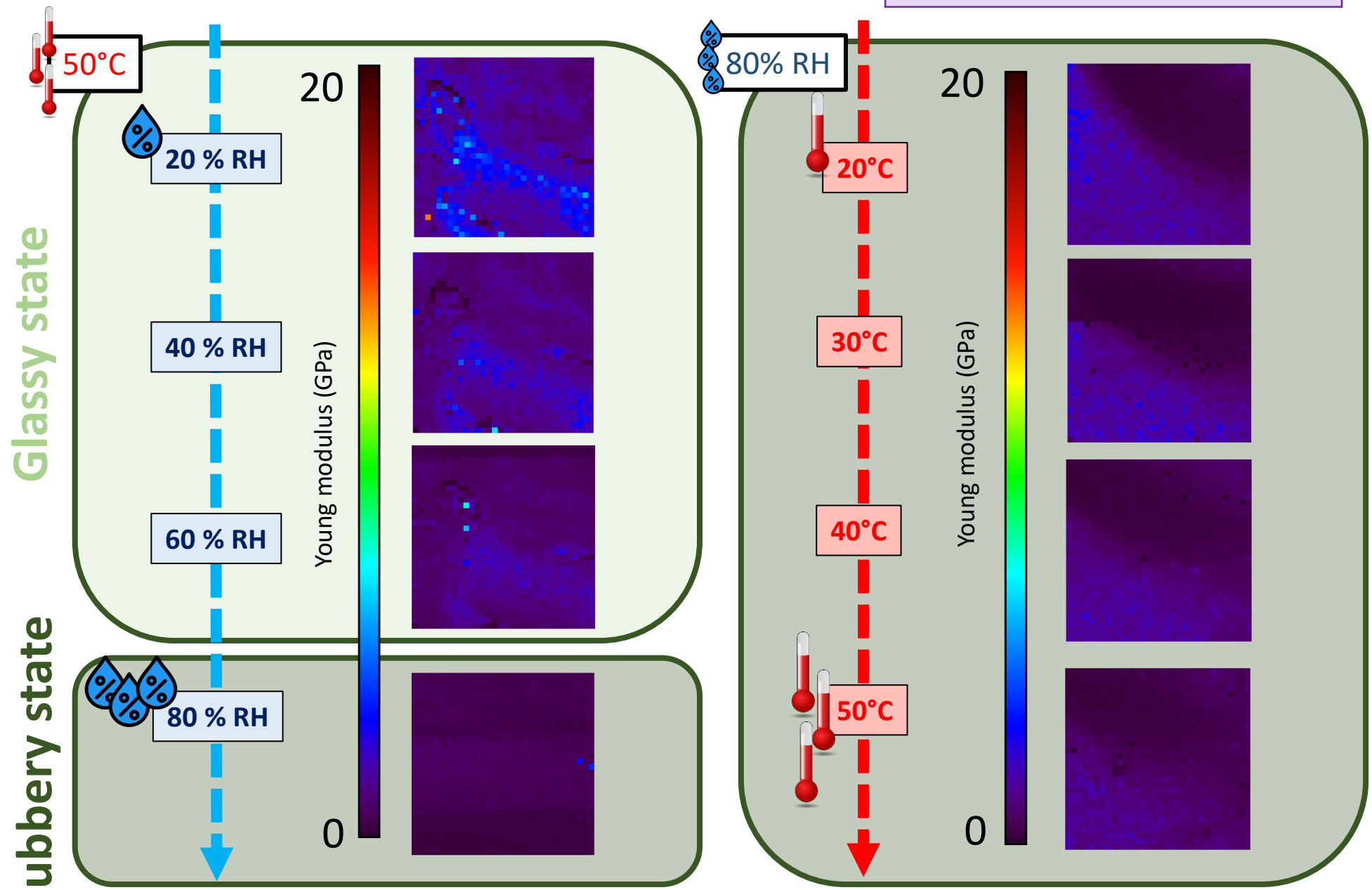
Nanomechanical Properties ?

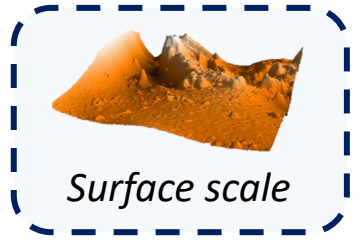

Glassy state
20°C
20 % RH
40 % RH
60 % RH
80 % RH
20
Young modulus (GPa)
0
20% RH
20°C
30°C
40°C
50°C
20
Young modulus (GPa)
0

