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RHEO-OPTICAL STUDIES OF COMPLEX FLUIDS UNDER THERMO-MECHANICAL TREATMENTS USING CONFOCAL MICROSCOPY

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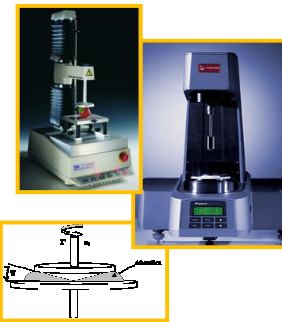


UMR1145 Ingénierie Procédés Aliments

□ Rheo-Optic: 2 possibles strategies

Rheology = Properties

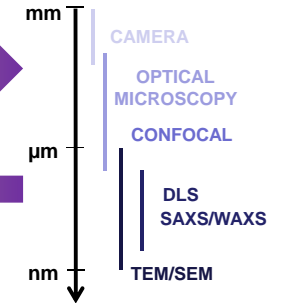
Observation = Structure



Baravian *et al.*, 2001
Nicolas et Paques, 2003
Besseling *et al.*, 2009



Taylor, 1932
Birkhofer *et al.*, 2005
Wu *et al.*, 2007



RHEOPTICAD

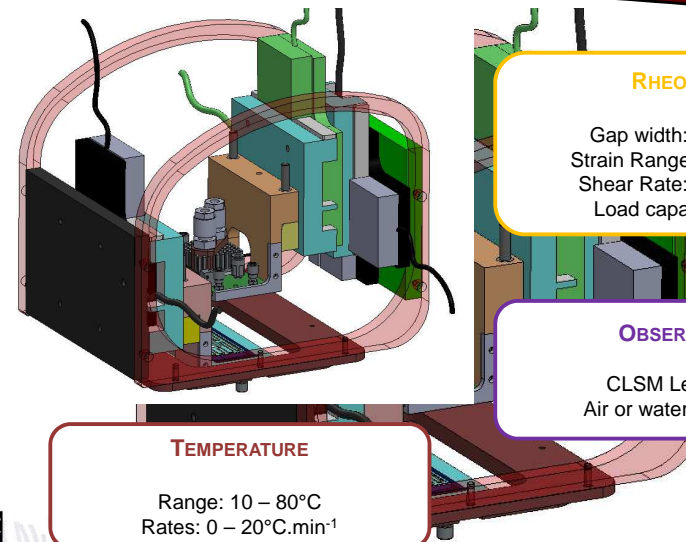
A THERMO-MECHANICAL DEVICE FOR CLSM



(Boitte *et al.*, *Rev. Sci. Instruments*, 84, 2013)



RheOptiCAD – Specifications



RHEOLOGY

Gap width: 0 – 5 mm
Strain Range: 0.02 – 320
Shear Rate: 0 – 400 s⁻¹
Load capacity: 16 N

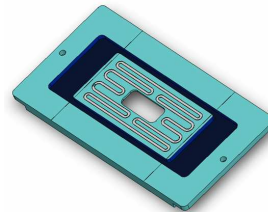
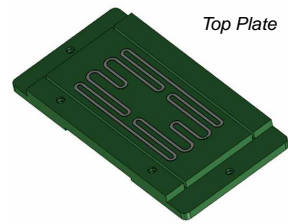
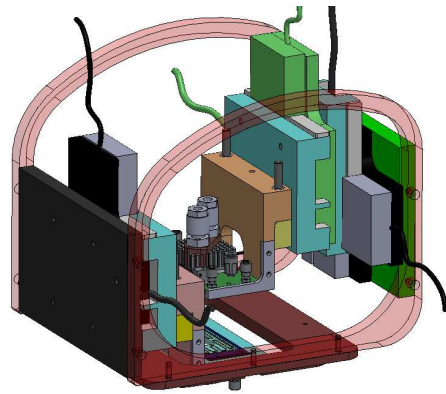
OBSERVATION

