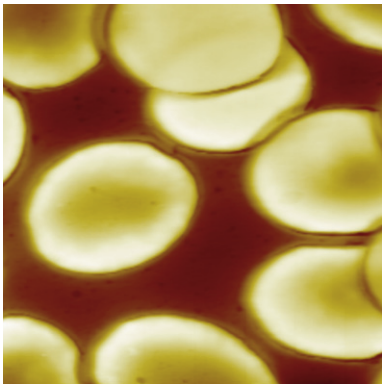
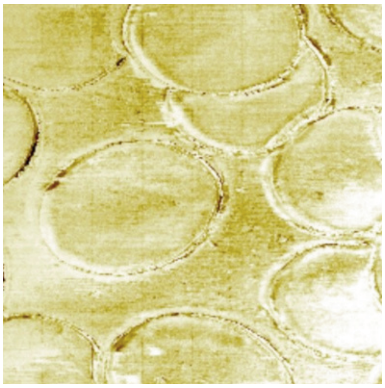
Nano Mechanical Imaging

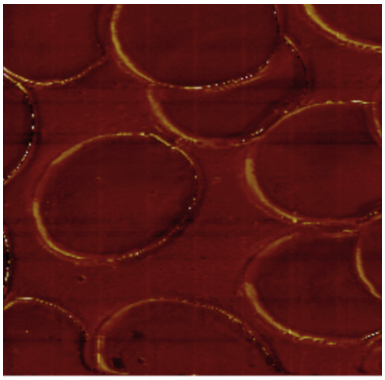
Red blood cells are measured under NMI mode:



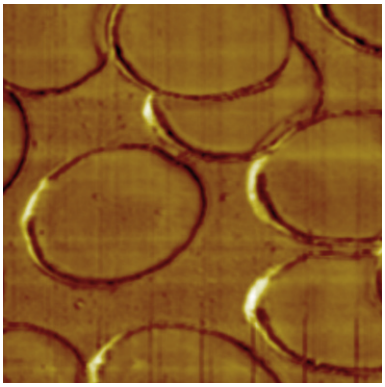
Topography



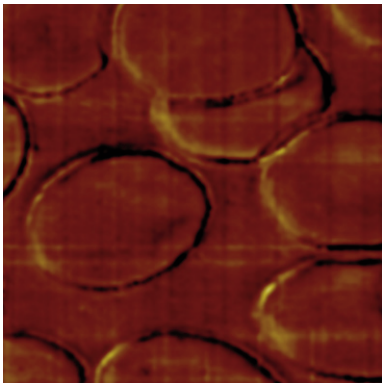
Adhesion



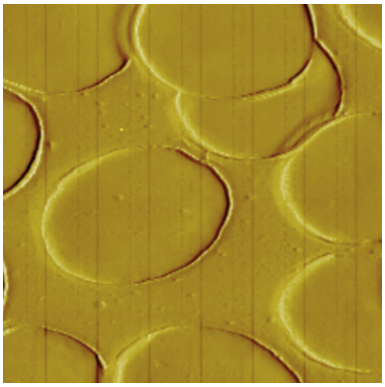
Deformation



Dissipation



Young Modulus



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The nano mechanical imaging (NMI) mode is an extension of the contact mode. The static force acting on the cantilever is used to produce a topography image of the sample. Simultaneously, at each pixel force curves are produced and used to extract quantitative material properties data such as adhesion, deformation, dissipation.

The force curve plot is analyzed, on the fly, to produce the peak interaction force as the control feedback signal and the mechanical properties of the sample (adhesion, modulus, deformation, dissipation).

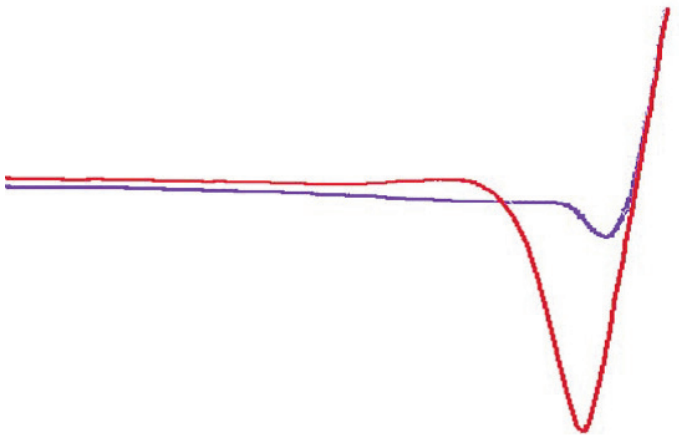

Figure 1-1-1: Force Curve

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NMI PROBE SELECTION

It is important to choose a probe that can cause enough deformation of the sample and still retain high force sensitivity. Therefore cantilever stiffness should be selected based on the sample stiffness.

