LECTURE 4: FORCE-DISTANCE CURVES

Outline :

Objectives: To understand high resolution force spectroscopy data; i.e. how it is converted from raw data, interpretation of different regions, and different types (i.e. normal, lateral, & chemically specific)

Readings: Course Reader Document 10-11.

Multimedia : Watch movie *Introduction to AFM* by Asylum Research, Inc., and the Force curve animation from NCState.

LAST TIME : ADDITIONAL NANOMECHANICS INSTRUMENTATION COMPONENTS

High resolution displacement detection : Optical Lever (Beam) Deflection Technique

High resolution displacement control : "piezoelectric materials" : material which exhibits a change in dimensions in response to an applied voltage due to dipole alignment

ε *is linearly proportional to electric field strength :*

$$\varepsilon_j = d_{ij} E_i$$

$$\varepsilon_j = \frac{\Delta L}{L_o} = \text{strain } (m/m = \text{unitless})$$

d_{ij} = *strain coefficients or sensitivity (m/Volt)*

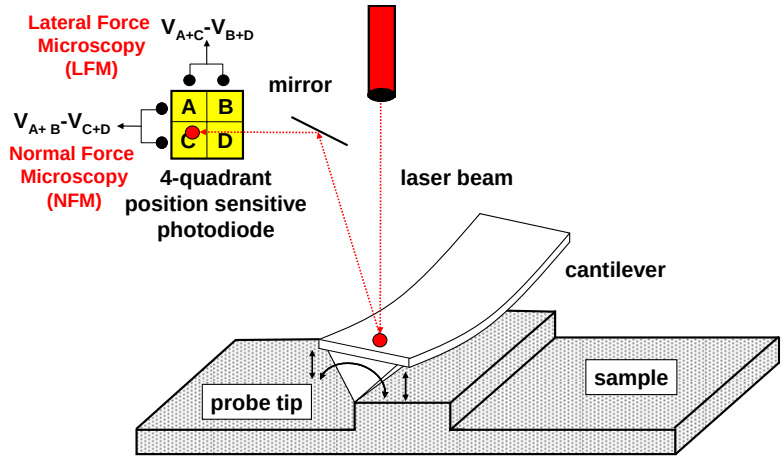
E_i = *electric field strength (Volt/m)*

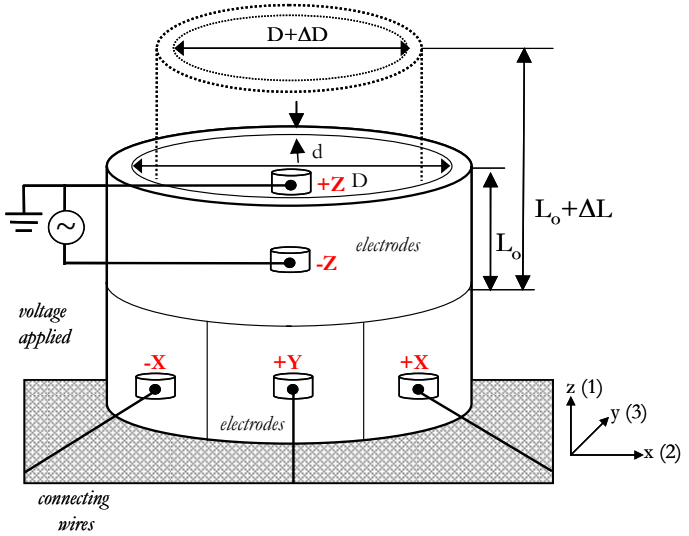
i = *direction of applied field,* j = *direction of strain*

