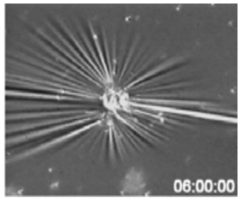
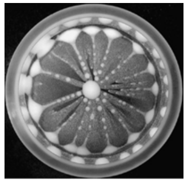
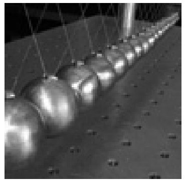
Materials far from equilibrium
Universidad de Santiago de Chile.

•Cell mechanics
(R. Bernal, Pramod P.
Germany.)

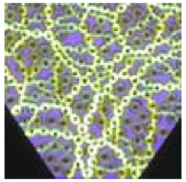




•Dynamics of vibrated grains.
Droplets forming (with L. Caballero)



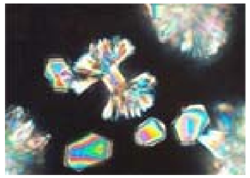
•Solitons and sound in granular materials
(with S. Job)



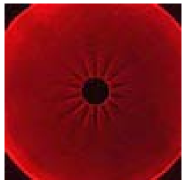
•Gravity flows and segregation
Exp. and Num. studies, with F. Vivanco

•**Mechanical properties:**
•Speckle for displacement field (with E. Hamm)
•Acoustical methods for soft materials, J-J. Ammann.
•Mechanics of bioceramics with (E. Hamm, V. Apablaza.)

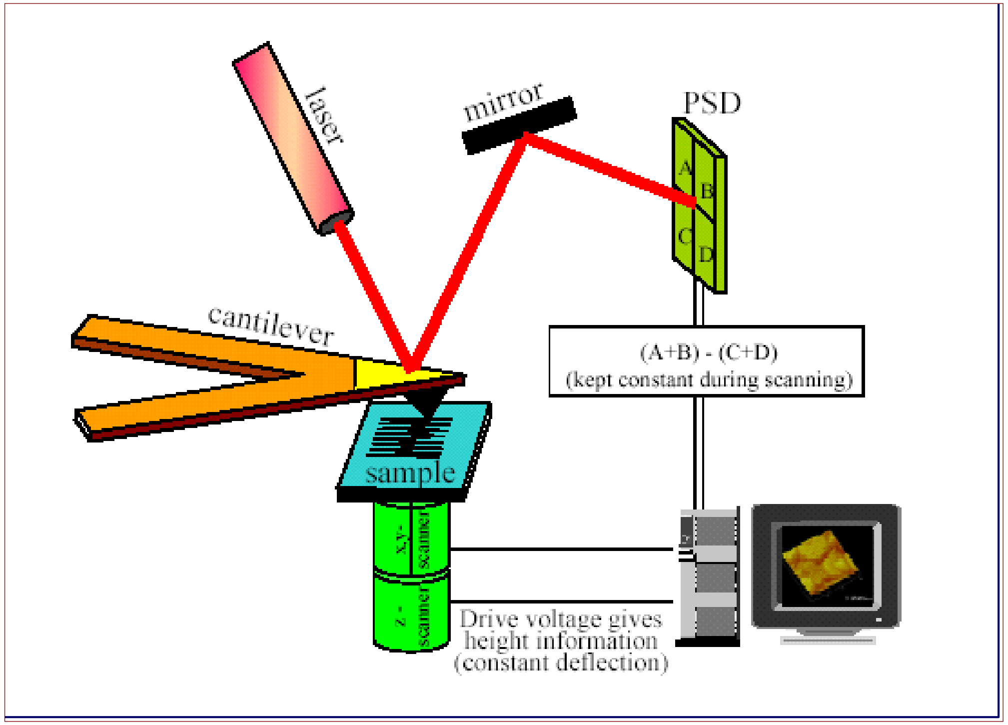
•Cristal growth (with J. Pavez)
Atomic force microscopy techniques

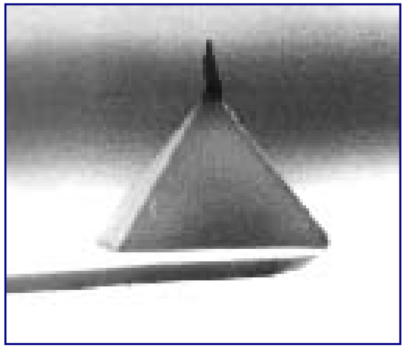


•Wrinkling in elastic
membranes: (with J.C. Geminard)

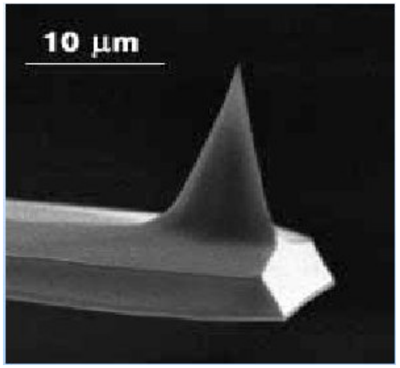


•*Crystal growth: Atomic Force microscopy:*





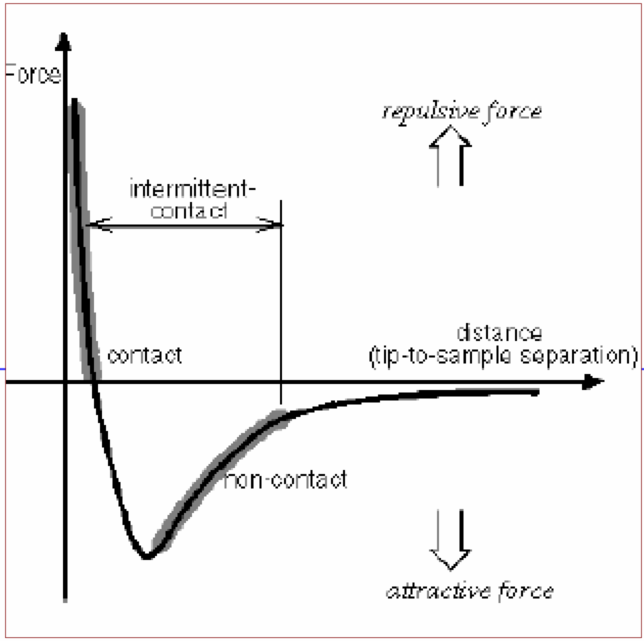
Tips: N_4Si_3 ;
0.06 y 0.58 N/m.

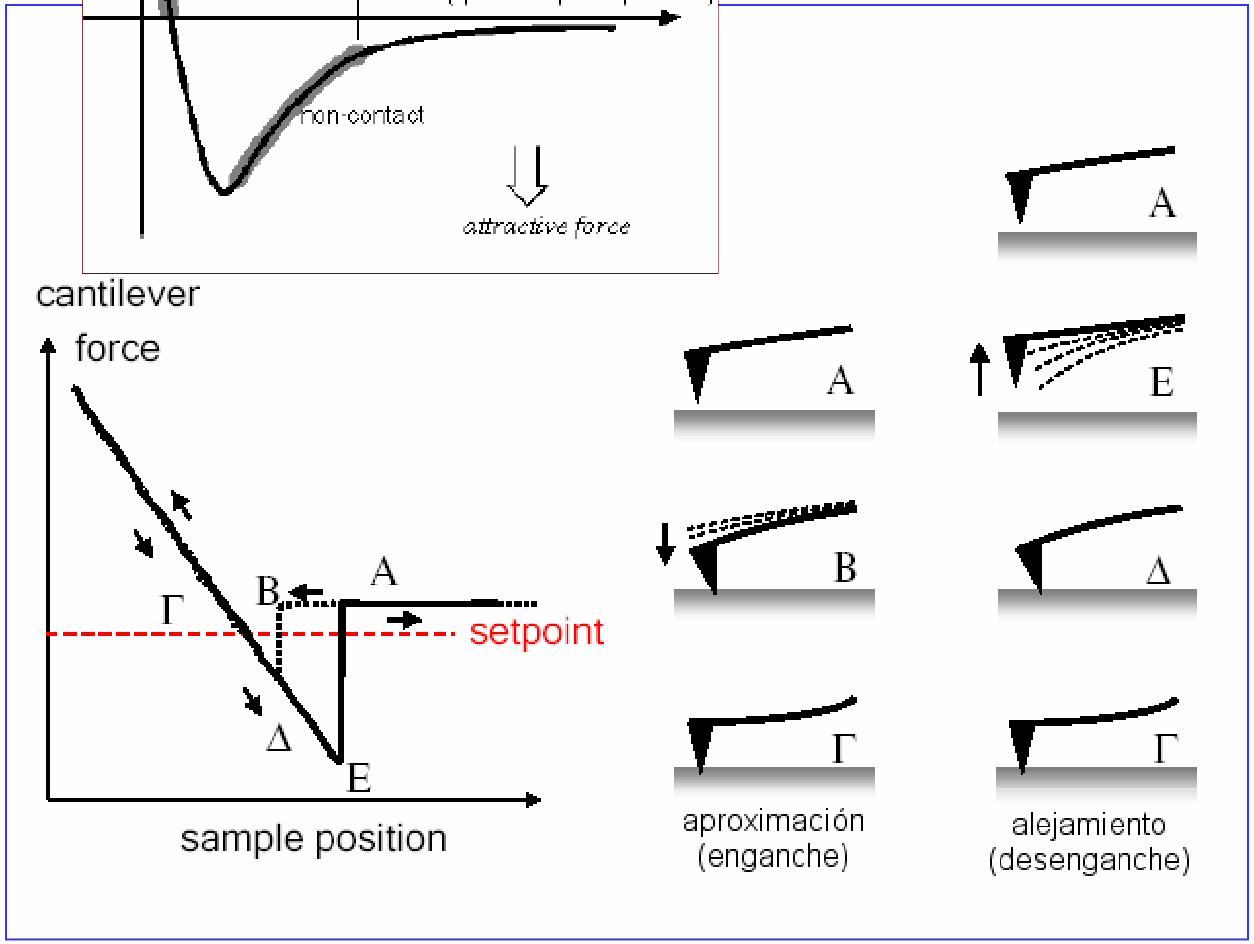


Lateral resolution: 1-5 nm.
Vertical resolution: <0.5 Å. Thermal noise!

$$z_T = m_S \frac{l_T}{3d_S}$$

Tip substrate interactions: Force Vs distance





F Vs d depends on
-Adhesion
-pH, solution
-Solution salt concentration

-Elasticity

$$d = z + \delta$$

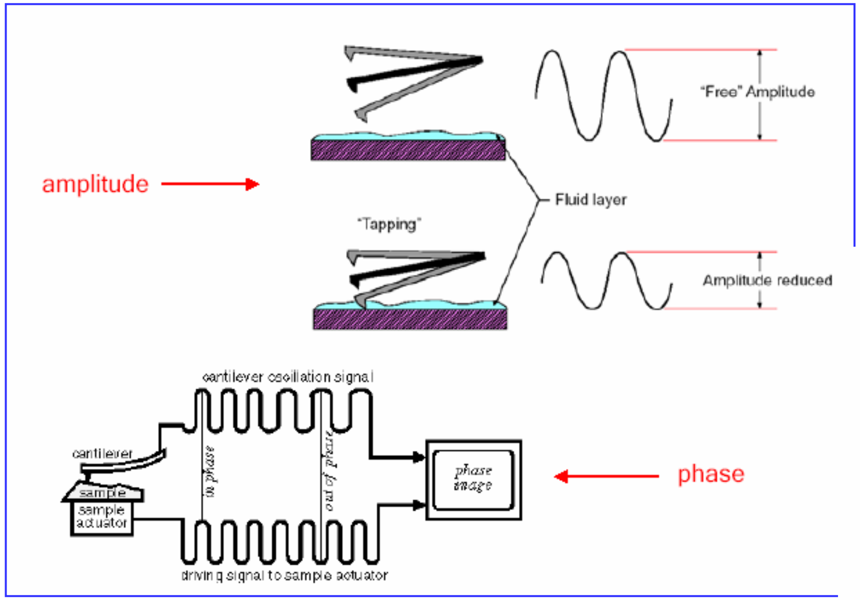
$$F_T = k_T z$$

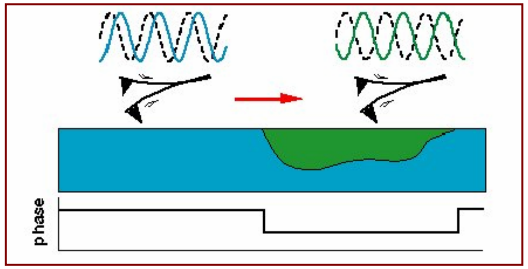
$$F_S = k_S \delta^{3/2}$$

$$d = z + k\left(\frac{k_T}{k_S} z\right)^{2/3}$$

Useful to detect soft coating on hard substrate.