CLSM Leica SP2
Air or water objectives

TEMPERATURE

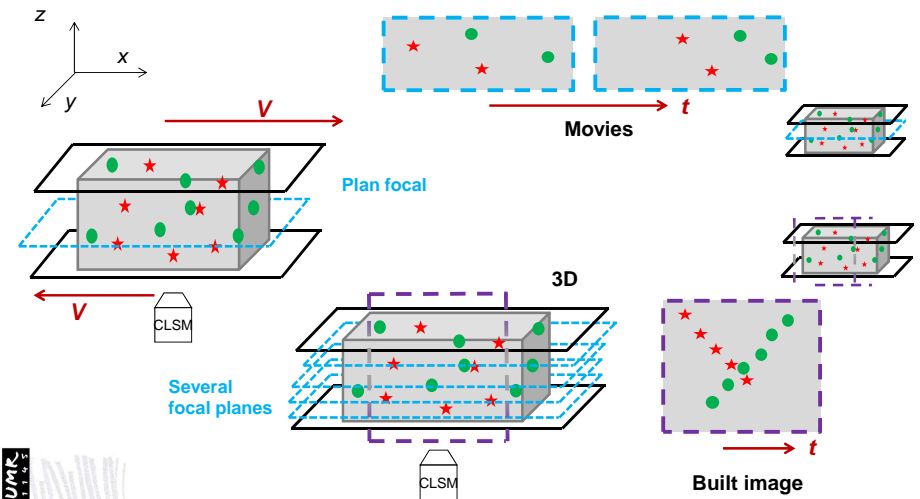
Range: 10 – 80°C
Rates: 0 – 20°C.min⁻¹



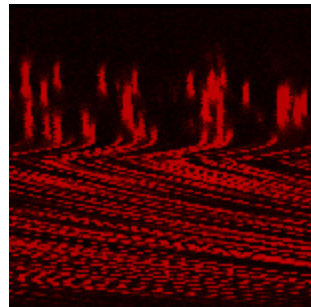
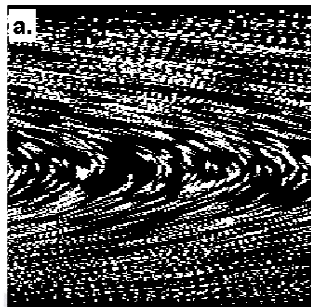


- ▶ Suction system for holding the glasses
- ▶ Easy, fast and reproducible sampling

Observation using a CLSM



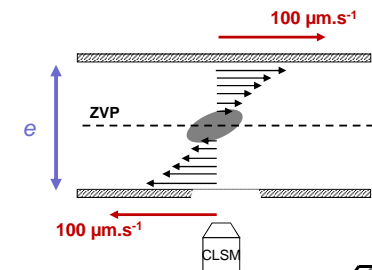
CHARACTERIZATION OF MODEL SYSTEMS



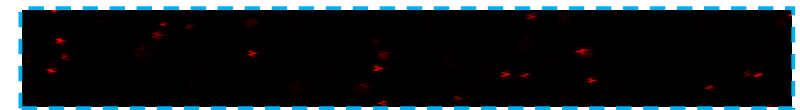
Microgel + fluorescent probes ¹

- Localization of a Zero Velocity Plane?
- Additional questions

- ▶ 'Uni-axial motion'
- ▶ 'Plates parallelism'



- ▶ 'Continuous mode' (movie 110 images along time)