1,2,3 = normal axes ; 4,5,6 = shear

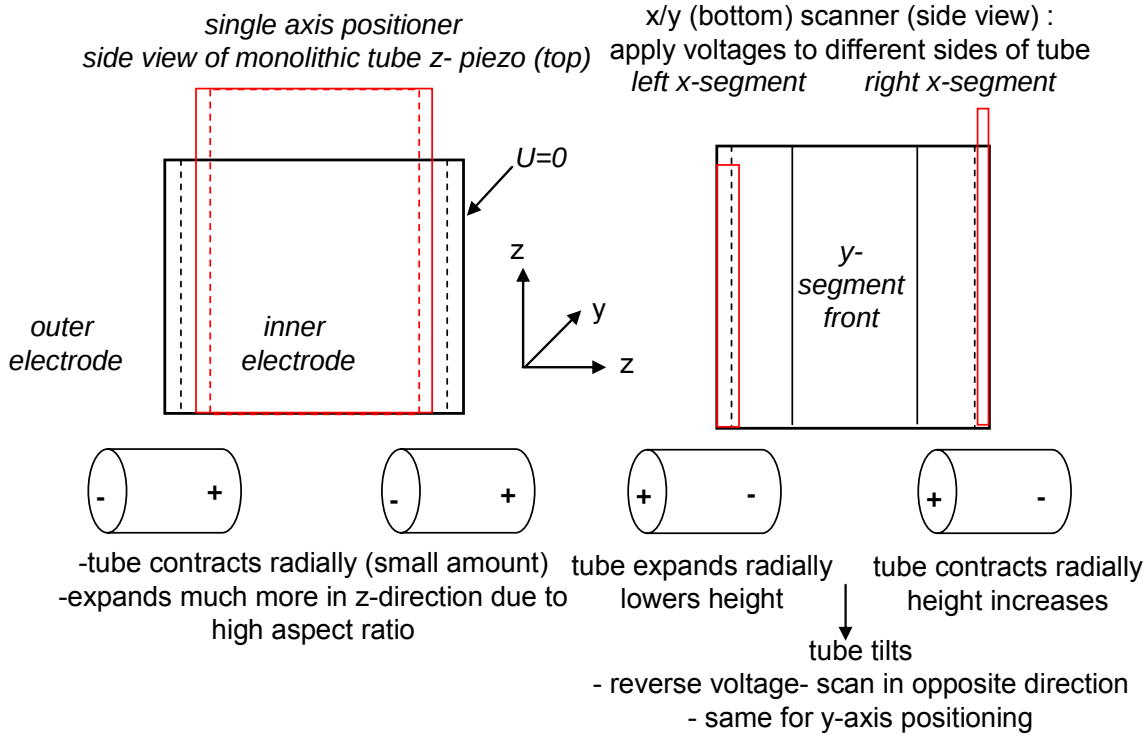
+ Poisson's ratio

$$\Delta L = \frac{L_o d_{31} U_3}{d} \text{ where } d = \text{wall thickness}, U = \text{operating voltage}$$





