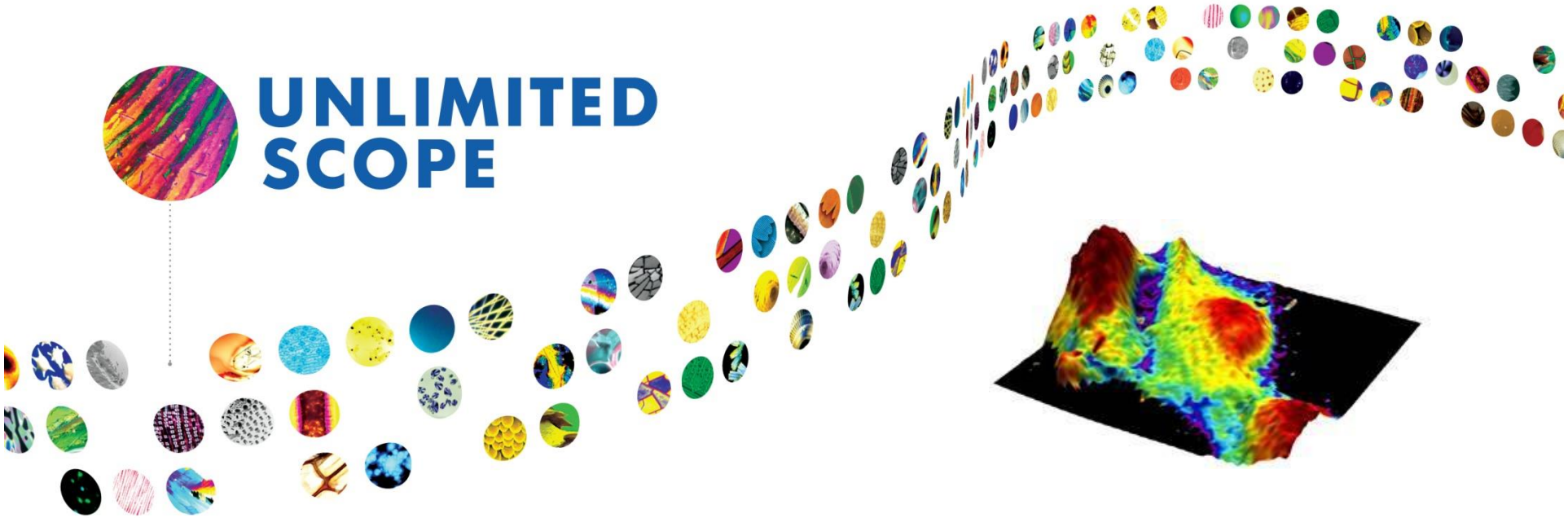



# Measuring Stiffness and Adhesion on the Nanoscale with AFM

Dalia Yablon, Ph.D.
A.B. Chemistry, Harvard University
Ph.D. Physical Chemistry, Columbia University

- TYPE QUESTIONS INTO THE QUESTION FIELD
- WEBINARS ARE BEING RECORDED
- RECORDED WEBINARS CAN BE FOUND AT www.mccrone.com

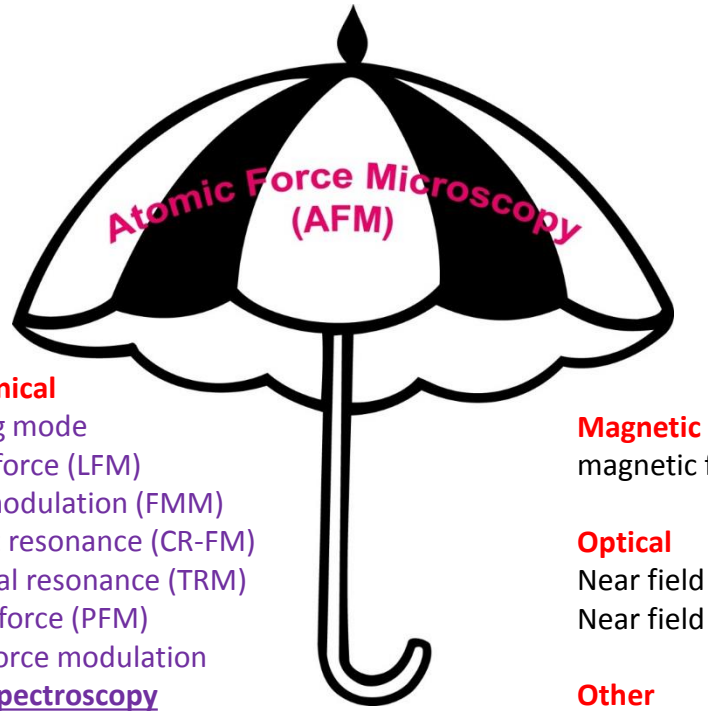
SurfaceChar

# *Measuring Stiffness and Adhesion on the Nanoscale with AFM*

**Dalia Yablon**

dalia.yablon@surfacechar.com

# *AFM can measure many other useful surface properties*




**Mechanical**
Tapping mode
lateral force (LFM)
force modulation (FMM)
contact resonance (CR-FM)
torsional resonance (TRM)
pulsed force (PFM)
shear force modulation
**Force spectroscopy**

**Electrical**
Kelvin force (KFM)
Electrostatic force (EFM)
Piezo force (also PFM!)
Conducting AFM (C-AFM)
Scanning capacitance (SCM)