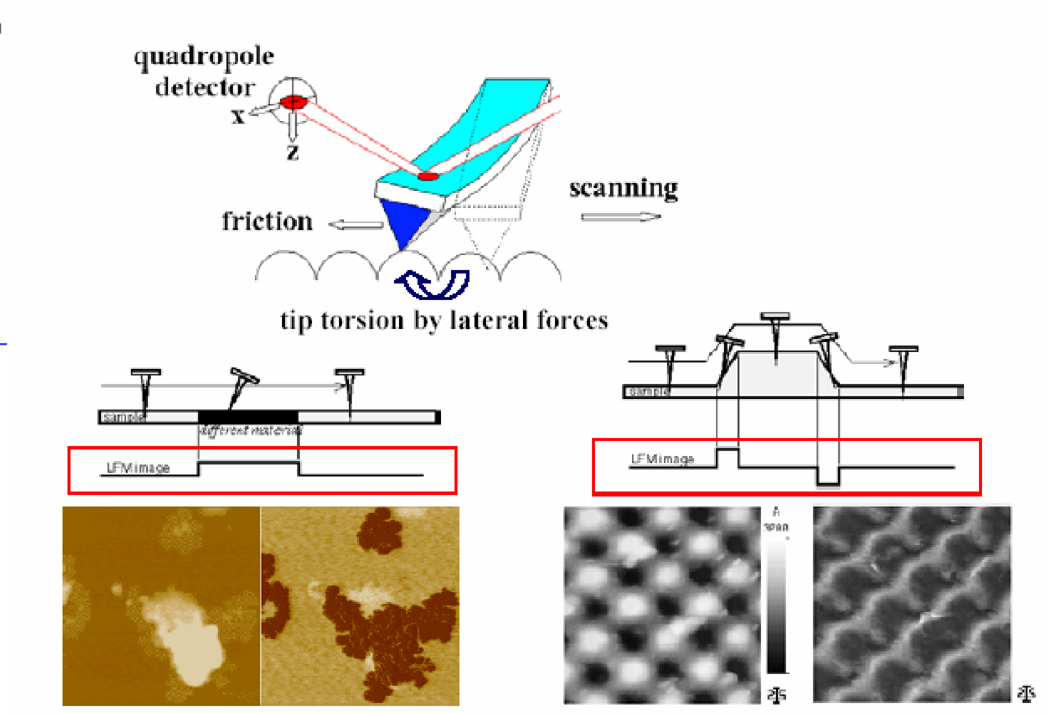
∗*Tapping for soft materials*





Phase

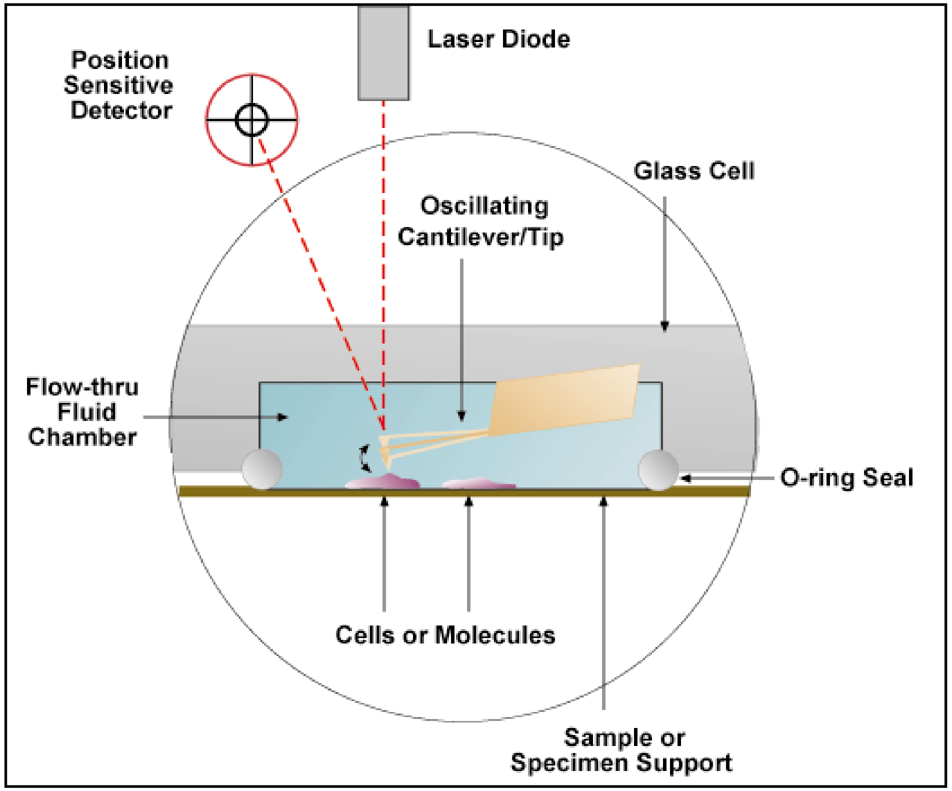
∗*Contact mode and lateral force*

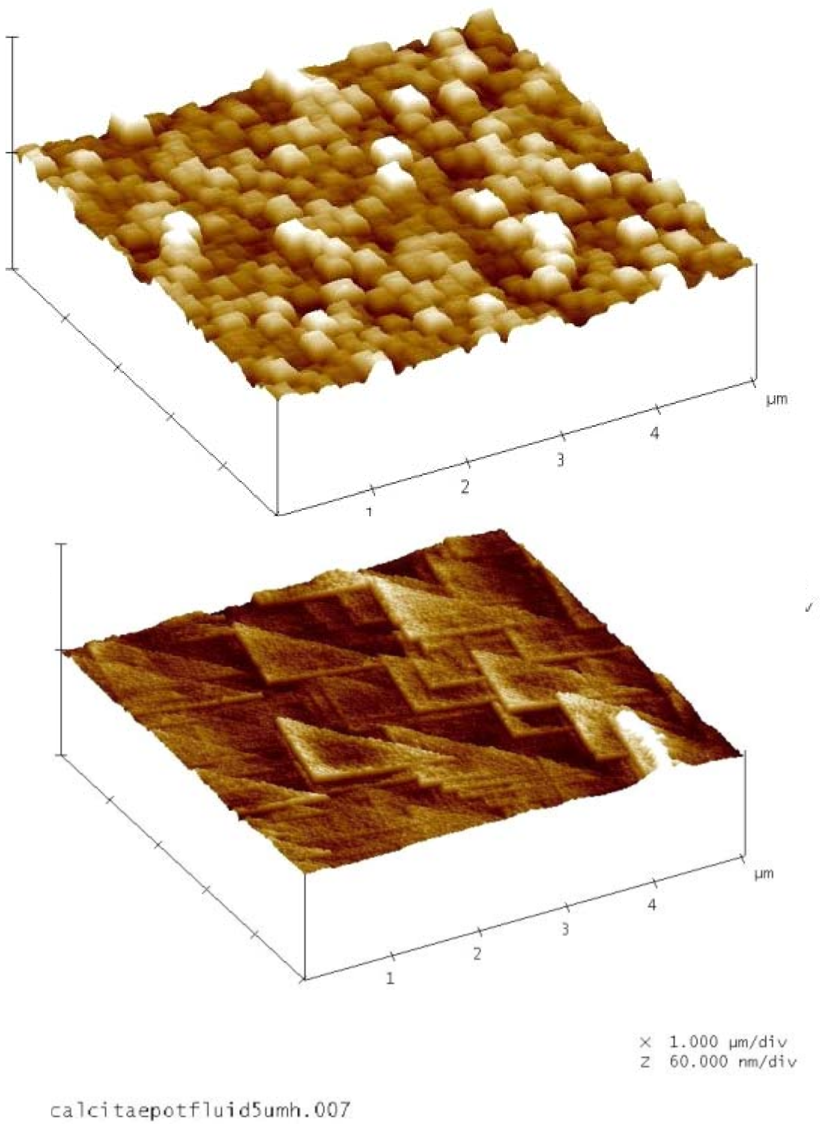


Langmuir-Blodgett-film (1µm-scan)
Topography (left) and LFM (right)

mica surface (3nm-scan)
Topography (left) and LFM (right)

Crystal growth: In situ experiments. (J. Pavez).



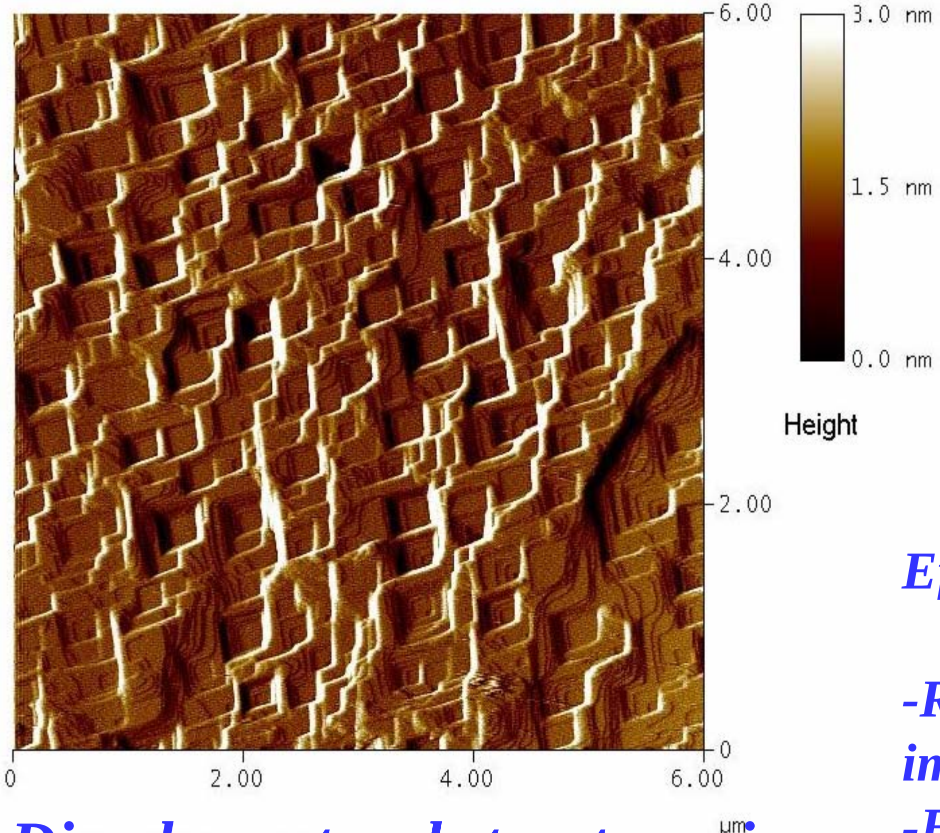


Injection of fresh solution and direct observation of the surface time evolution.

Ongoing research.

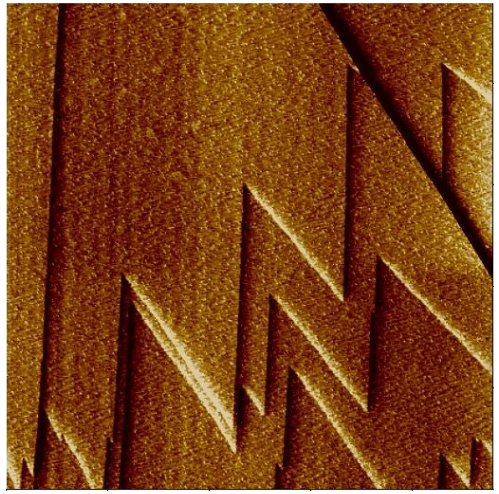
-Calcium Carbonate dissolution and growth, afm in situ.

Unsaturated solution



Dissolve natural structures in situ to reveal natural growth processes.