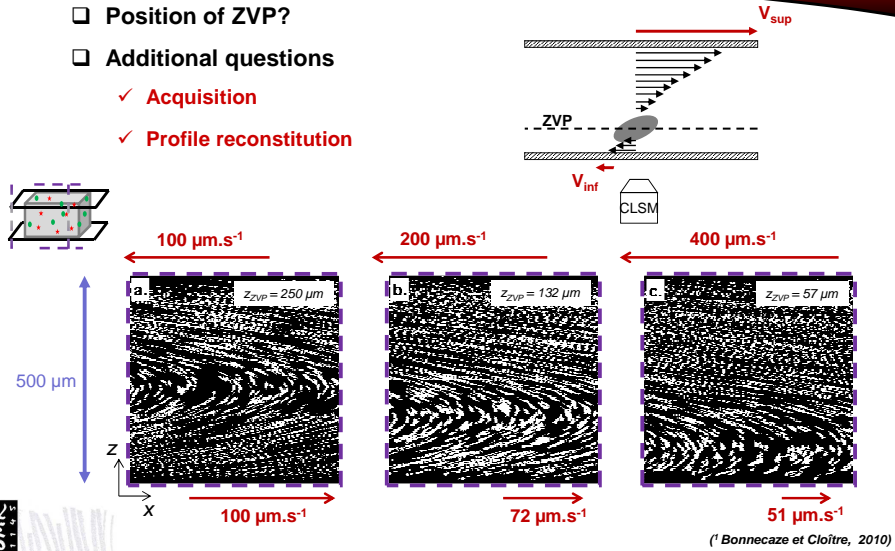


20 μm

(¹ Bonnacaze et Cloître, 2010)

Microgel + fluorescent probes ¹

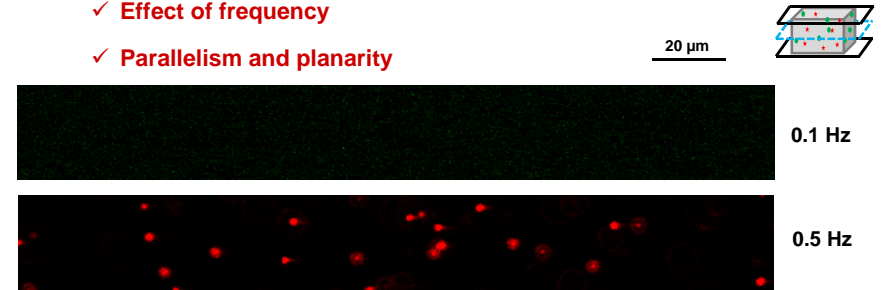
- ❑ Position of ZVP?
- ❑ Additional questions
 - ✓ Acquisition
 - ✓ Profile reconstitution



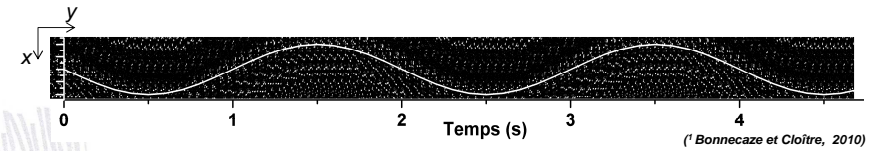
(¹ Bonnecaze et Cloître, 2010)

Microgel + fluorescent probes ¹

- ❑ Controlled deformation
 - ✓ Effect of frequency
 - ✓ Parallelism and planarity



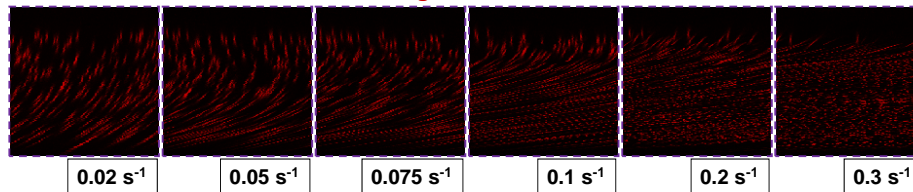
- ✓ Reconstitution et validation



(¹ Bonnecaze et Cloître, 2010)

Carrageenan + fluorescent probes

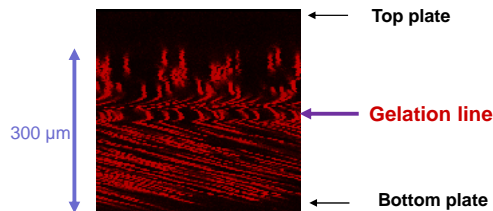
- ❑ Characterization of flow properties?
 - ✓ Wall slips?
 - ✓ Gelation under shearing?



