Materials far from equilibrium
Universidad de Santiago de Chile.

• 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

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

• Wrinkling in elastic membranes: (with J.C. Geminard)
Crystal growth: Atomic Force microscopy:

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

Tips: $N_4Si_3$; 0.06 y 0.58 N/m.

$Z_T = m_S \frac{l_T}{3d_S}$
Tip substrate interactions: Force Vs distance

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

Useful to detect soft coating on hard substrate.
Tapping for soft materials

Contact mode and lateral force

Phase

Langmuir-Blodgett-film (1 μm-scan) Topography (left) and LFM (right)
mica surface (5 μm-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

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

Friction in progress
Mechanical properties of bio ceramics.

Spines

It seems adapted to minimize bending.

Egg shells

Package: not clear what optimizes

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

Nacre shells

High fracture resistance.
Ping pong shells: mimic egg shells

The contact region is unstable: bending and stretching competition

Contact zone in white
Egg Shells: Elasticity

- 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*

**Plasticity**

- Compression
- Tension

**Stress (MPa)** vs **Strain (%)**

- $\sigma_{ss}$

Dimensions:
- 2.5 mm
- 0.5 mm
- 12 mm
- 5-8 µm
- 0.2-0.9 µm

Modulus of Elasticity (E): 70 GPa
Isotropic solid

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

\[ \sigma_{yy}\big|_{x=0} = -\frac{2P}{\pi} \frac{1}{y} \]

\[ \sigma_{yy}(x, y) = -\frac{P}{\sqrt{4\pi D_o y}} e^{-\frac{(x-x_0)^2}{4D_o y}} \]

\[ w(x, y) \big|_{x=x_0} = -\frac{P}{\sqrt{4\pi D_o y}} \]
Speckles methods for small samples

before

after

Displacement field

Correlation

ux

uy
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

PDMS substrate

(a)

(b)

150 μm

Laser

Micro needle

Deformation

Wrinkle pattern

θ

λ

O

drop

side view

gas burner

top view

R

sample
Elastic membranes under axial tension:
Experimental results:

Conclusions:
- Wrinkle length not good for force measurements.
- Wrinkle amplitude much better

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

\[ h_{\text{membrane}} = \frac{\lambda}{2n} \delta \approx 0.1 \mu m \]

\[ d = z + \delta \]

\[ F_T = k_T z \]

\[ F_M = k_M \delta^{3/2} \]

\[ d = z + k \left( \frac{k_T}{k_M} \right)^{2/3} z \rightarrow E \approx 5 \text{MPa} \]
Membrane tension

\[ \Delta P \approx 0 \quad \Delta P \neq 0 \]

- The membrane is under tension.

\[ \Delta P = \frac{2}{R} \left( \gamma_{L-M} + \frac{B}{l_o} \right) x = \frac{r}{R} \]

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

\[ B = Eh \rightarrow E \approx 5\text{MPa} \]
Mechanical properties of axons (R. Bernal)

Bending of axons by the effect of a viscous force

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

\[ \omega = \frac{F}{l} = \frac{4\pi \eta U}{\ln \left( \frac{3.7v}{RU} \right)} \]
Results:

Axons response to tension

Active regime:  $T<T_l$; retraction

$T>T_h$; elongation

Passive regime:  Viscoelastic solid,  

$T_l<T<T_h$

Drug effects

Lat-A: Actin depolym.

Nocodasole: Microtub. depolym
**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.

**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:

Biomaterials growth: 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.