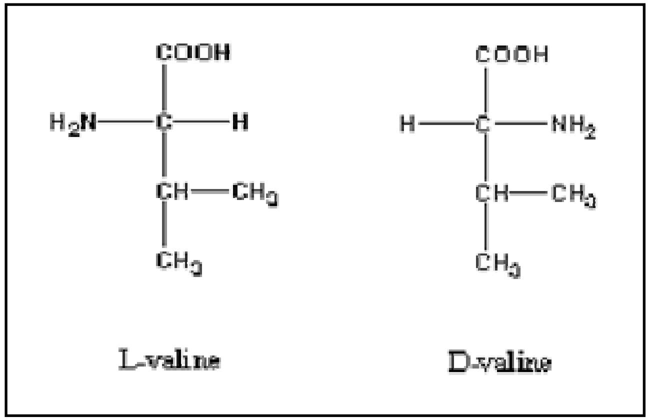
Supersaturated solution

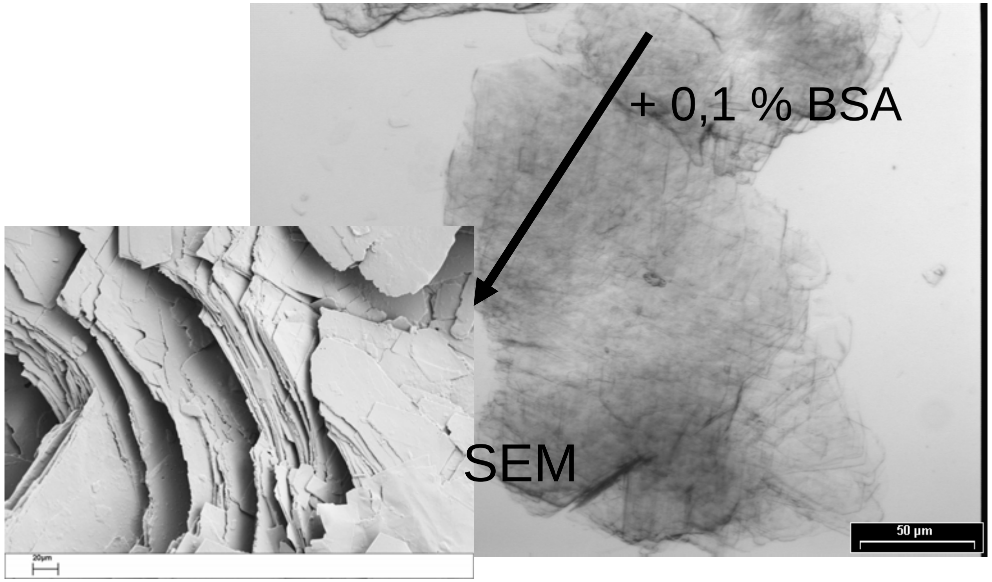


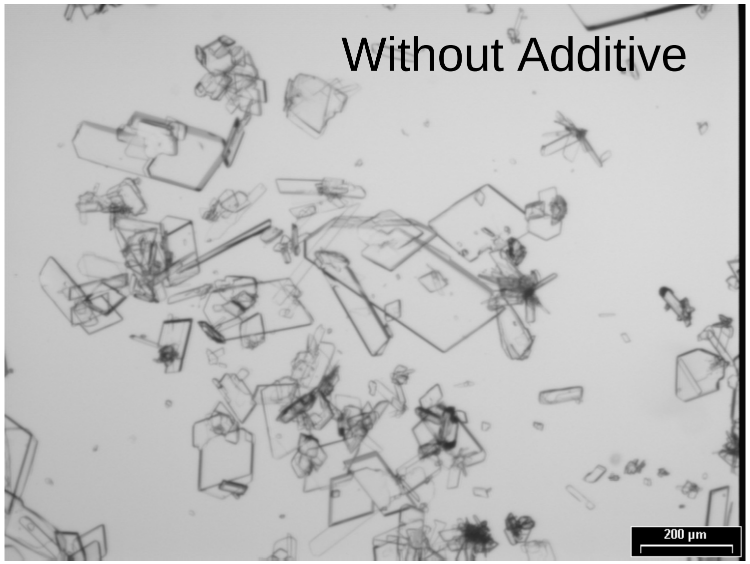
Effects on surface growth:

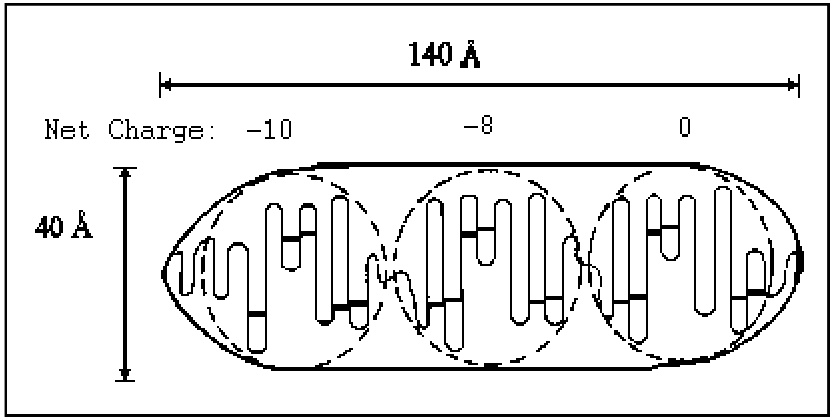
-Rough transition of steps due to impurities.
-Elastic effects, large distortions due to inclusion of large molecules.
-Sulfated macromolecules as in J. L. Arias talk: Macroscopic shapes, kinetics…

System Valine/BSA: Composite Nano sheet (H. Coelfen)



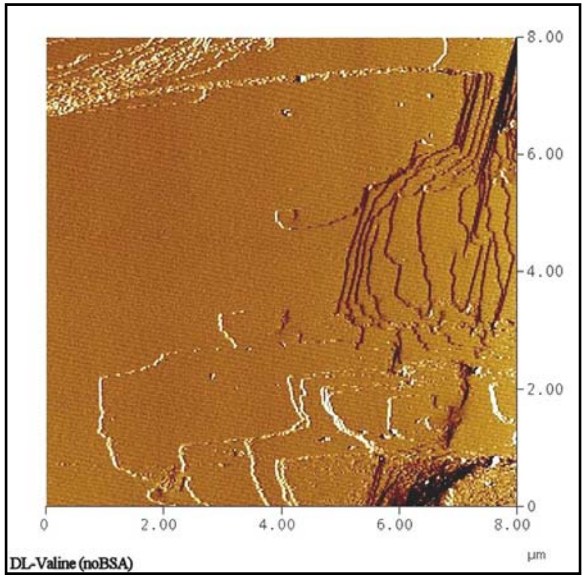


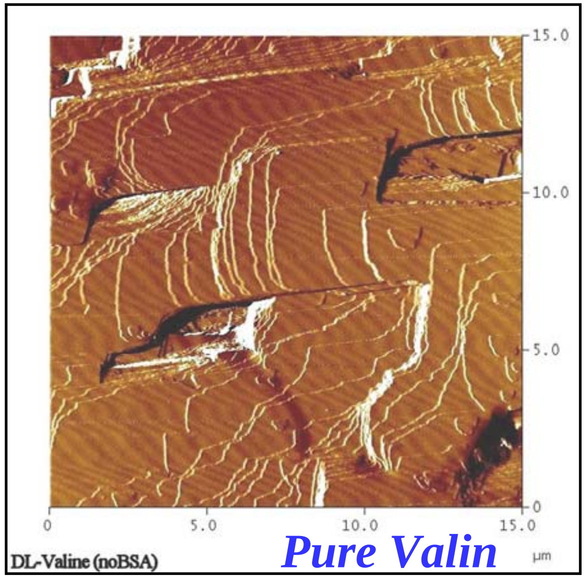




What selects the nano sheets thickness?

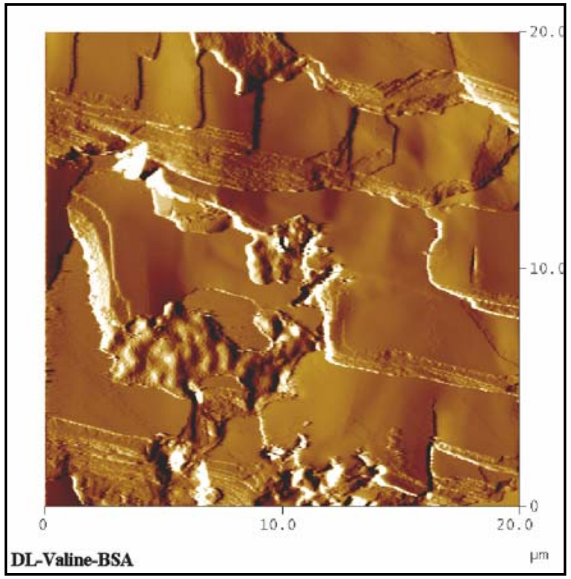
System Valine/BSA: growth at atomic scale





Pure Valin

With BSA



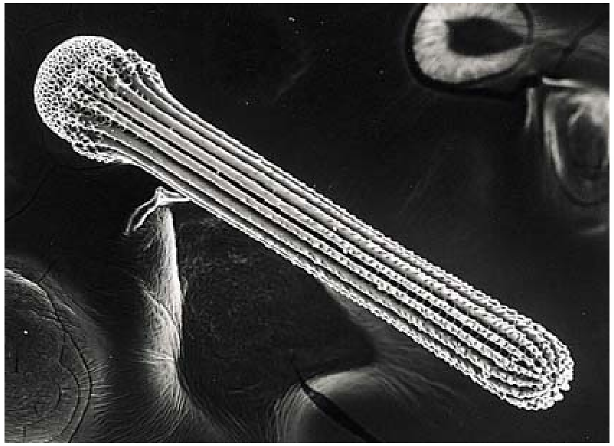
Friction in progress

Two dimensional nucleation of islands, screw dislocations. Model TLK. ***Step roughness on screw dislocations depends on organics molecules***

Effect of BSA:
Difficulties at high concentration of BSA.
Several T quenching

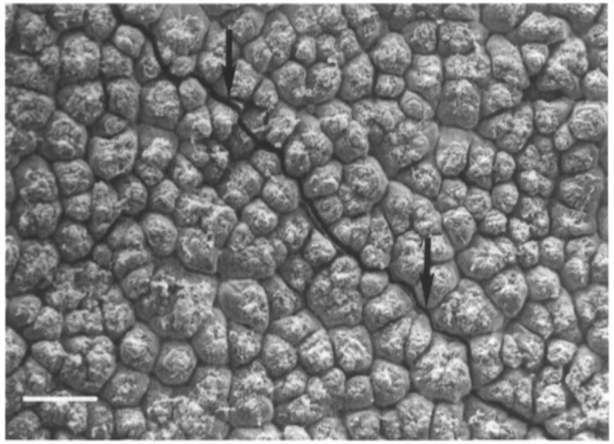
Mechanical properties of bio ceramics.

Spines



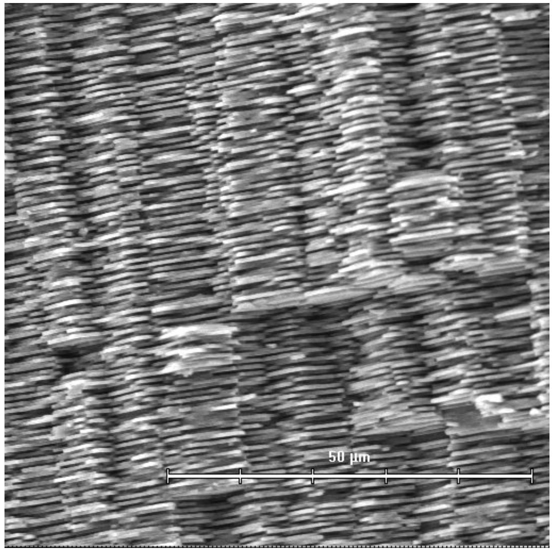
It seems adapted to minimize bending.

Egg shells



Package: not clear what optimizes

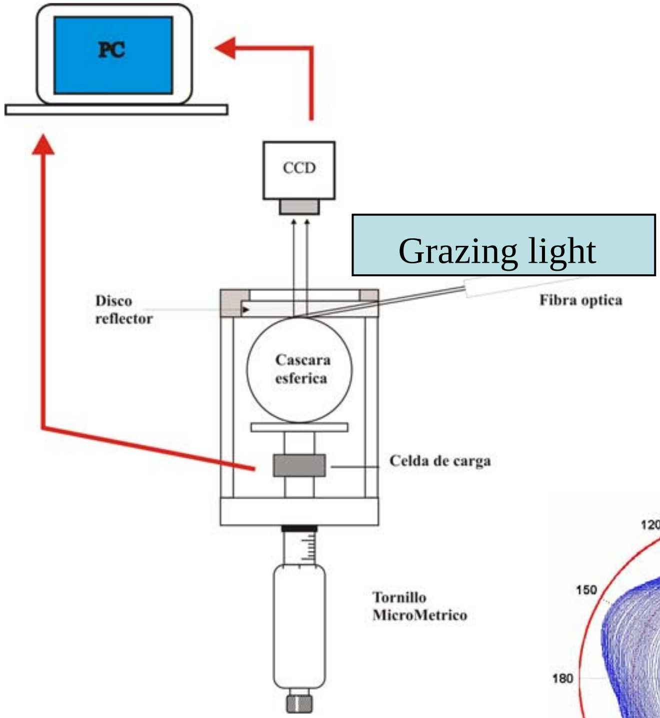
Nacre shells

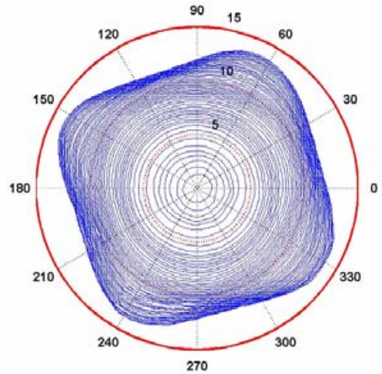


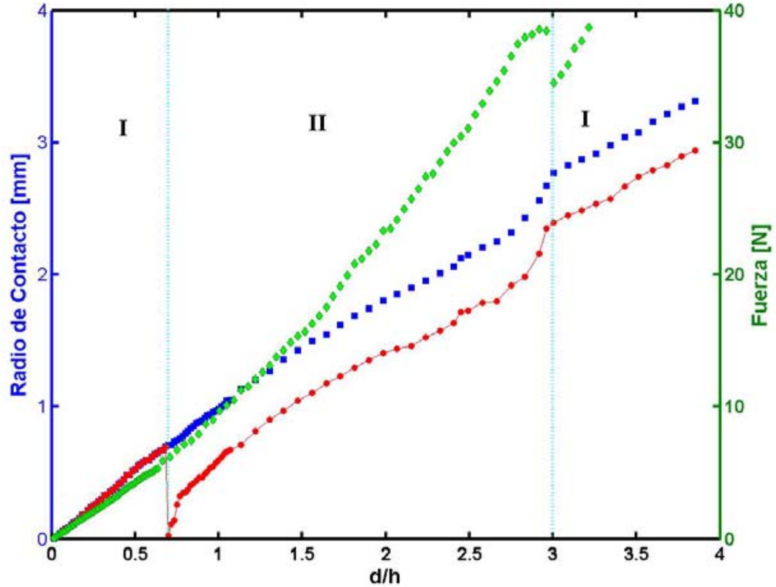
High fracture resistance.

