Observing atoms at work

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Nanoscience

Atomic Force Microscopy

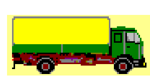
Observing atoms

What is Nano - what is 10^{-9} ?

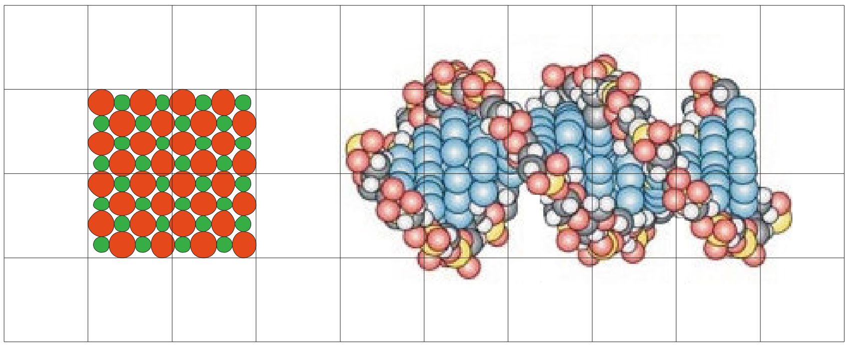
10^{-3} $\quad 10^{-6}$ $\quad 10^{-9}$

$$\frac{1}{1000} \quad \frac{1}{1000000} \quad \frac{1}{1000000000}$$

milli *micro* *nano*

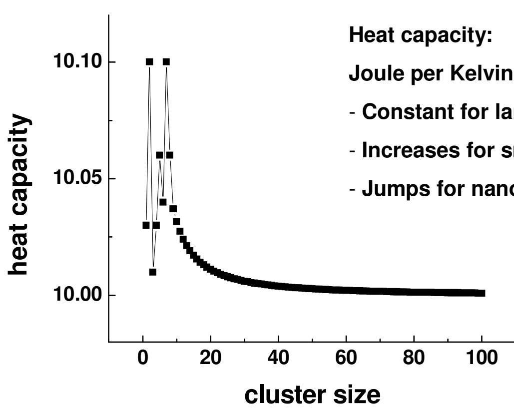


Length scale nanometer



The world of atomic and molecular structures.

Why Nanoscience?
Small is different!

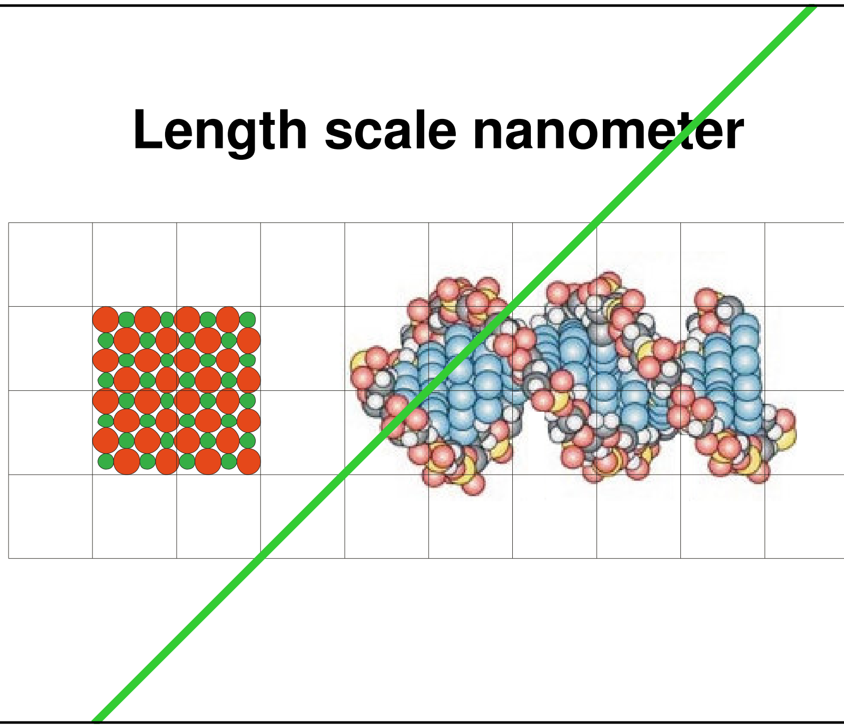


Heat capacity:

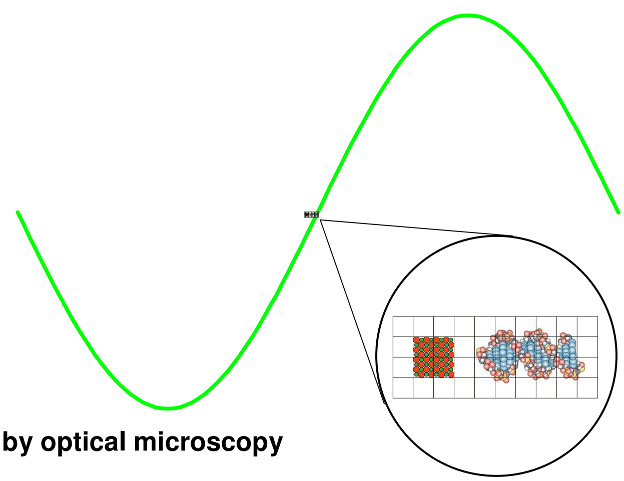
Joule per Kelvin and per gram

- **Constant for large bodies**
- **Increases for small clusters of atoms**
- **Jumps for nanoclusters**

Length scale nanometer

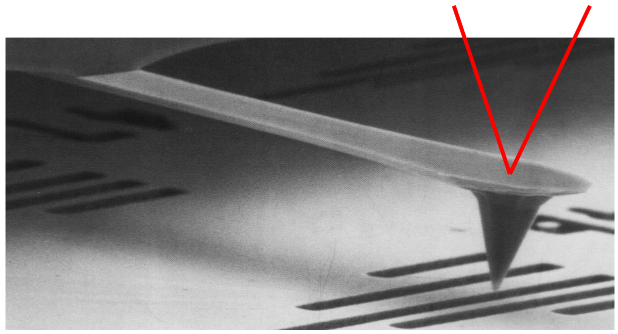


Nanometer and the wavelength of light



No imaging by optical microscopy

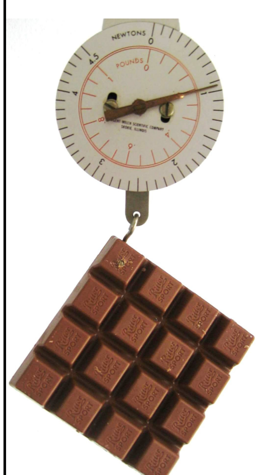
Atomic Force Microscopy



Atomic Force Microscopy measures force between tip and surface.

Deflection of the cantilever beam is probed by laser beam.

What is a NanoNewton?



What is 1 Newton?
  A chocolate-oriented unit for force.

Nanoscience of chocolate?
  1 bar are 100 cm^3 or 10^{23} nm^3
  Weight of 1 nm^3 is 10^{-23} nN (=0)

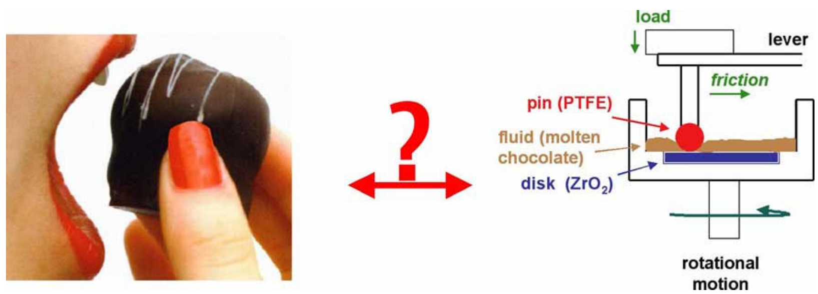
Binding forces in chocolate
  Cross-section 1 cm^2 or 10^{14} nm^2
  Weight carried 4 kg
  Rupture force $4{\times}10^{-13}$ N/nm^2

PicoNewton describe molecular forces in softer materials.
NanoNewton describe molecular forces in harder materials

Tribology Letters, Vol. 16, No. 3, April 2004 (© 2004) 239

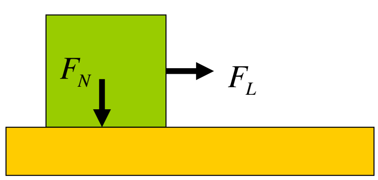
A tribological model for chocolate in the mouth: General implications for slurry-lubricated hard/soft sliding counterfaces