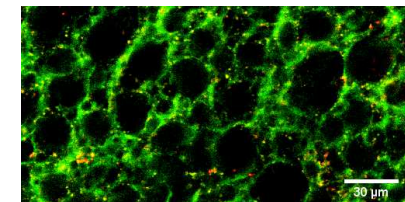
Cooling under shearing

T = 45°C
-5°C.min⁻¹
T = 20°C

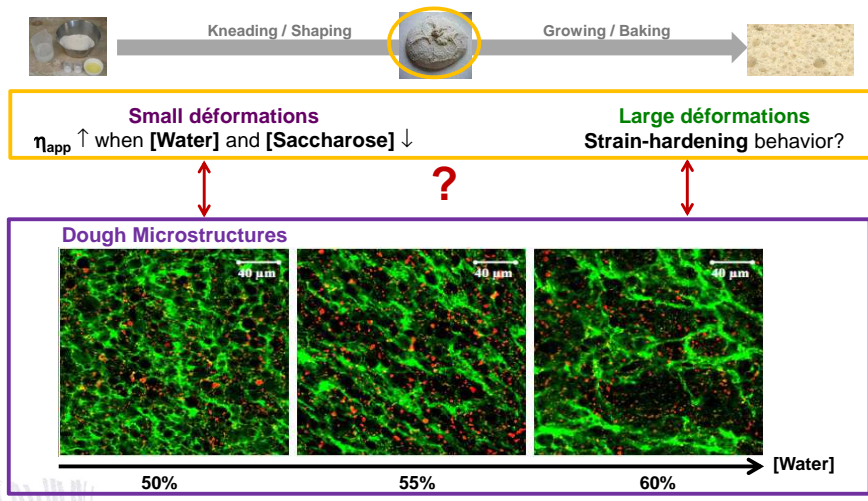
Acquisition
150 images in t=33.5 s



WHEAT FLOUR DOUGH MICROSTRUCTURES UNDER MECHANICAL TREATMENTS



Bread: structures at all scales

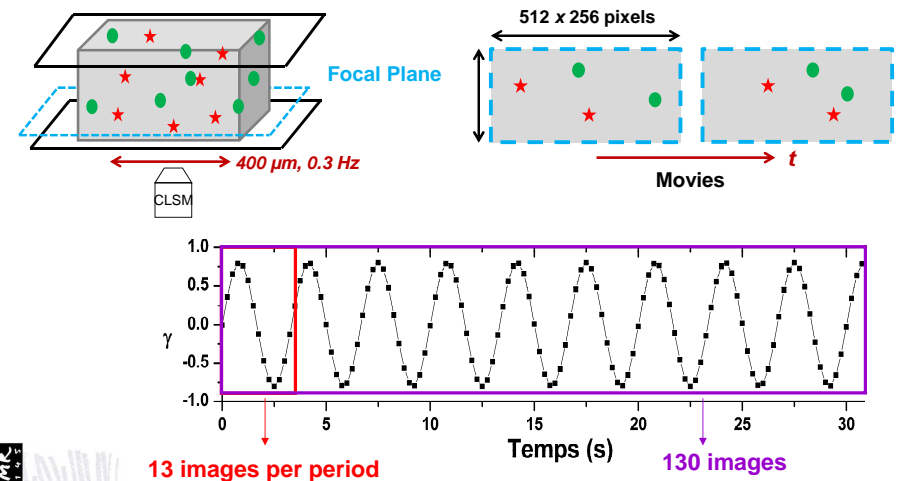


(Lassoued, 2005)

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Wheat Flour Dough Microstructures - Materials and Method