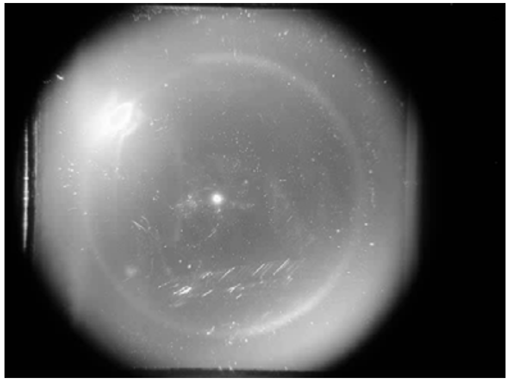
Question: The role of the intermediate structures on the mechanical properties.

Ping pong shells: mimic egg shells





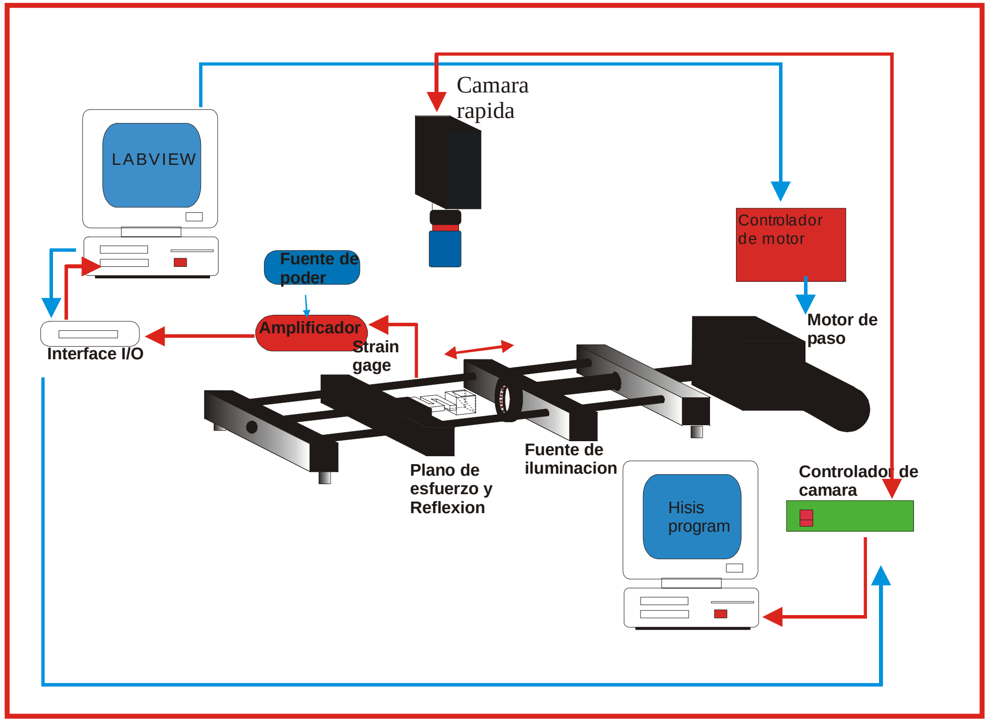




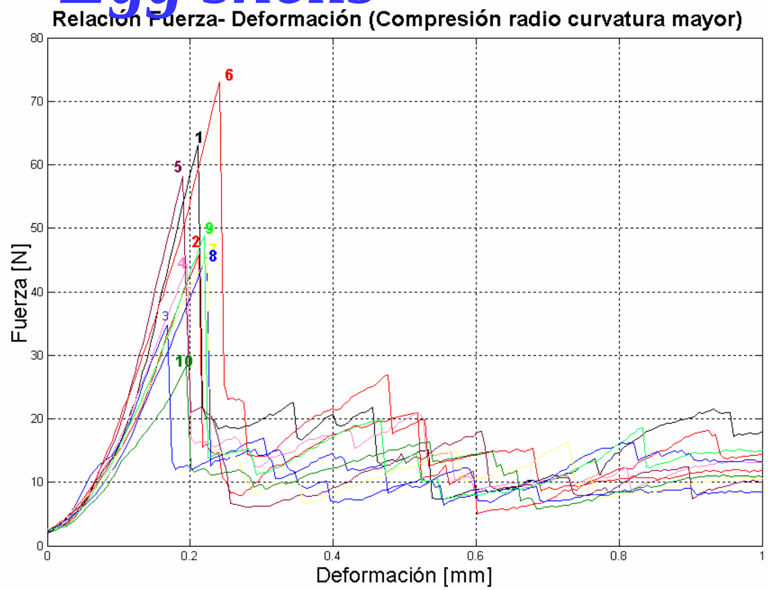
Contact zone in white

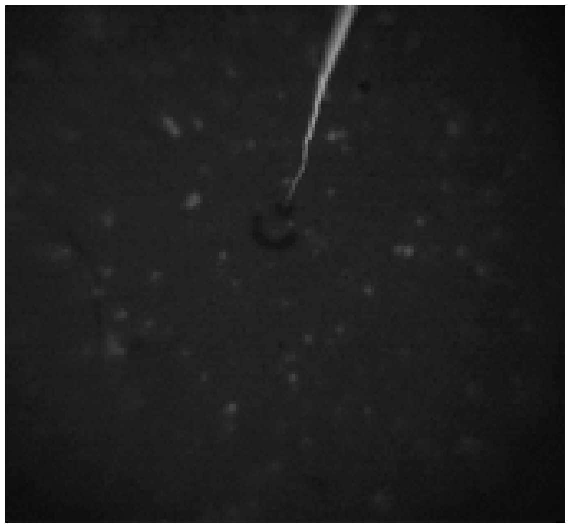
The contact region is unstable: bending and stretching competition

Egg Shells: Elasticity



Egg shells



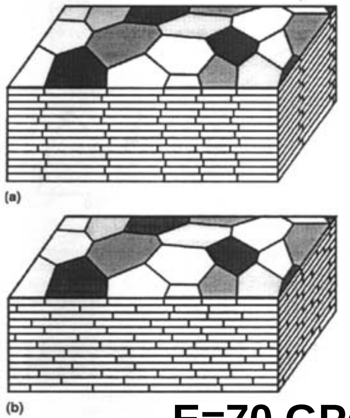


-The egg shell fracture is likely to be a result of an instability which is sub critical at constant force.
-Theory predicts a higher value of deformation for the instability threshold.
-Threshold is independent on Young modulus.

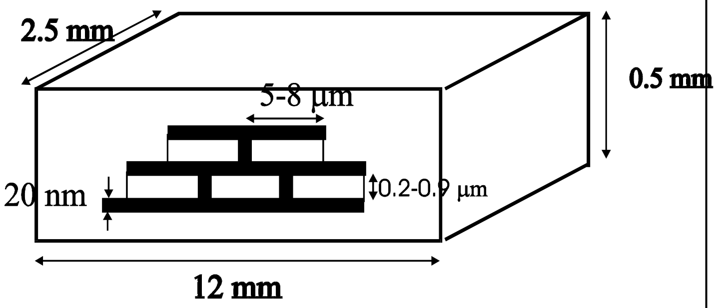
Nacre: Bases

Abalone

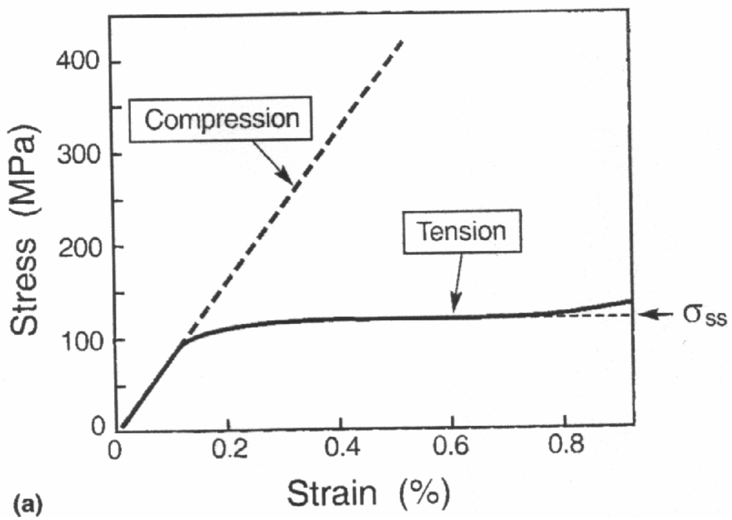
Mother of pearl

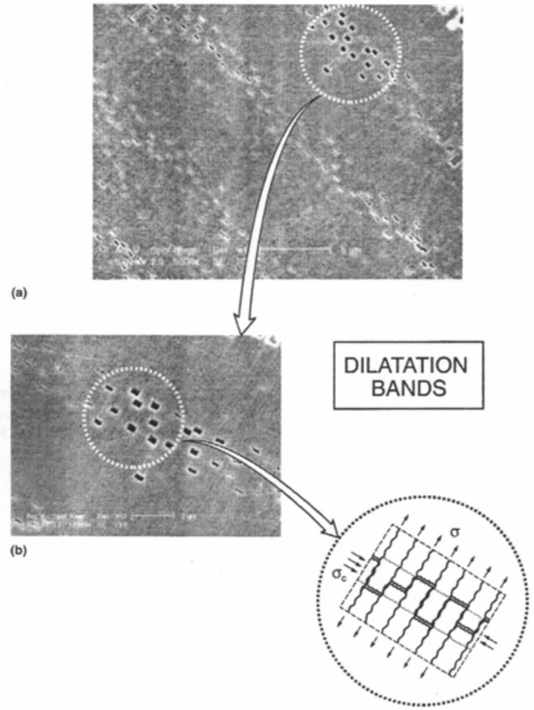


E=70 GPa

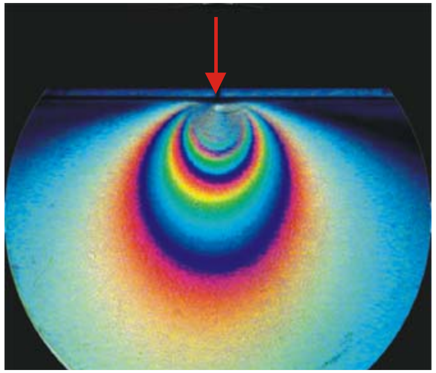


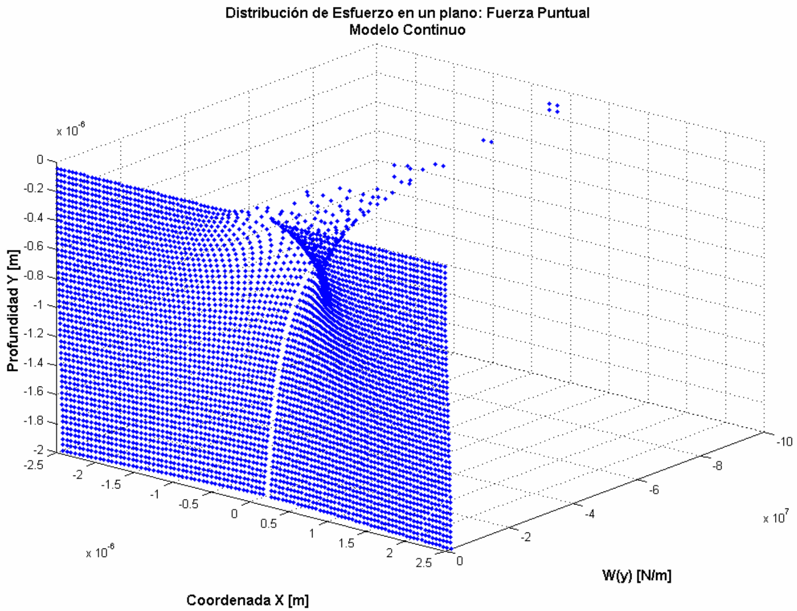
Plasticity





Isotropic solid

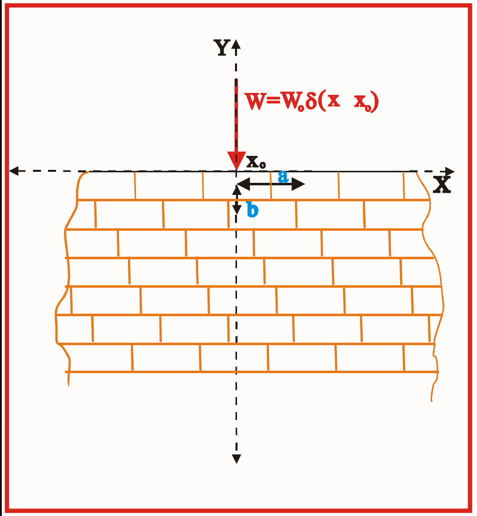


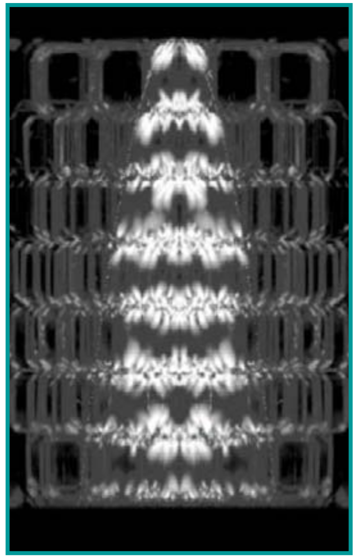


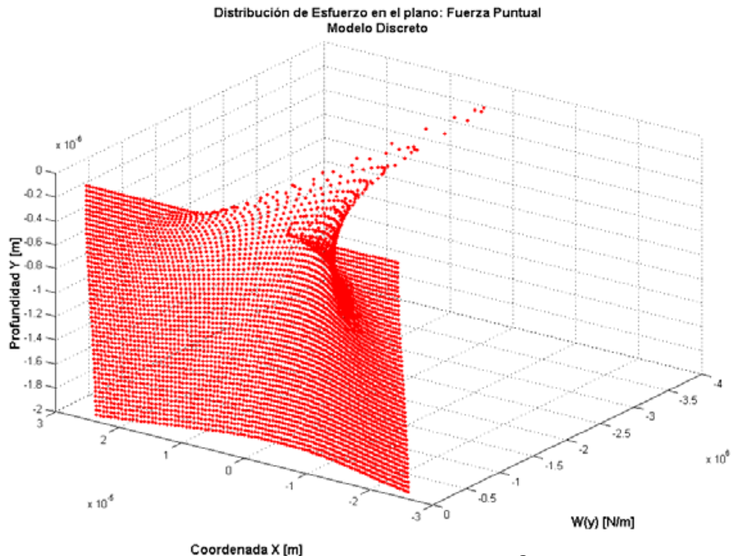
$$\sigma_{yy}(x,y) = -\frac{2P}{\pi}\frac{\cos^3\alpha}{(x^2+y^2)^{1/2}} \Rightarrow$$