PIEZO TUBES X/Y SCANNING



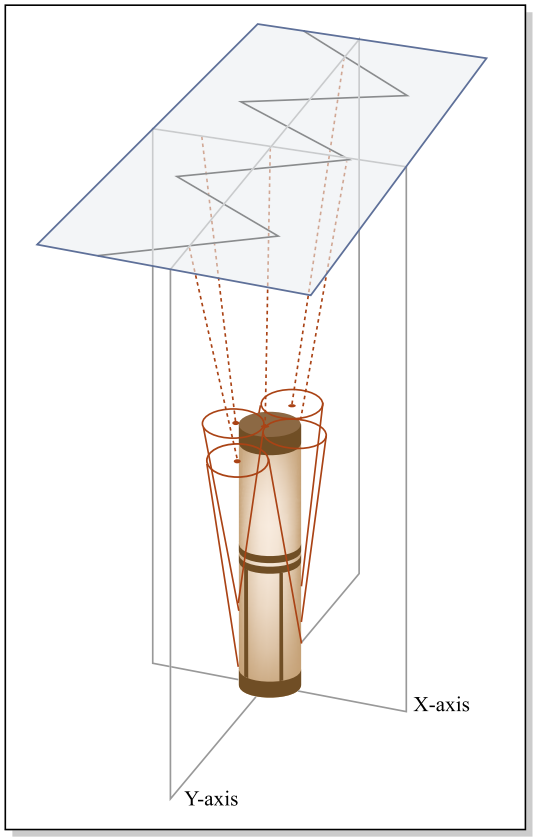
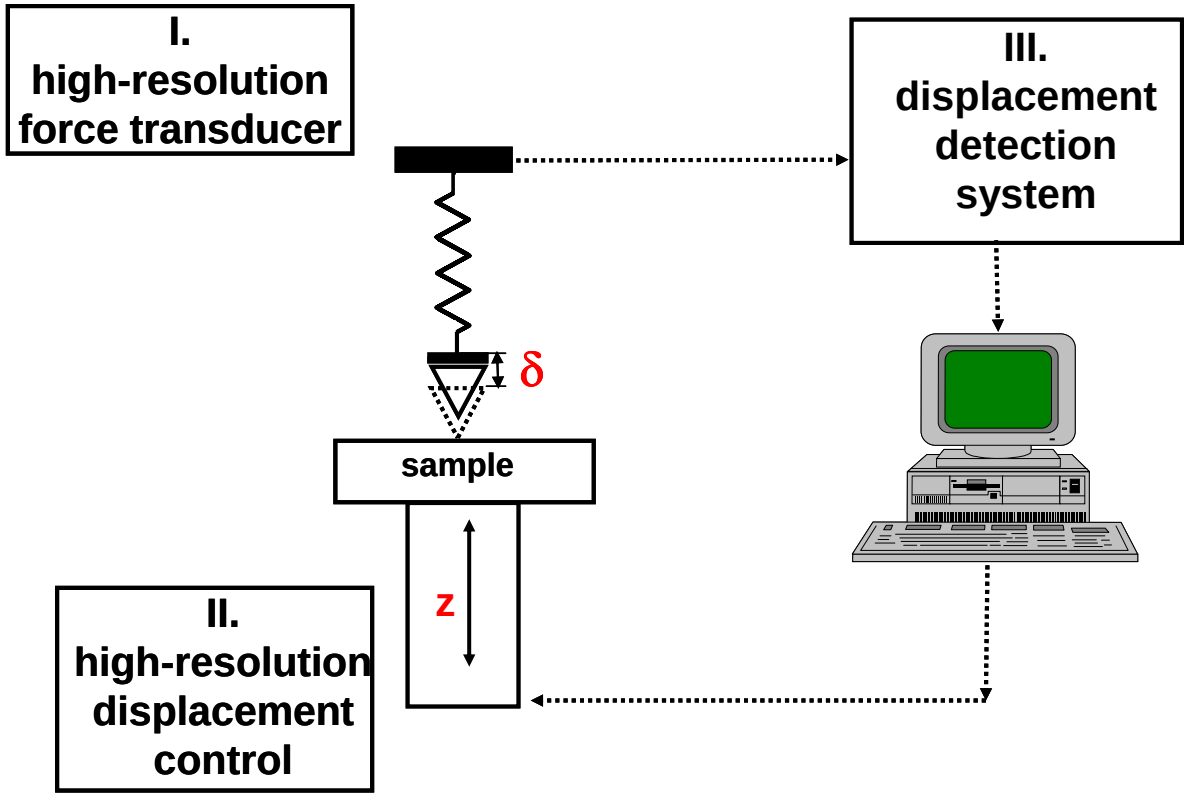


Figure by MIT OCW.

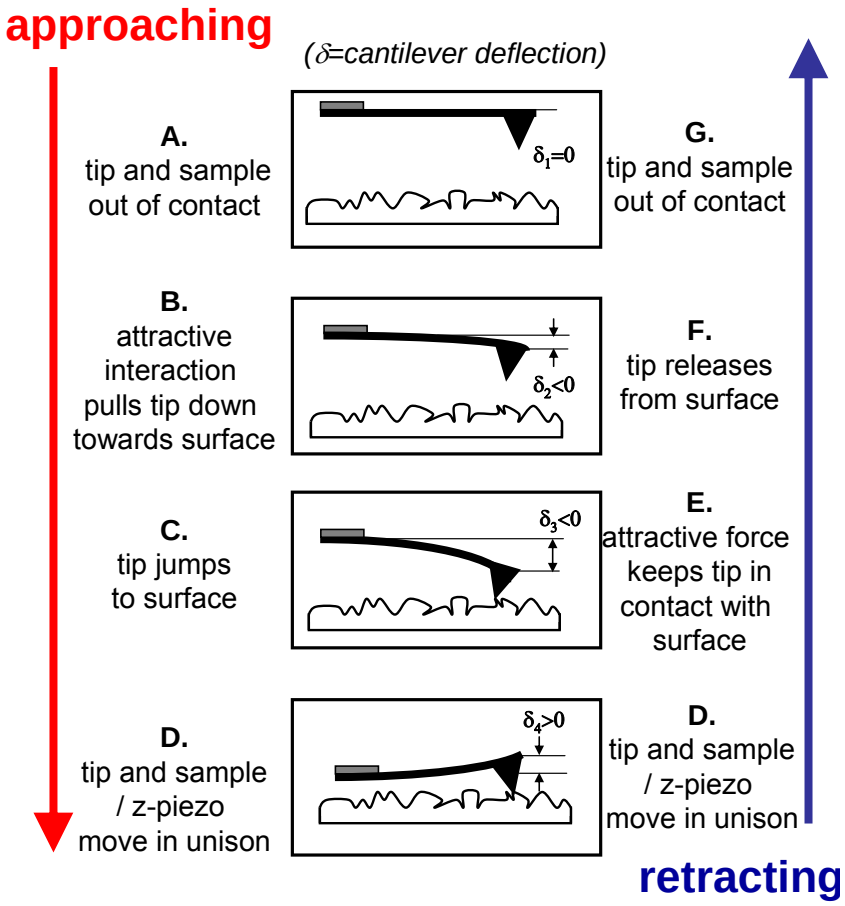
-*Coupling* - if you tell the piezo tube to move in x-direction, it will also move a bit in y and z, x is coupled to y and z