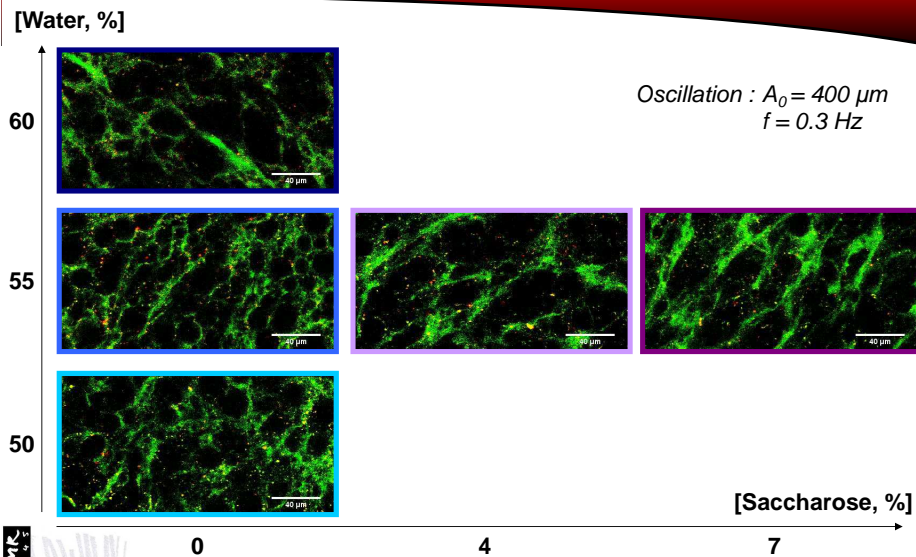
Balance optic - mechanic



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Wheat Flour Dough Microstructures - Results

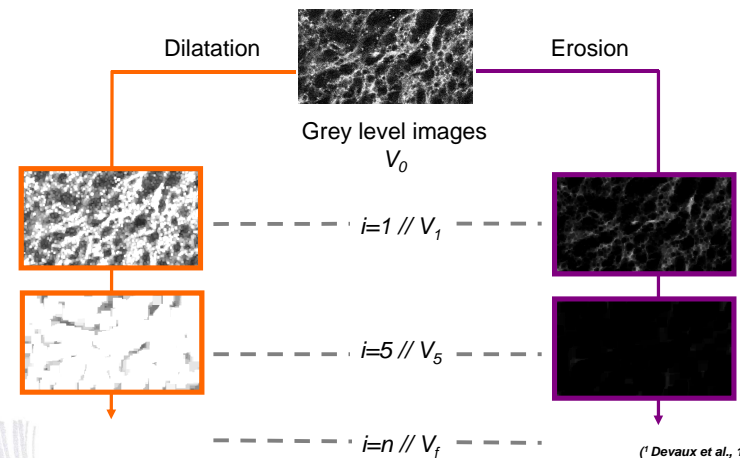


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Wheat Flour Dough Microstructures - Results

Greyscale mathematical morphology

► Module GranuloMorpho¹, MATLAB (The MATHWORKS, USA)



(¹ Devaux et al., 1997, 2008)

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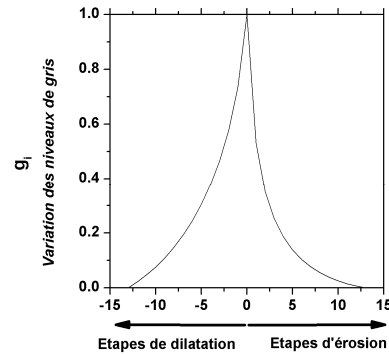
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Wheat Flour Dough Microstructures - Results

□ Greyscale mathematical morphology

- ✓ Linear pattern: $r = 1$ pixel, $\theta = 45^\circ$ or 135°
- ✓ 30 successive steps erosion-dilatation = grey level mean
- ✓ Variation of grey level mean (g_i)