$$\sigma_{yy}\Big|_{x=0} = -\frac{2P}{\pi}\frac{1}{y}$$

Nacre



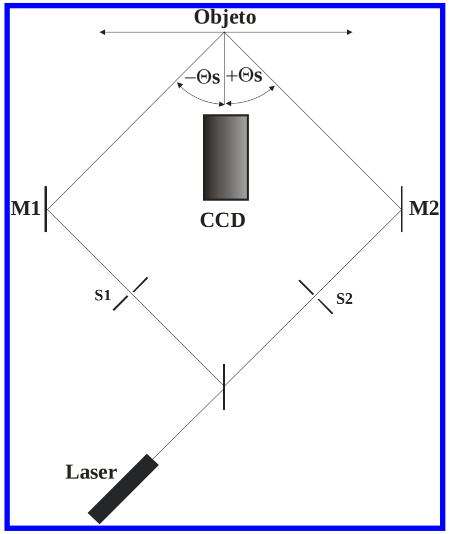


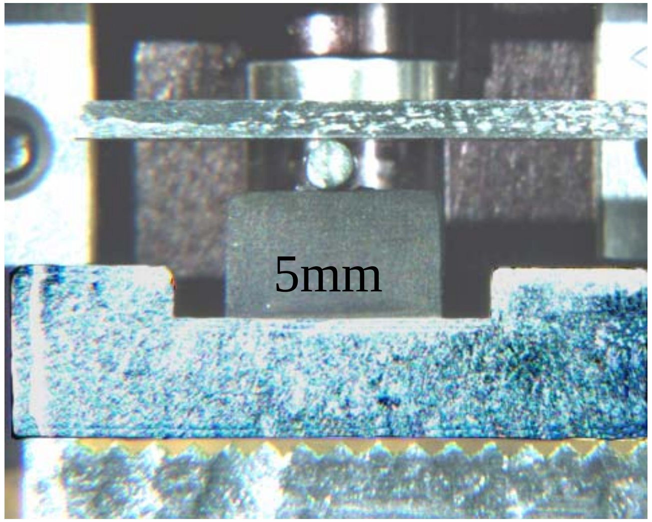


$$w(x,y) = -\frac{P}{\sqrt{4\pi D_o y}}\, e^{-\frac{(x-x_o)^2}{4D_o y}} \Rightarrow$$

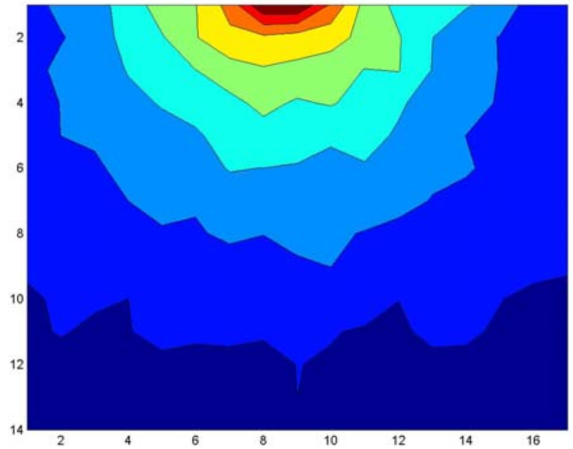
$$w(x,y)\Big|_{x=x_o} = -\frac{P}{\sqrt{4\pi D_o y}}$$

Speckles methods for small samples

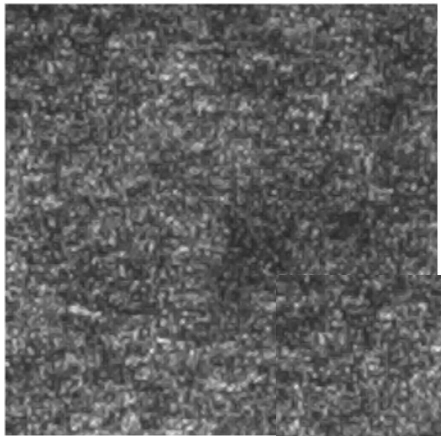




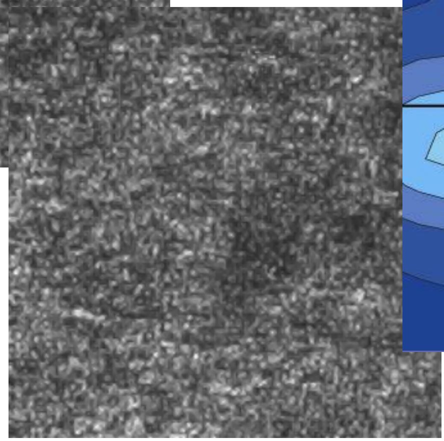
Displacement field

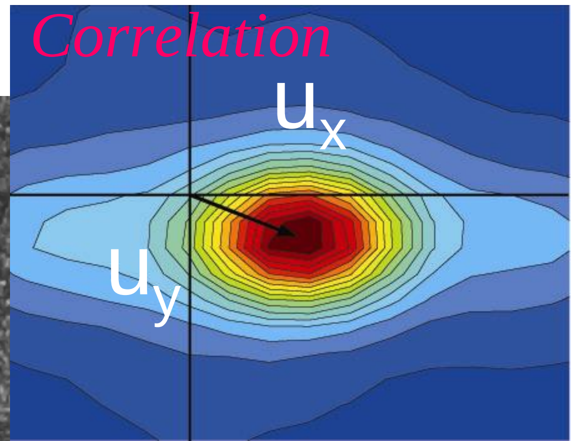


before

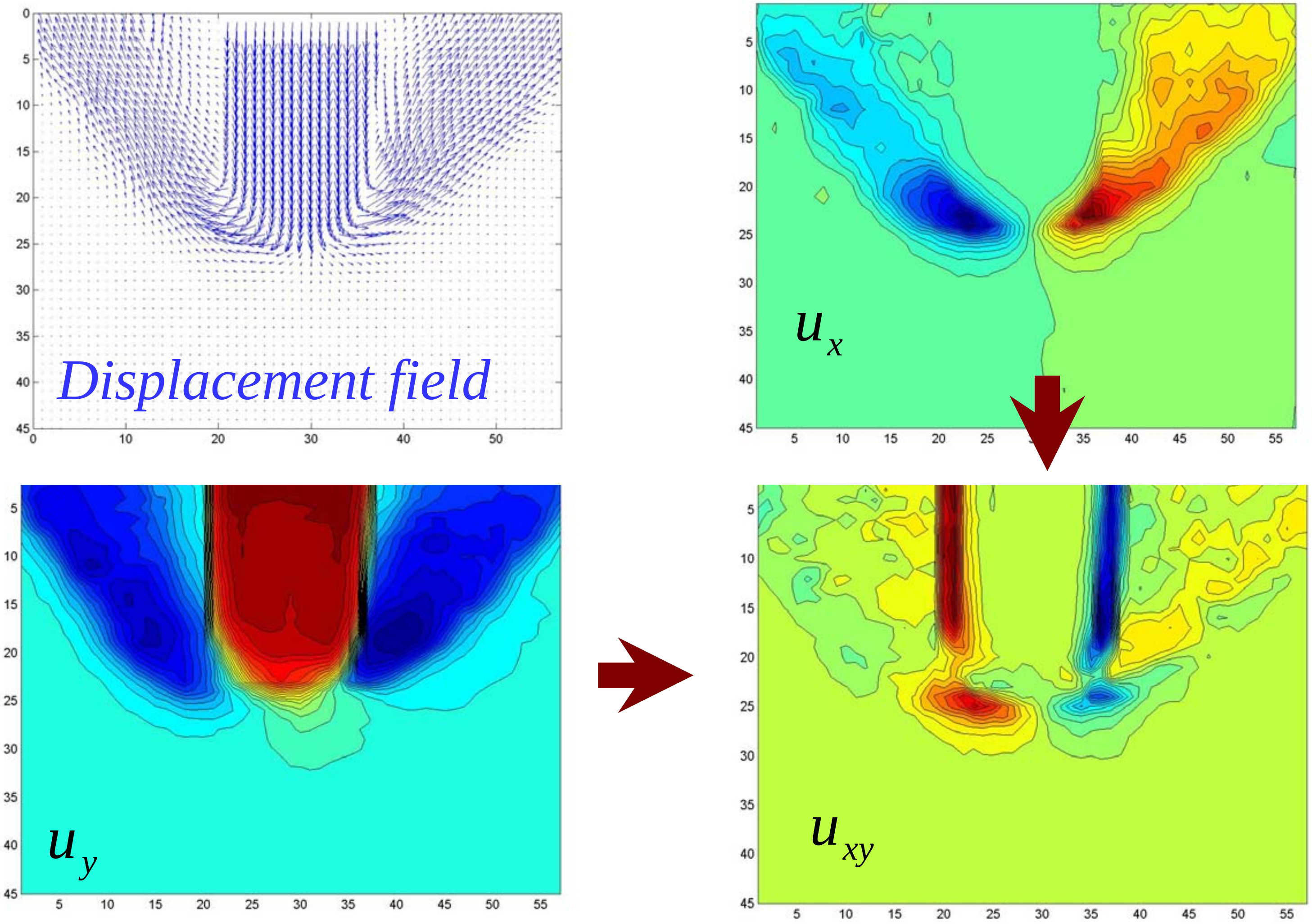


after





Plastic flows applications: granular materials



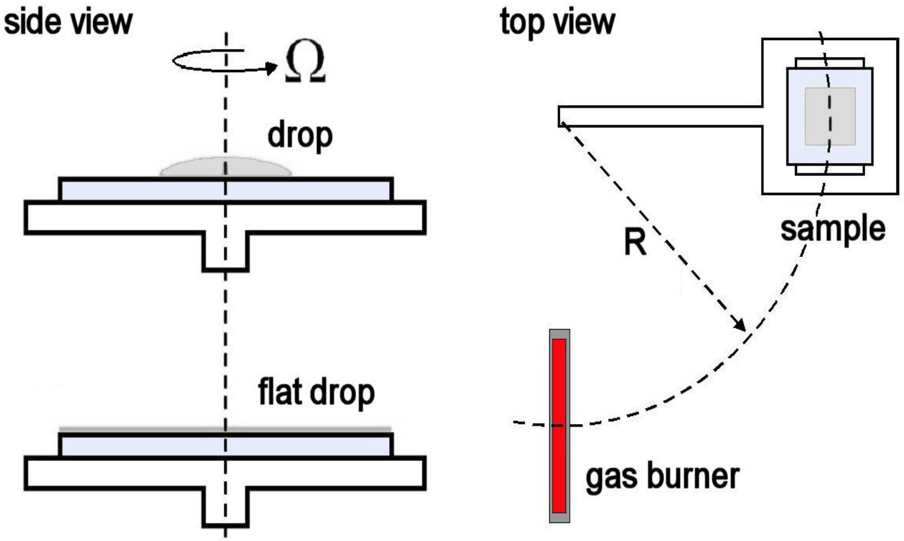
$$u_{\alpha\beta} = \frac{1}{2}\left(\frac{\partial u_{\alpha}}{\partial u_{\beta}} + \frac{\partial u_{\beta}}{\partial u_{\alpha}} \right)$$