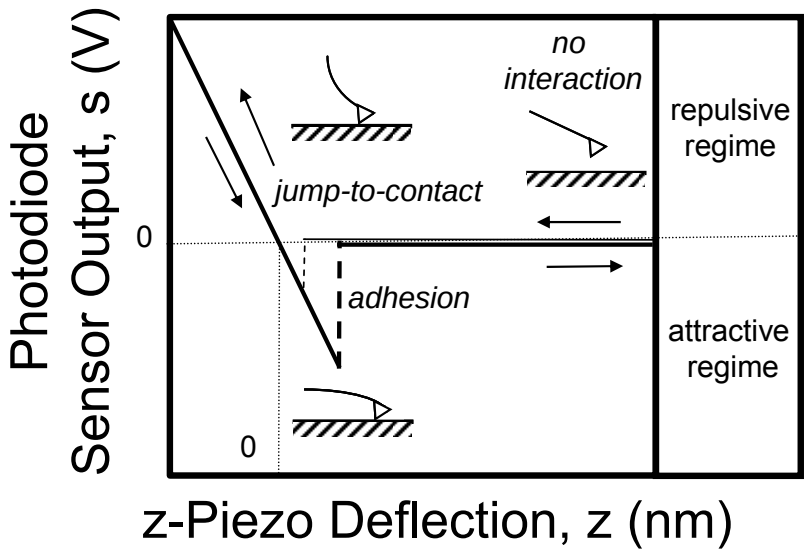
-Another approach : individual "piezo stacks" with flexures in a "nested design" (*Introduction to AFM by Asylum Research, Inc. (Quicktime Movie)*- Pset 2

GENERAL COMPONENTS OF A NANOMECHANICS DEVICE



HIGH RESOLUTION FORCE SPECTROSCOPY EXPERIMENT (HRFS): RAW DATA



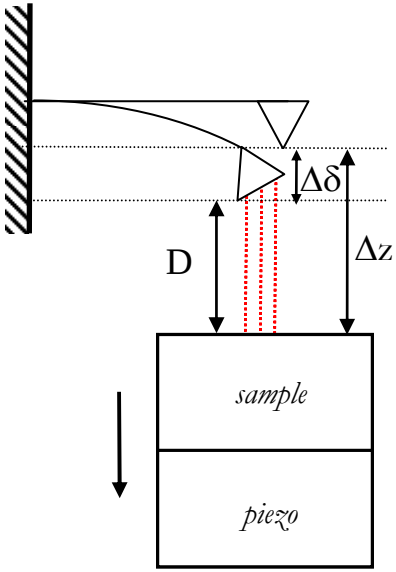


- Measure sensor output (Volts) vs. z-piezo displacement/deflection

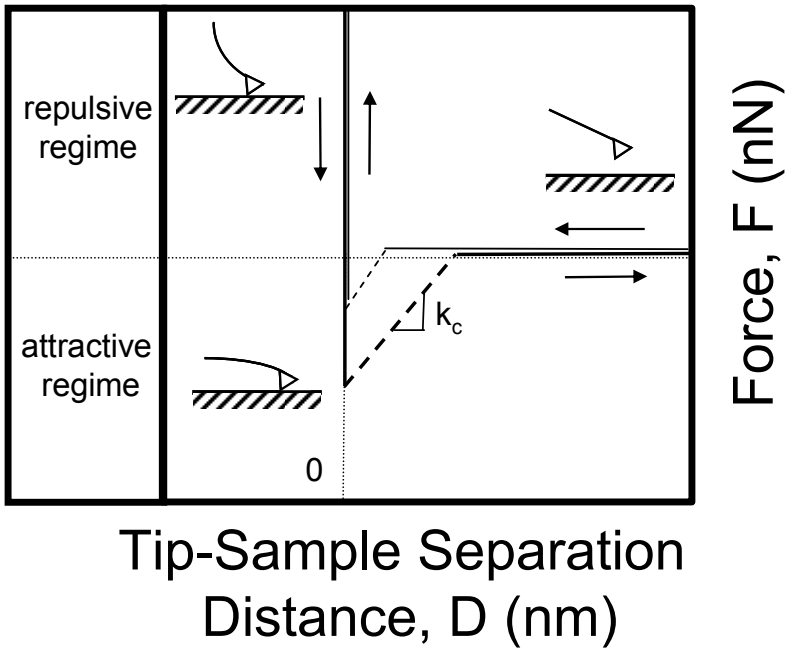
- See animation on the MIT Server (Force curve anirnation from NC State).