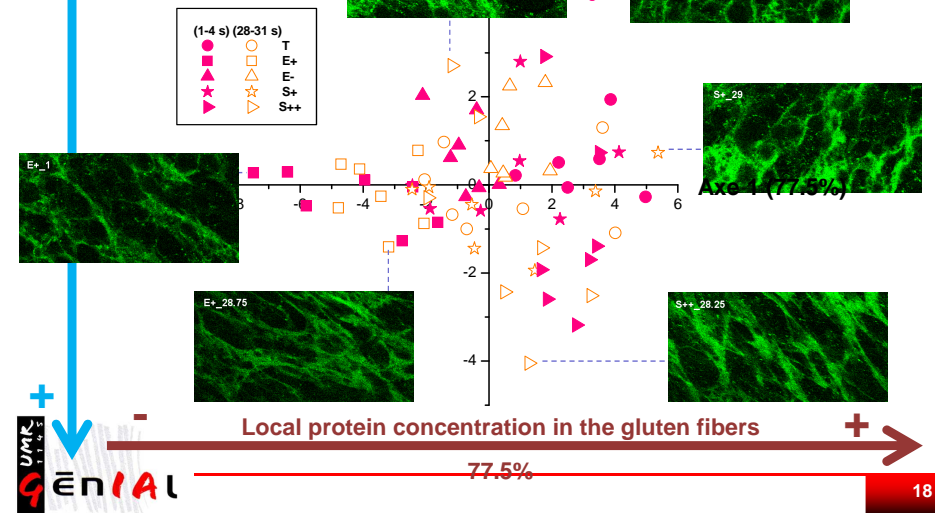
$$g_i = \frac{V_i - V_{i+1}}{V_0 - V_f}$$



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Wheat Flour Dough Microstructures - Results

Orientation level of the gluten network 21.1%

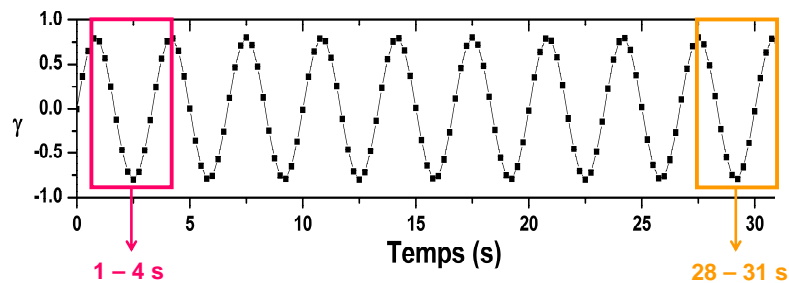


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Wheat Flour Dough Microstructures - Results

□ Analyse en Composantes Principales (ACP)

- ▶ 2 périodes x 13 images x 5 recettes = 130 images
- ▶ Positionnement et différenciation sur une carte ACP
- ⇒ Effet de la déformation, du temps de cisaillement

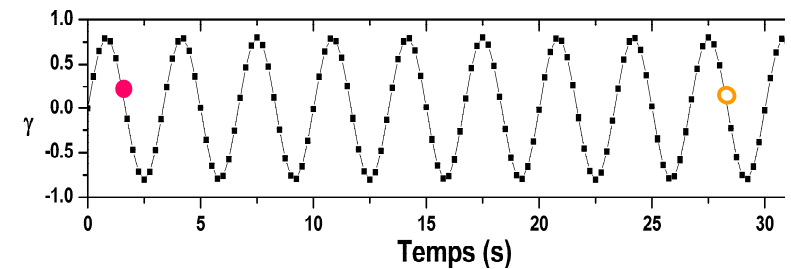


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Wheat Flour Dough Microstructures - Results

□ Analyse en Composantes Principales (ACP)