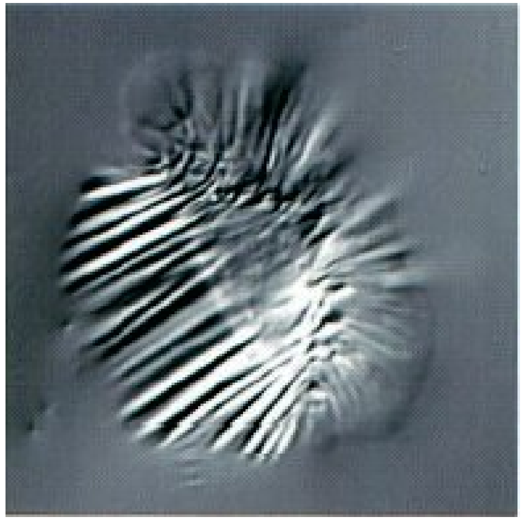
Defocusing to measure strain field: in progress

$$A_x^+ - A_x^- = 2\frac{\Delta l}{M}\varepsilon_{xx}\sin\vartheta_s$$

$$\Rightarrow \varepsilon_{xx} = \frac{M}{2\Delta l \sin\vartheta_s}\left(A_x^+ - A_x^-\right)$$

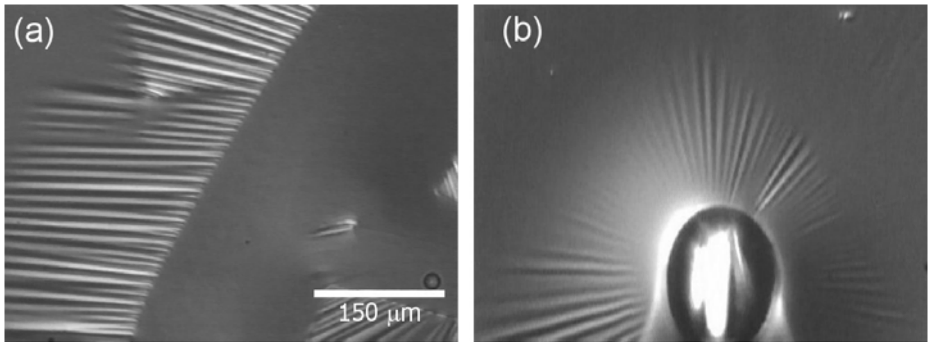
Membranes and cell mechanics

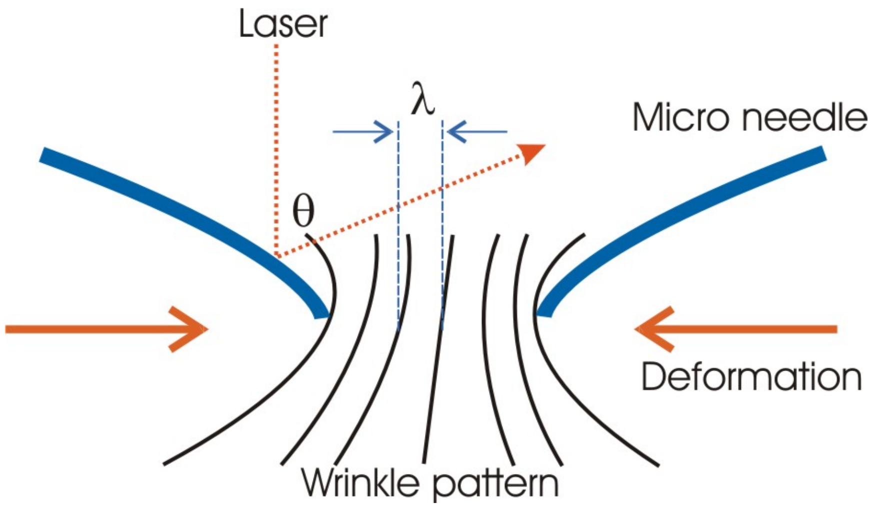




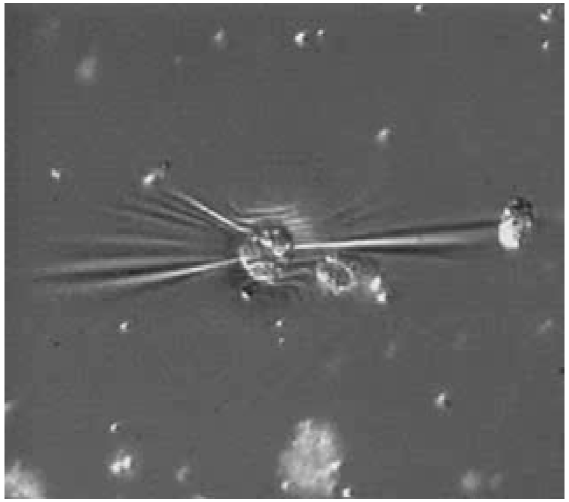
Burton K., et al.

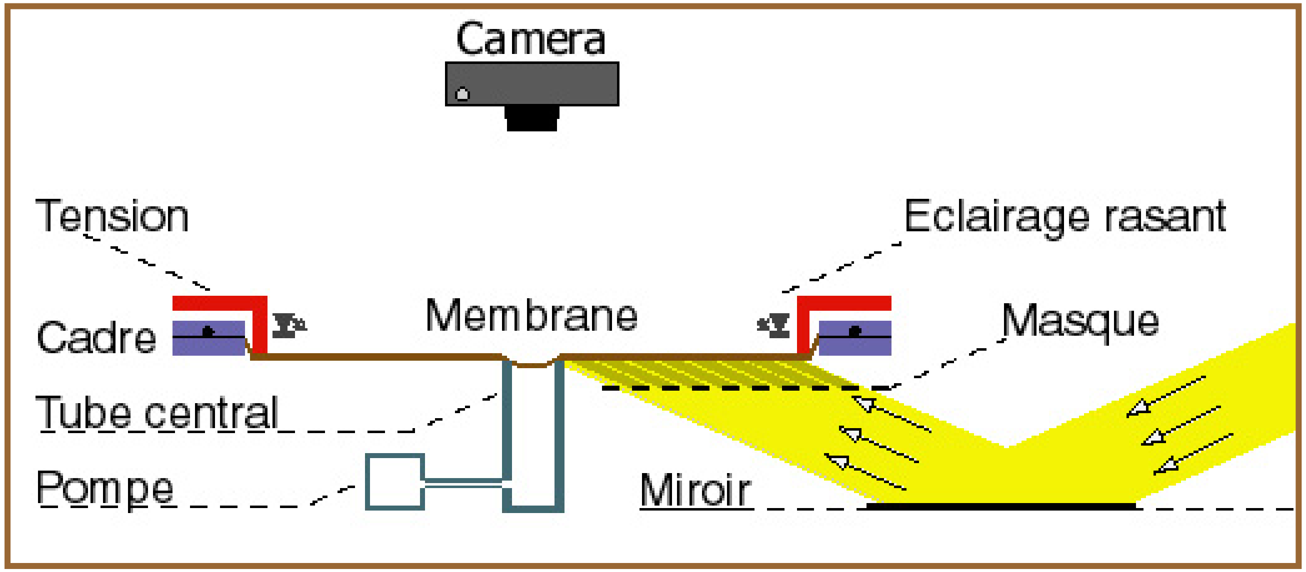
PDMS substrate

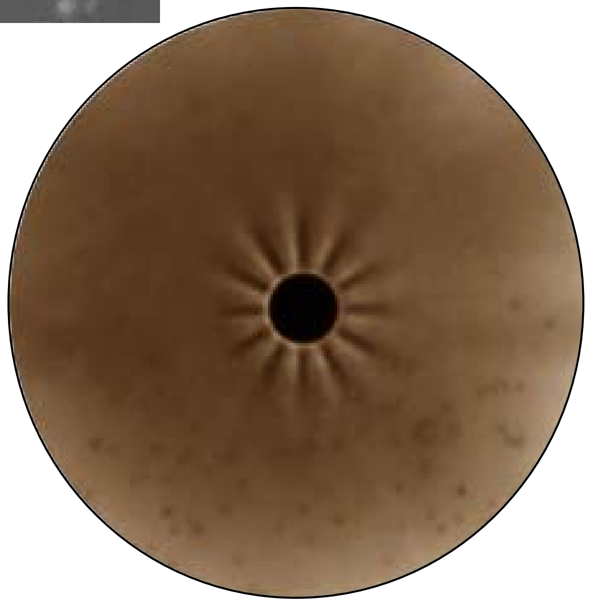


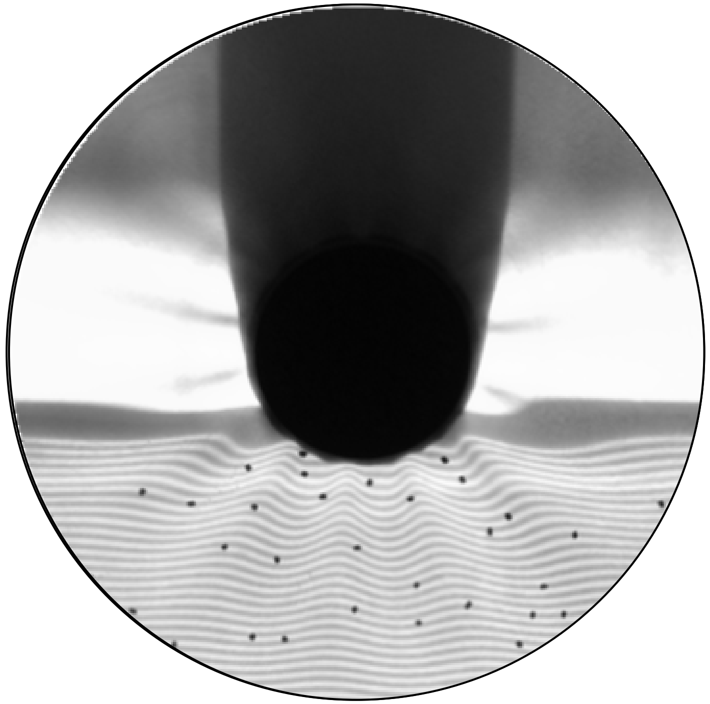


Elastic membranes under axial tension:

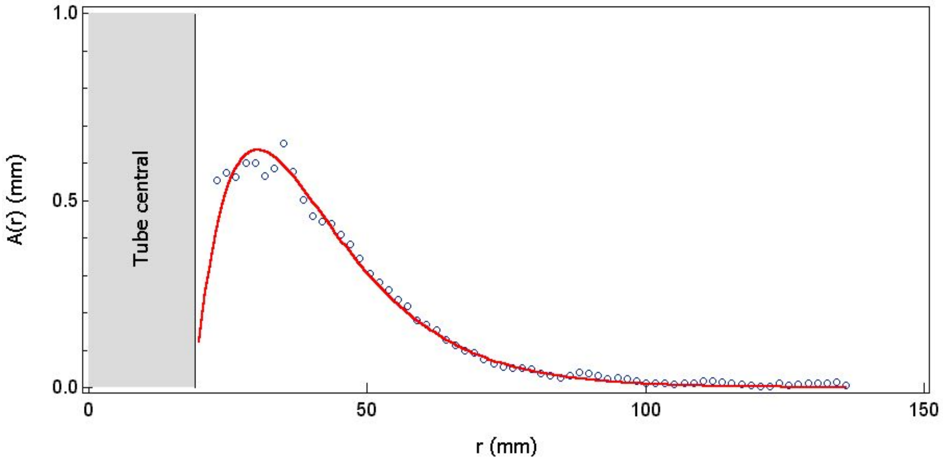


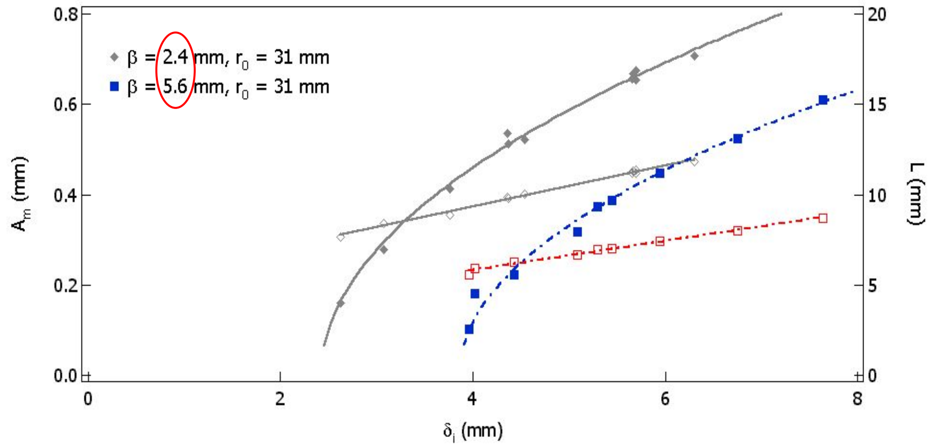


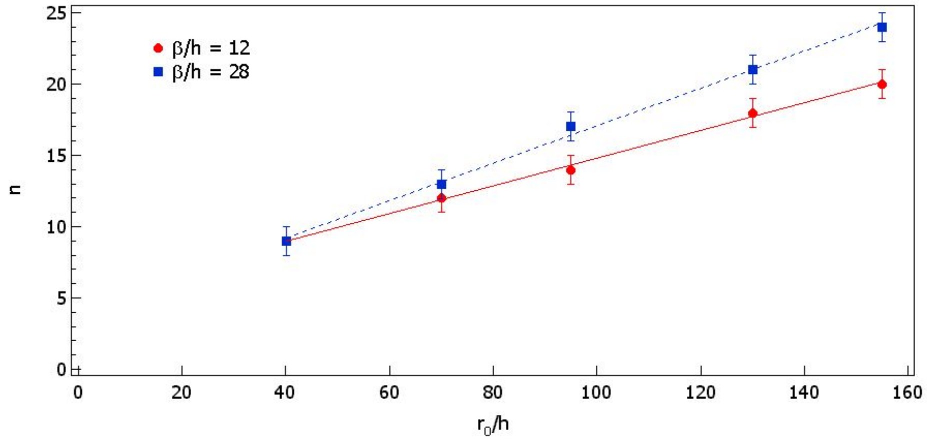




Experimental results:



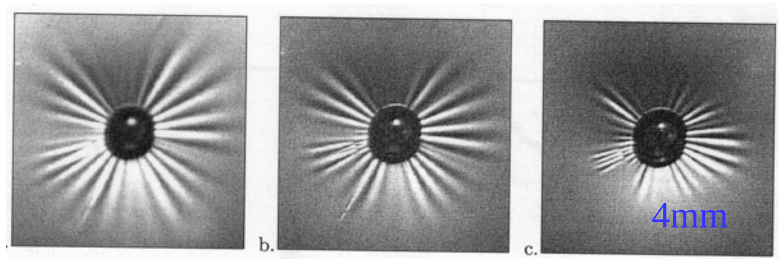




Conclusions:

-Wrinkle length not good for force measurements.