Sample Modulus	Probe	Spring Constant (k)
1 MPa < E < 20 MPa	PPP-XYCONTR	0.5 N/m
5 MPa < E < 500 MPa	PPP-EFM, PPP-XYNCSTR	5 N/m
200 MPa < E < 2000 MPa	PPP-NCLR, PPP-XYNCHR	40 N/m

NMI CHANNELS

YOUNG'S MODULUS

The reduced Young's Modulus, E*, is obtained by fitting the retract using the Derjaguin, Muller, Toropov (DMT) given by:

$$F_{tip} = \frac{4}{3}E^* \sqrt{Rd^3} + F_{adh}$$

Where Ftip is the force on the tip, Fadh is the adhesion force, R is the tip end radius and d is the tip sample separation:

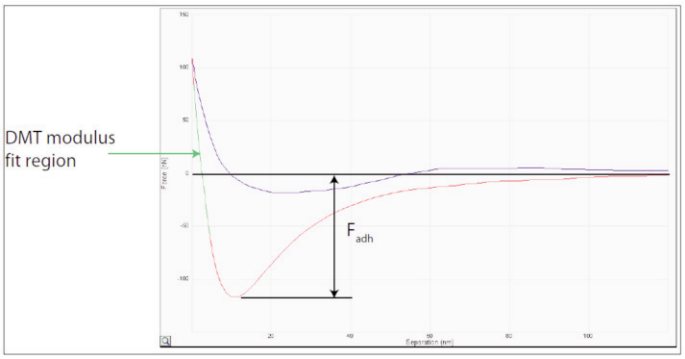
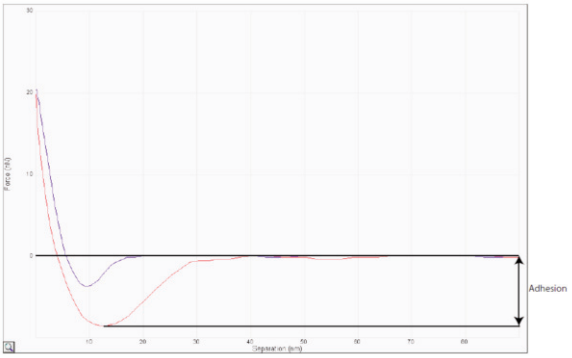


Figure1-1-2 Force vs. Separation plot

ADHESION

The peak force below the baseline, shows an adhesion map:

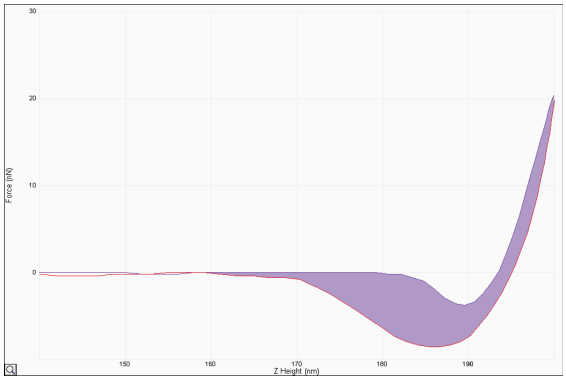


DISSIPATION

Energy Dissipation (W) is given by the force times the velocity integrated over one period of the vibration:

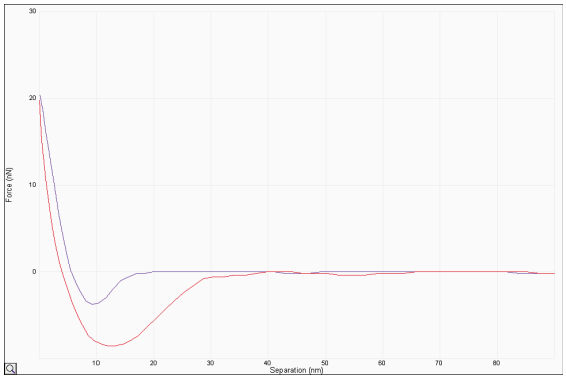
$$W = \int_0^T \bar{F} \bullet \bar{v} dt = \int \bar{F} \bullet d\bar{Z}$$

F is the interaction force vector and dZ is the displacement vector. Because the Z motion and the velocity reverse direction in a half cycle, the integral is zero if the load and unload curves coincide. The dissipation is therefore the hysteresis between the load and unload curves. Pure elastic deformation has no hysteresis which corresponds to very low dissipation. Energy dissipated is displayed in electron volts as the mechanical energy lost per tapping cycle. The dissipation channel plots the dissipated energy in each cycle by integrating the area between the **trace** (load or extend) and **retrace** (unload or retract) curves as shown in the blue area:



DEFORMATION

The maximum deformation of the sample (defined as the distance from the base of the deformation fit region position to the peak interaction force position) caused by the probe. The total deformation will be slightly larger than the displayed deformation because the default deformation fit region is 85% of the full deformation:



CANTILEVER PARAMETERS

The following parameters are needed to calibrate NMI channels.

Spring Constant: Measure the spring constant of the probe and input that value into this panel. Spring constant may be measured using the thermal tune function

Tip Radius: Measure the tip radius and input the value in this panel. Tip radius may be measured using a tip characterizer sample or learn from manufacturer.

Poisson's Ratio: Poisson's ratio of the sample. This is used to calculate the sample modulus, Es, from the measured reduced modulus, E*.

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