Lecture: P1_Wk4_L4
Processing Force Curves

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The Basic Force vs. z-Displacement Experiment

Assume that $k$ is well known

$F = kq$

$F_{ts}$

$d$

$+q$

$+z$

$R$

$d$

$\alpha_0$
I. Infinitely hard materials, no surface forces

During contact: $q = -z$  
(infinitely hard sample, no deformation: $D=0$)

Find $S$ such that:  
$S \times V_{PSD} = S(-mz) = q$

$m' = -mS = -1; \quad S = 1/m$

Non-contact regime:  
convert $z$ to $d$ using $d = z$  
(since $q=0$ because $F_{ts}=0$)
II. Infinitely hard sample/tip, repulsive surface force

During contact: \( q = -z \)  
(infinitely hard sample, no deformation: \( D = 0 \))

Find \( S \) such that:
\[ S \times V_{PSD} = S(-mz) = q \]

\( m' = -mS = -1; \quad S = 1/m \)

Non-contact regime:
convert \( z \) to \( d \) (\( d = z + q \))

\[ q = S V_{PSD} \]

\[ F = kq \]
III. Soft material, no surface forces

During contact: sample deforms

Find $S$ such that:

$$S \times V_{PSD} = m(-Sz) = q$$

$m' = -mS = -1; \quad S = 1/m$

Non-contact regime:
convert $z$ to $d$ ($d = z + q$)

$q = SV_{PSD}$

Deformation

$$F = kq$$

Non-contact

$d = z + q$
Calibration on hard sample, usually done after data acquisition on softer sample.

The calibration depends on:
- the set-up and alignment of the laser with the cantilever
- the piezo displacement velocity (speed of indentation)
- the amount of cantilever deflection
- any non-linearity in piezo displacement
- piezo-aging

Use same parameters and alignment as when taking the original data.
Applied Force vs. Displacement

infinitely hard sample

Relaxation - Turn off hardness

$E^* = 5$ GPa
$R = 5$ nm
Errors Can Be Large When Measuring Deformation

Best fit to theory

Applied Force (nN)

D - Deformation (nm)
Force spectroscopy – an example
Convert cantilever deflection vs. z-displacement to force vs. separation (gap)

Piezo displacement $z$ (nm)
Tip-sample distance $d$ (nm)

Noise gives indication of minimum detectable force

$d = z + q$

d axis is often re-centered to zero where force is a minimum
Artifacts when measuring cantilever deflection vs. z-displacement

1. Laser spot not centered on photodiode. Re-center to make PSD output zero when far from sample

2. Laser spot reflecting off sample into PSD, interfering with laser light reflected from back side of the cantilever.

Offset

Oscillation
3. z-piezo hysteresis - exercise the piezo or switch to closed loop scanner

4. hydrodynamic drag - reduce speed
Artifacts

5. Large indentation produces plastic deformation - reduce applied force
Simulations: Force-Distance
Outputs in VEDA

Observed cantilever deflection vs. z distance

Tip-sample interaction force vs. z distance

Tip-sample gap vs. z distance

Tip-sample interaction force vs. d

Indentation vs. z distance
Up Next: Modulus and Adhesion Maps