-Wrinkle amplitude much better

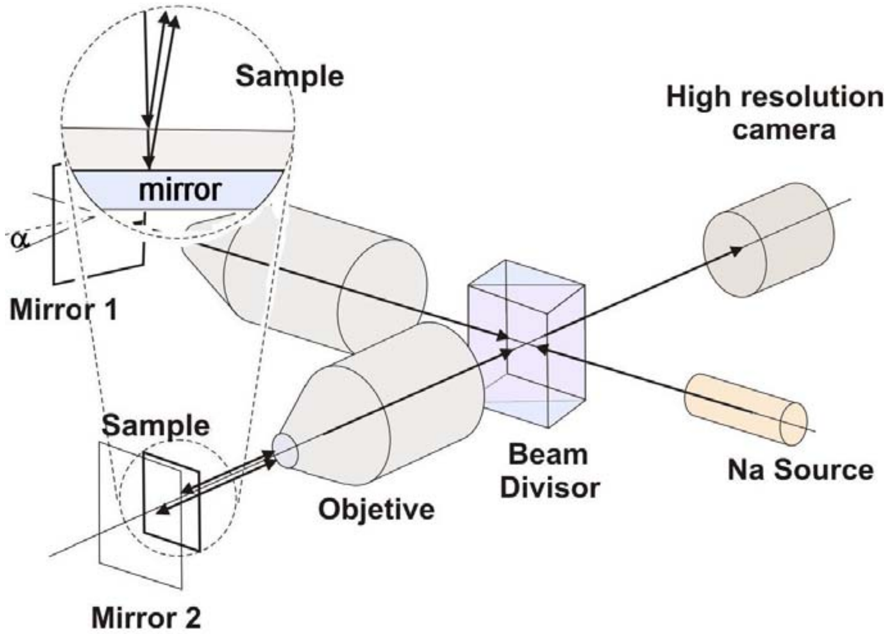


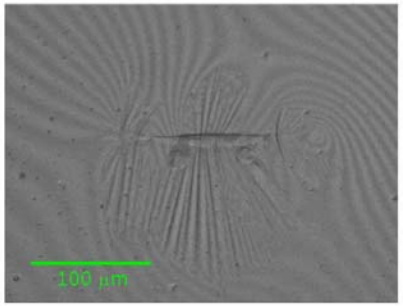
T →

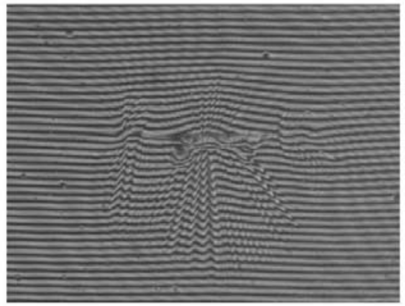
Glass transition in polymers films, Young modulus, Grenoble

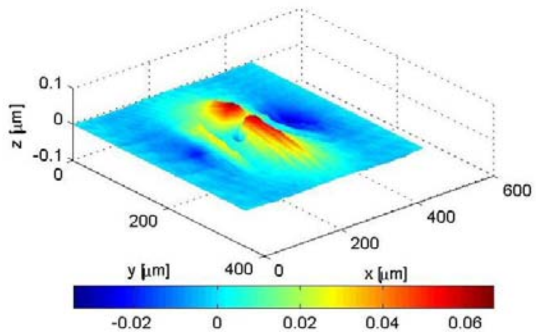
Method to measure wrinkles amplitude at cell scale.

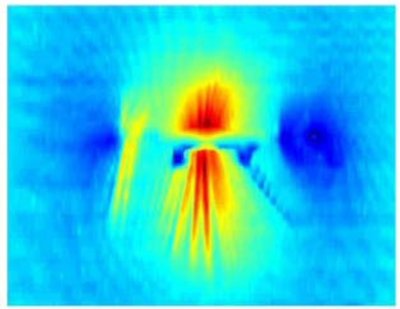
Linnix interferometer.