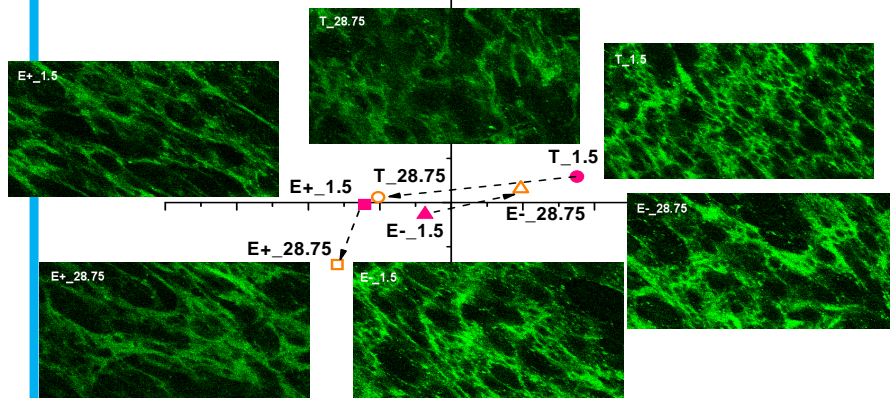
- ▶ Teneur en eau
- ▶ Effet de la recette et du temps de cisaillement



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Wheat Flour Dough Microstructures - Results

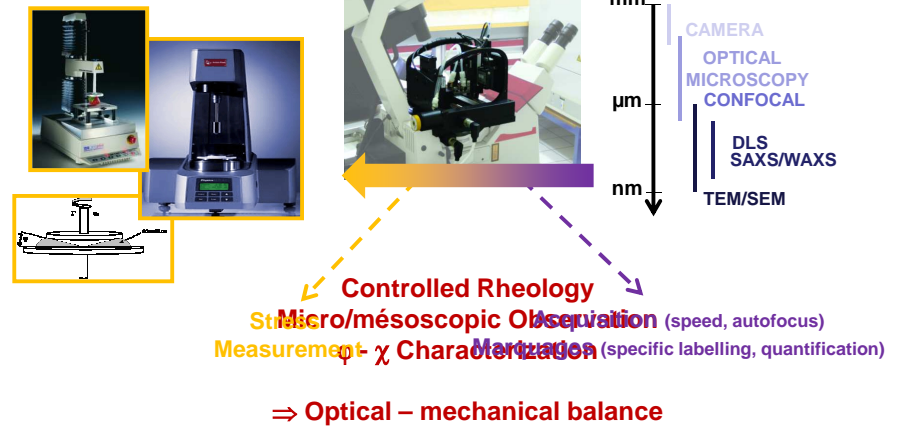
- Niveau d'orientation du réseau de gluten 21.1%



Conclusions - Perspectives

Rheology = Properties

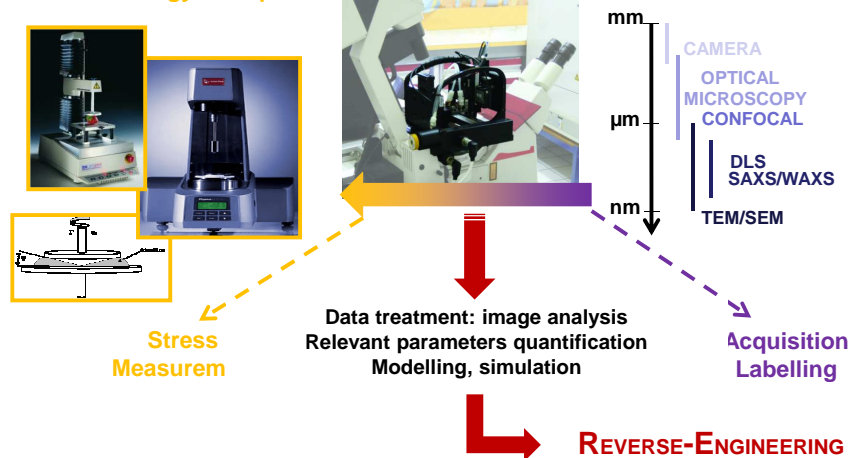
Observation = Structure



Conclusions - Perspectives

Rheology = Properties

Observation = Structure



Applications: foams, dairy systems, biofilms, paints...

Thanks for your attention