HIGH RESOLUTION FORCE SPECTROSCOPY EXPERIMENT: CONVERTED F-D DATA

x-axis conversion



$D = \Delta z - \Delta\delta$



Contact vs. Noncontact region

Zero x-axis position chosen (x=0) : by baseline far away from sample

Zero y-axis position chosen (D=0) : as region of apparent infinite slope (artifact of soft spring, stiff sample)

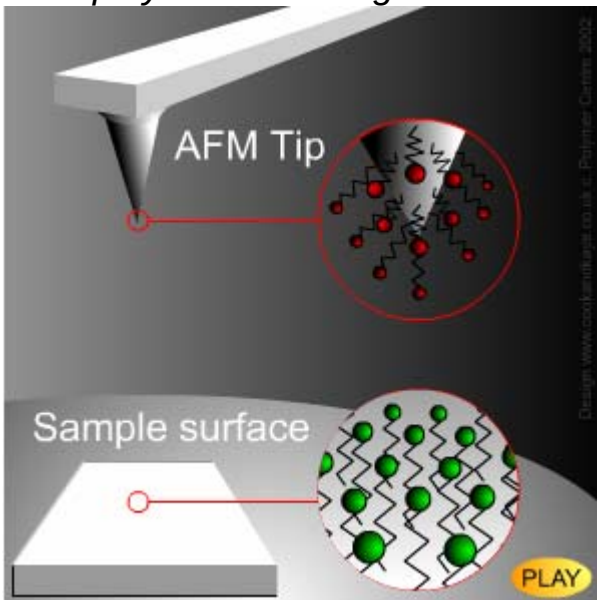
Jump to contact region : region of mechanical instability, cantilever moving too fast to collect data, lose all data in this region

Adhesion force : maximum force needed to separate two bodies, determined by surfaces force/ intermolecular interactions; sources; hydration capillary forces in air, noncovalent interactions, polymer interactions, etc.

CHEMICAL FORCE MICROSCOPY (CFM)

Vezenov DV, Noy A, Rosznyai LF, Lieber CM. 1997. J. Am. Chem. Soc.

www.polymercentre.org.uk



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to copyright restrictions.
See Vezenov DV, Noy A, Rosznyai LF,
Lieber CM. 1997. J. Am. Chem. Soc.

Courtesy of The University of Sheffield Polymer Centre. Used with permission.

MEASURING MACROMOLECULAR ADHESION : CARTILAGE AGGRECAN

Cartilage **aggrecan** is a very unique "bottle-brush" macromolecule that is largely responsible for the mechanical properties and health of cartilage tissue in our joints. (*podcasts later on in the semester on this topic, unpublished data by L. Han)