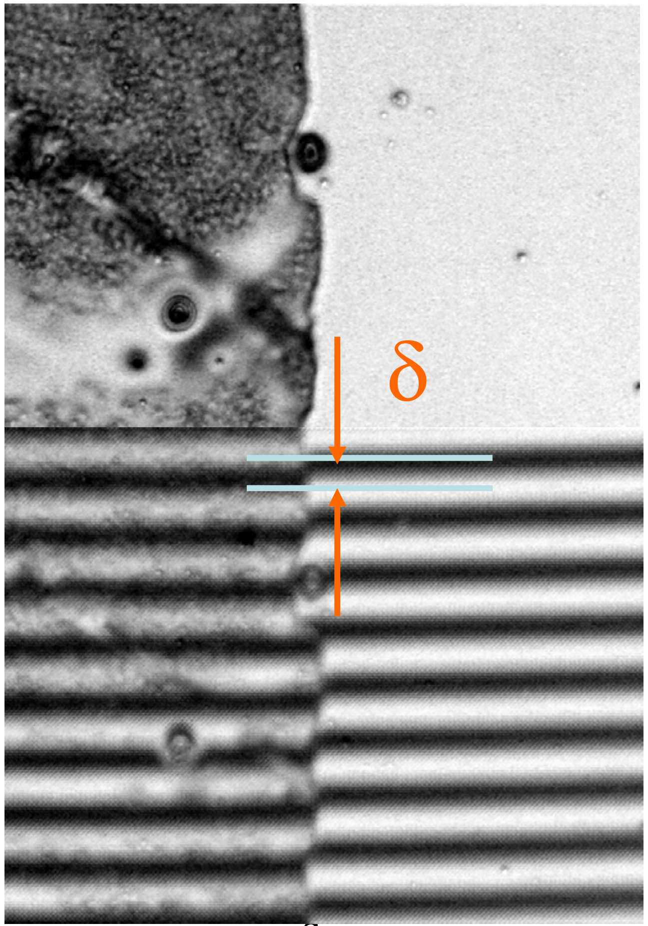




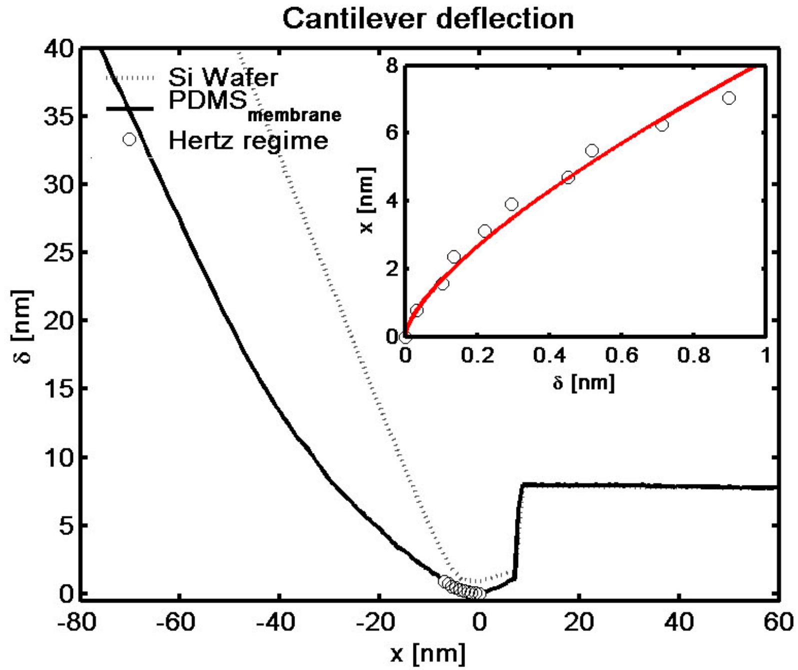




Nanometric elastic membranes
Thickness and Young modulus



$$h_{membrane} = \frac{\lambda}{2n}\delta \approx 0.1\mu m$$



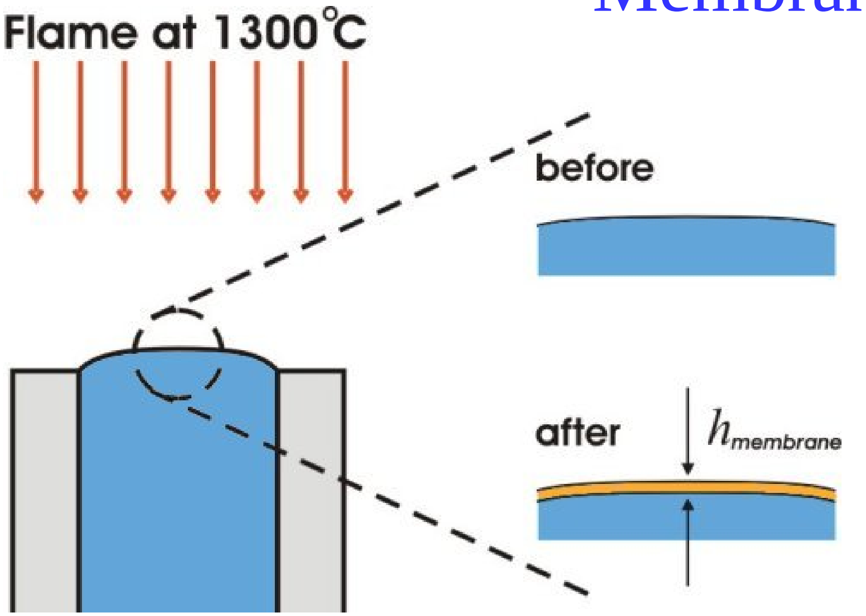
$$d = z + \delta$$

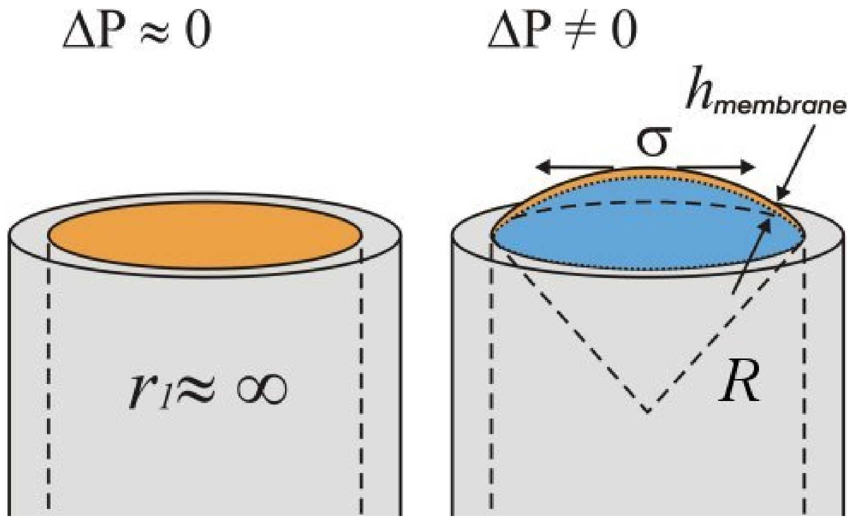
$$F_T = k_T z$$

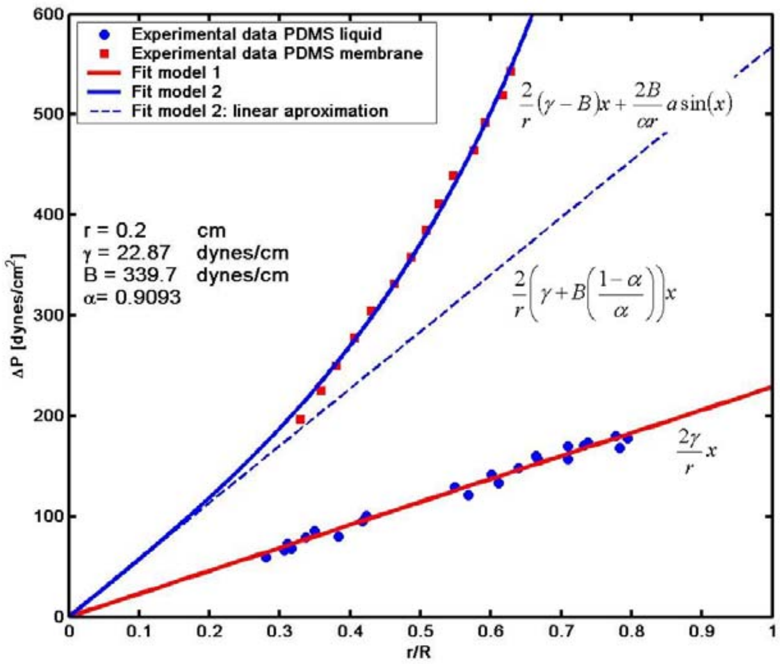
$$F_M = k_M \delta^{3/2}$$

$$d = z + k\left(\frac{k_T}{k_M} z\right)^{2/3} \longrightarrow E \cong 5MPa$$

Membrane tension







- ***The membrane is under tension.***

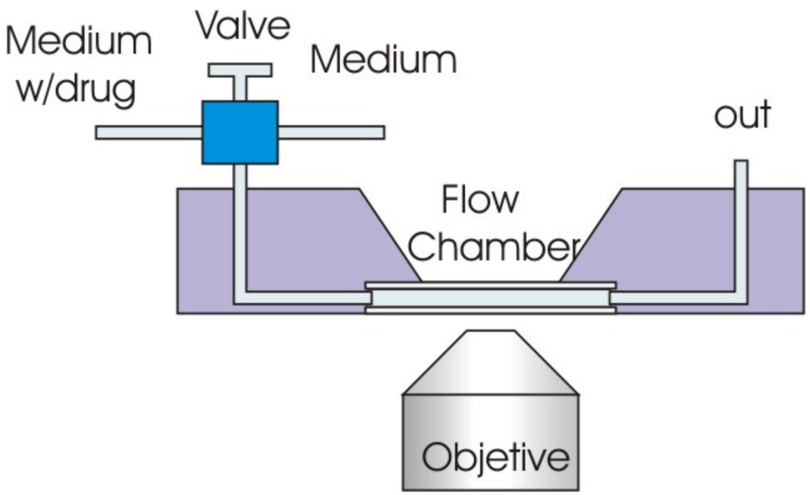
$$\Delta P = \frac{2}{R}\left(\gamma_{L-M} + B\frac{\delta l}{l_o^{'}}\right) \qquad x = \frac{r}{R}$$

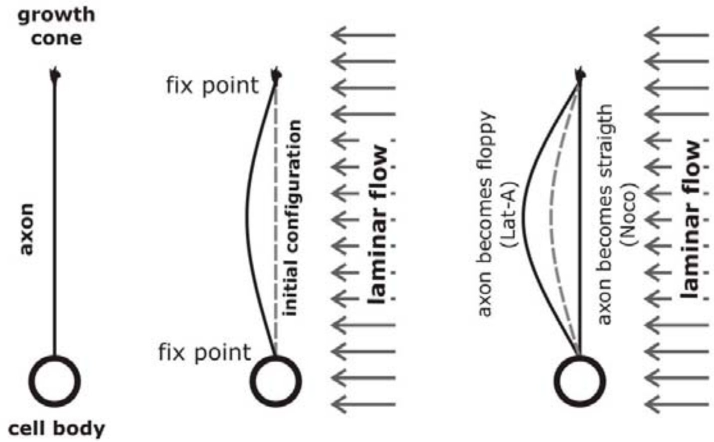
$$\Delta P = \frac{2}{r}(\gamma_{L-M} - B)x + \frac{2B}{\alpha r}\sin^{-1}(x)$$

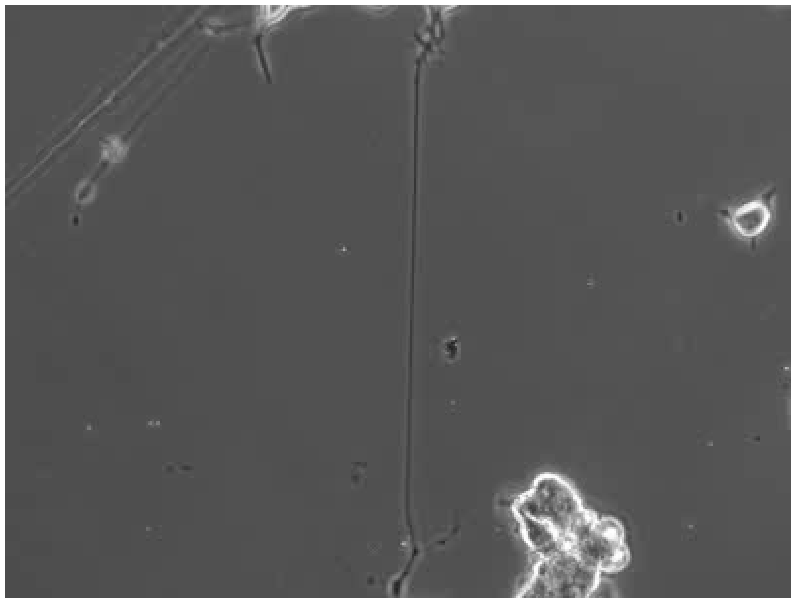
$$B = Eh \longrightarrow E \cong 5MPa$$

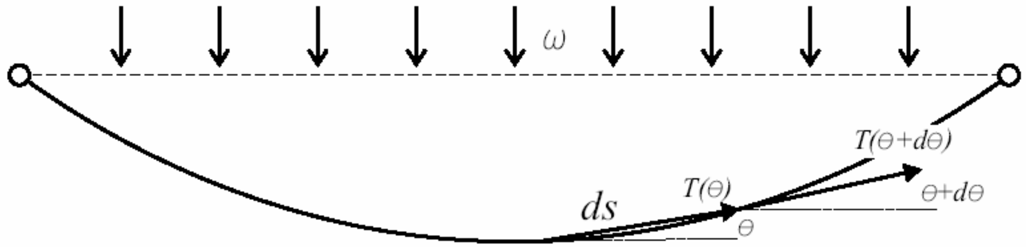
Mechanical properties of axons (R. Bernal)

Bending of axons by the effect of a viscous force









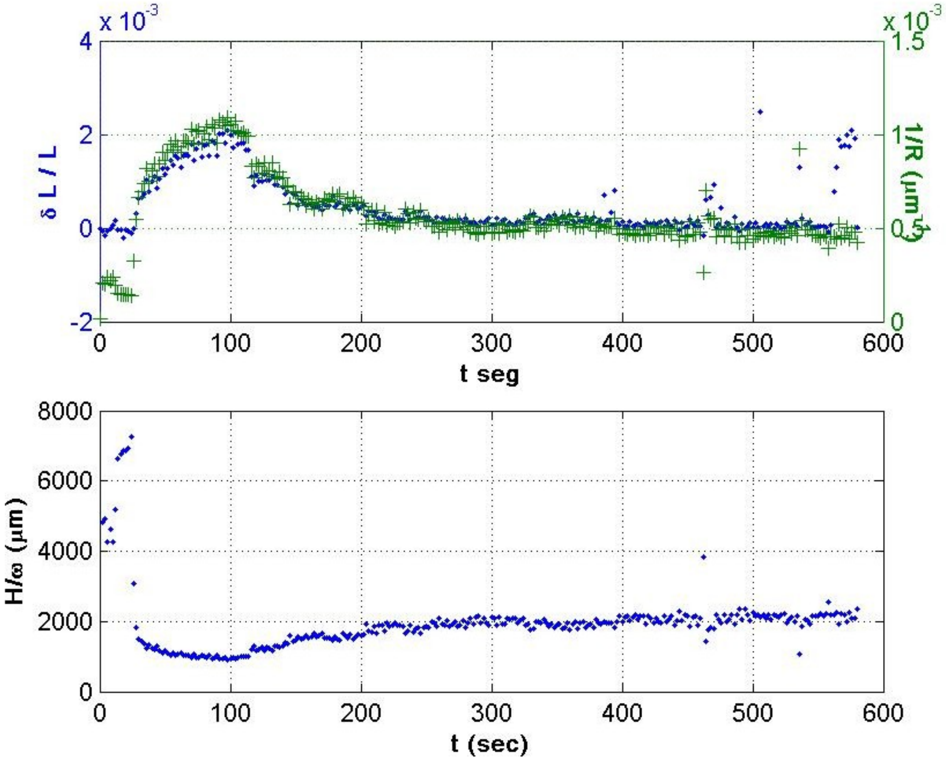
$$y(x) = \frac{H}{\omega}\cosh\left(\frac{\omega}{H}x\right)$$

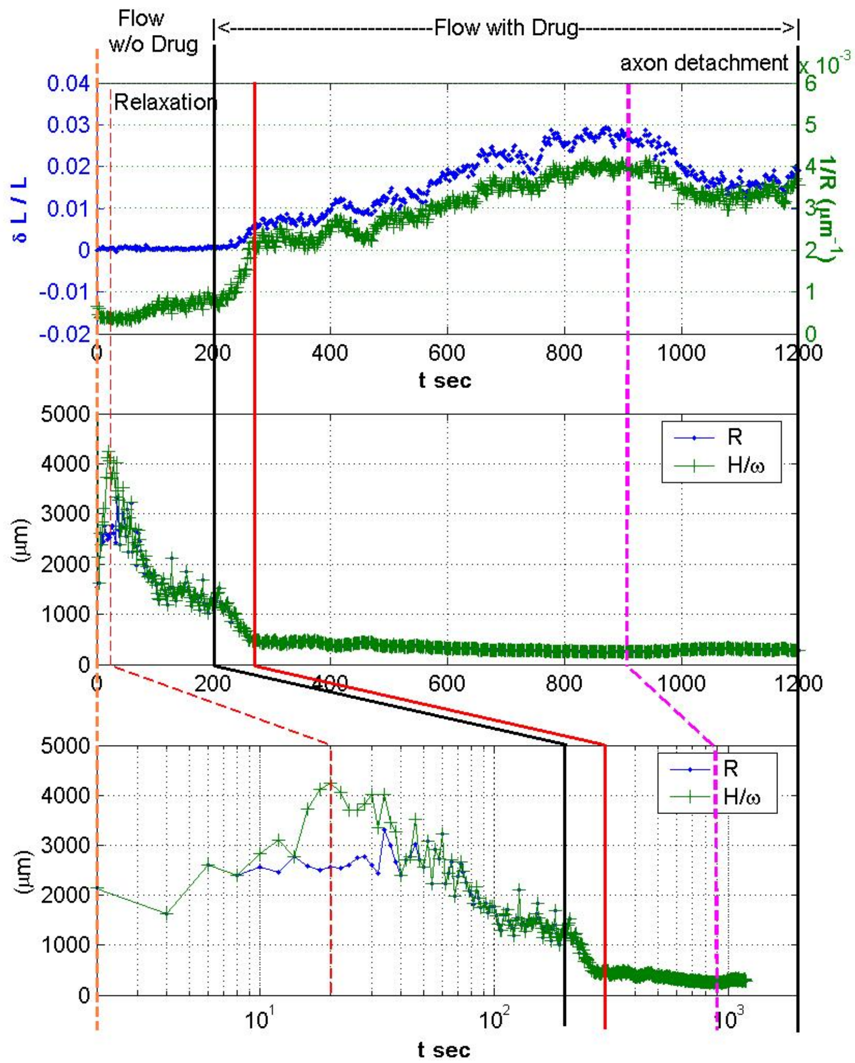
$$\omega = \frac{F}{l} = \frac{4\pi\eta U}{\ln\left(\frac{3.7\nu}{RU}\right)}$$

Results:

Drug effects
Lat-A: Actin depolym.
Nocodasole: Microtub. depolym

Axons response to tension





Active regime: $T<T_l$*; retraction*

$T>T_h$*; elongation*

Passive regime: Viscoelastic solid,
$T_l<T<T_h$

New Group: Mechanics of Complex Materials:

Theory: *F. Lund, M. Clerc, E. Tirapegui, P. Cordero, D. Risso and R. Soto.*
Experiments: *N. Mujica, J-J. Ammann, S. Rica, and F. Melo.*

CIMAT

Main goals for the next five years I:

Granular Materials.
-Development of numerical simulations in three dimensions.
-Strong interaction experiments, theory and numerical simulations. Specific problems are convection, segregation, avalanches, rarefaction fronts, fluidized beds, sound propagation and ***flows of importance in mining processes.***

Mechanical properties of complex materials.
-Sound materials interactions: Acoustical interaction in suspensions, sound dislocations interactions, dynamic of phase transitions, sound emission by bursting bubbles; volcanoes.
-Optic and acoustic speckles: Elastic properties of biomaterials (optic) and soft materials (acoustic), for instance, fruits.
-Biomechanics: Membranes, axons and molecular motors?.

Main goals II:

<u>Biomaterials growth:</u> Atomic force techniques.

How biomolecules modify crystal growth: ***Sulfated macromolecules provided by J. L. Arias group.***

Super saturation effects:

-Elastic effects: large distortions of the crystal due to macromolecules inclusions.

-Electric field effects: anisotropy, large K contrast.

-Gradient of electric field effect, might favor an increase of local concentration of some species.