Seunghwan Lee[a], Manfred Heuberger[a], Philippe Rousset[b] and Nicholas D. Spencer[a,*]
[a] *Laboratory for Surface Science and Technology, Department of Materials, Swiss Federal Institute of Technology (ETH), Zürich, CH-8092, Switzerland*
[b] *Nestlé Research Center, Department of Food Science and Process Research, Vers-chez-les-Blanc, 1000 Lausanne 26, Switzerland*



http://www.surface.mat.ethz.ch/research/surface_forces/tribology_and_surface_forces

Textbook Friction



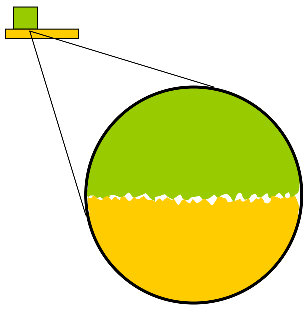
$$F_L = \mu F_N$$

$$F_L(A) = const.$$

$$F_L(v) = const.$$

$W = \int F_L ds =$ **20% of our energy turnover**

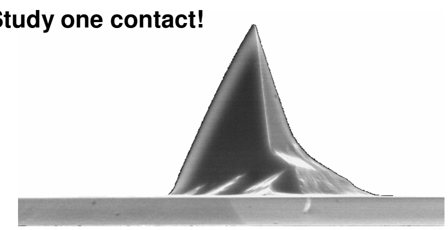
Microscopic friction



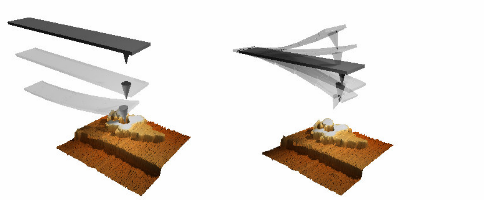
Friction is the result of formation, deformation, and rupture of many contacts.

Friction is proportional to the "real" area of contact.
(Tabor and Bowden)

Study one contact!

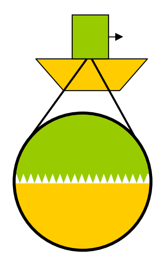


Projects



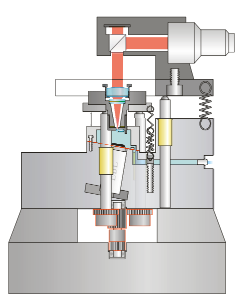
Tobin Filleter:

Force microscopy in vacuum



Jonathan David:

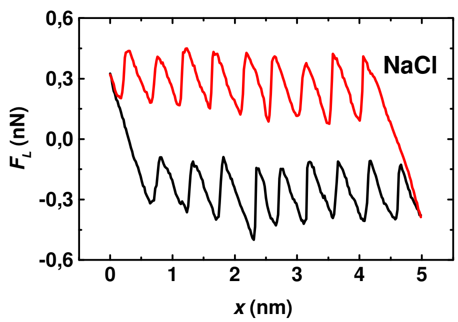
Friction experiments with many tips



Aleks Labuda:

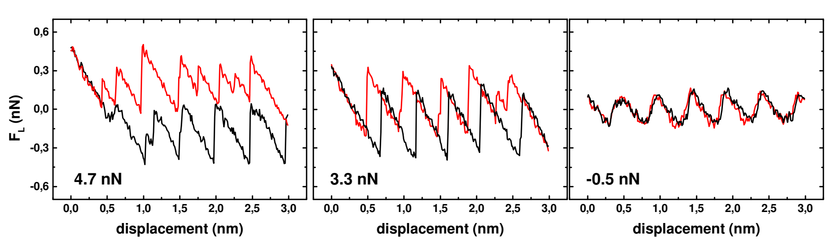
Force microscopy in liquids

Atomic friction



- Ultra-high vacuum
- Room temperature
- Atomically flat surfaces
- Atomic stick-slip with lattice periodicity

Load dependence of atomic friction on NaCl



Dissipation vanishes for low loads.

Transition from stick-slip to continuous sliding observed.

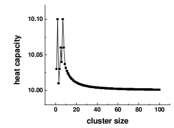
Instability as a fast process causes dissipation.

Occurrence of instability depends on stiffness of contact.

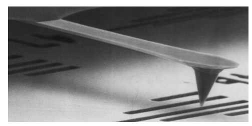
A.Socoliuc et al., Phys. Rev. Lett. 92 (2004) 134301

Summary

Nanoscience-
Small is different.



Force microscopy can
measure atomic forces.



Dissipation in atomic
friction depends on
instabilities.