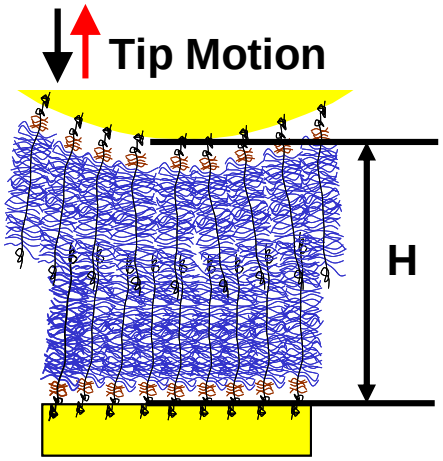
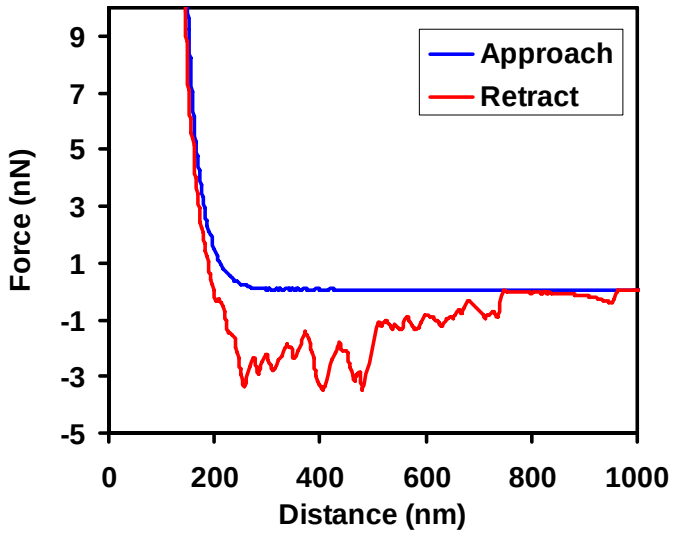
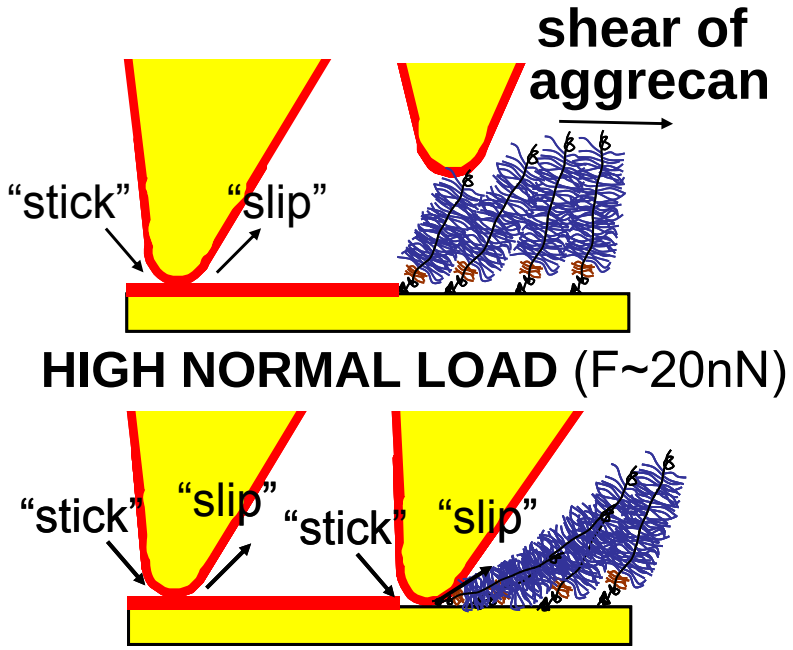
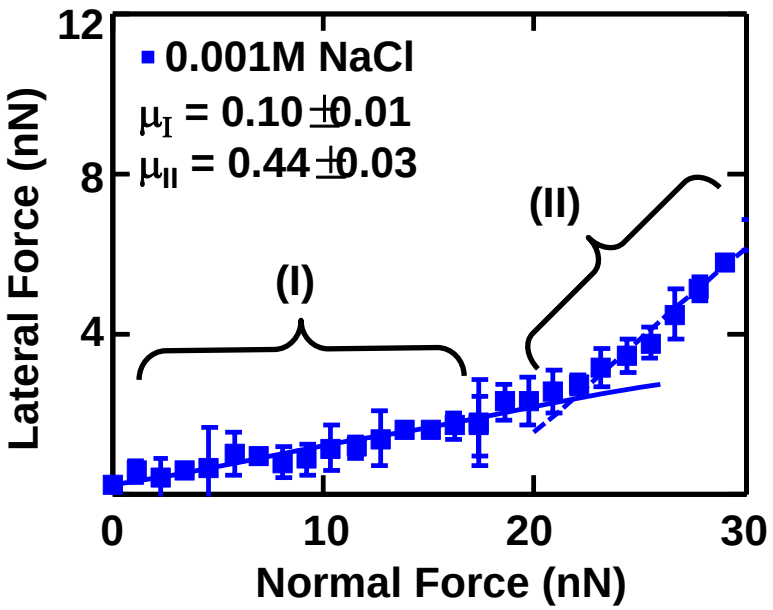


Image removed due to copyright restrictions. Diagram of cartilage aggrecan.



LATERAL FORCE MICROSCOPY (LFM)





-Measure shear / friction coefficient→nanotribology - study of friction and wear.
-Linear dependence of lateral force on normal force between OH-SAM and aggrecan changed upon the point of full penetration of aggrecan layer by the nanosized probe tip.
-At the same height, larger lateral forces were observed at lower IS, due to stronger shear resistance