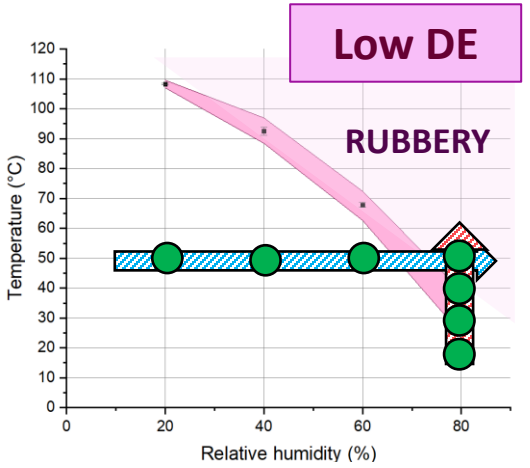

Surface scale

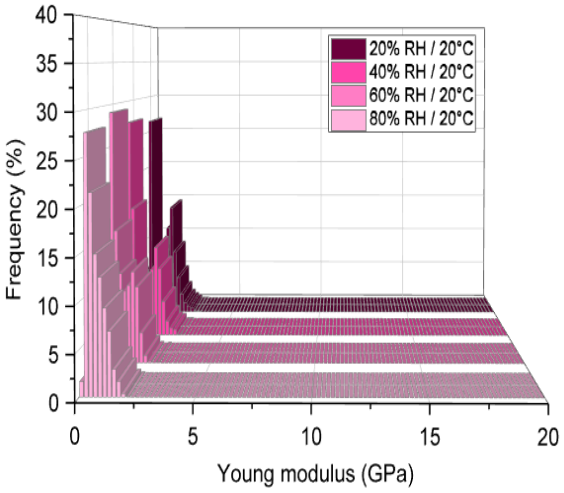

Low DE
RUBBERY ?
Temperature (°C)
Relative humidity (%)


20% RH / 20°C
40% RH / 20°C
60% RH / 20°C
80% RH / 20°C
Frequency (%)
Young modulus (GPa)


50°C
20 % RH
40 % RH
60 % RH
80 % RH
20
0
Young modulus (GPa)
Glassy state
Rubbery state
80% RH
20°C
30°C
40°C
50°C
20
0
Young modulus (GPa)


Surface scale

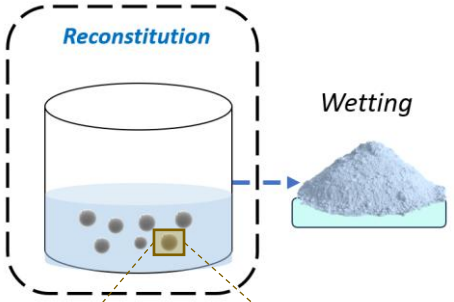

Low DE
RUBBERY
Temperature (°C)
Relative humidity (%)


20% RH / 20°C
40% RH / 20°C
60% RH / 20°C
80% RH / 20°C
Frequency (%)
Young modulus (GPa)

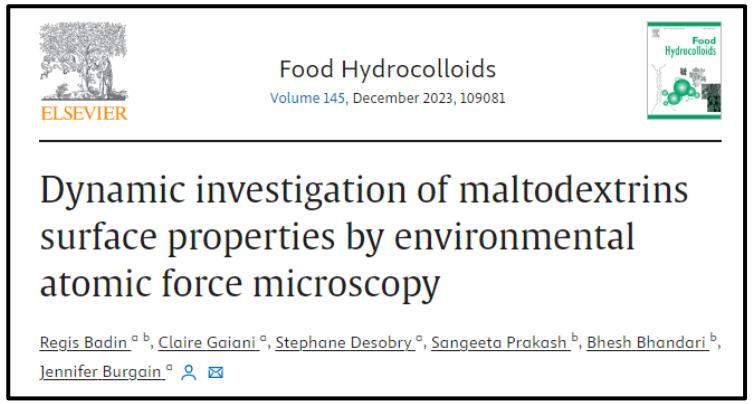
QUESTION 2

How does single particle surface properties evolve with environmental variations (RH, T°C) and glass transition ?

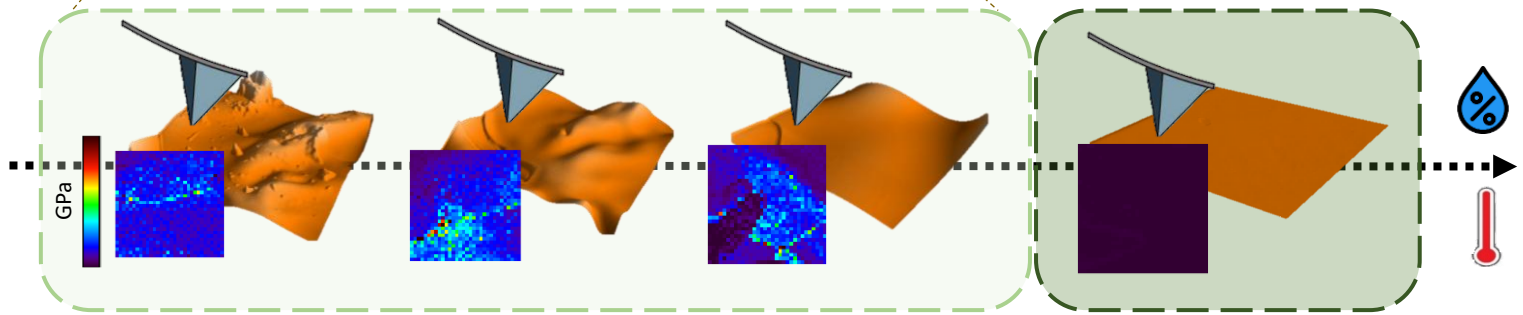
POWDER SCALE



PARTICLE SCALE



SURFACE SCALE



Conclusion and new prospects