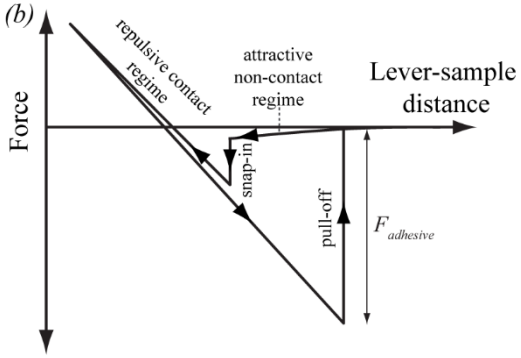
**Magnetic**
magnetic force (MFM)

**Optical**
Near field Raman (NSOM-Raman)
Near field IR

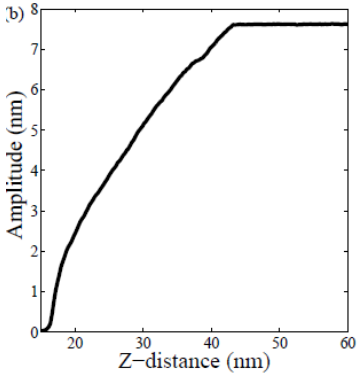
**Other**
molecular pulling
lithography
manipulation
thermal microscopy (SThm)
3-D nanoprinting

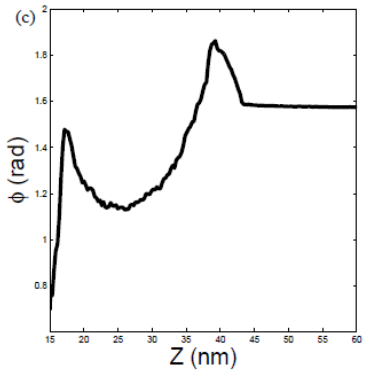
# *Force curves/force spectroscopy: single point measurements*

- Static force spectroscopy: Single point measurements where the tip goes in and out of the surface
  - Employ contact mechanics models to probe adhesion, capillary force, modulus
  - Can map force curves over the surface as well




- Dynamic force spectroscopy – force curves while cantilever is oscillating
  - Plot amplitude, phase as cantilever approaches the surface



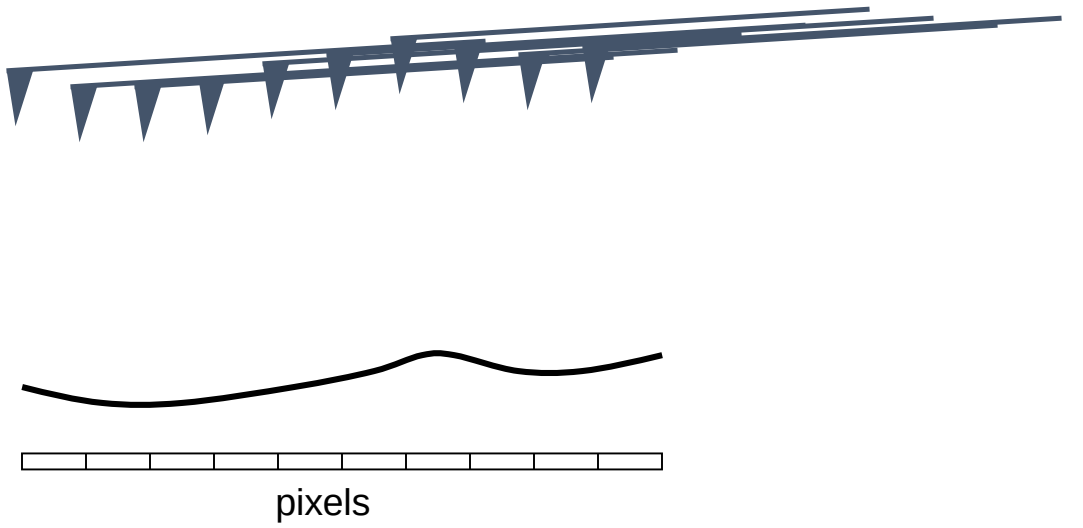



# *Force curve mapping vs tapping mode*

SurfaceChar

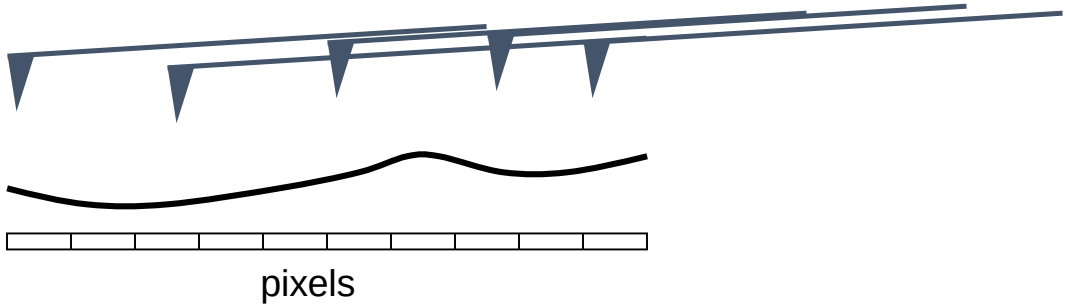
**Force Curve Mapping**:
"Force Volume"
"Volume spectroscopy"
"Pulsed Force mode"
"Peak Force QNM"
(quasistatic, reduce shear)

→ **NONRESONANT**
**(lower freq)**

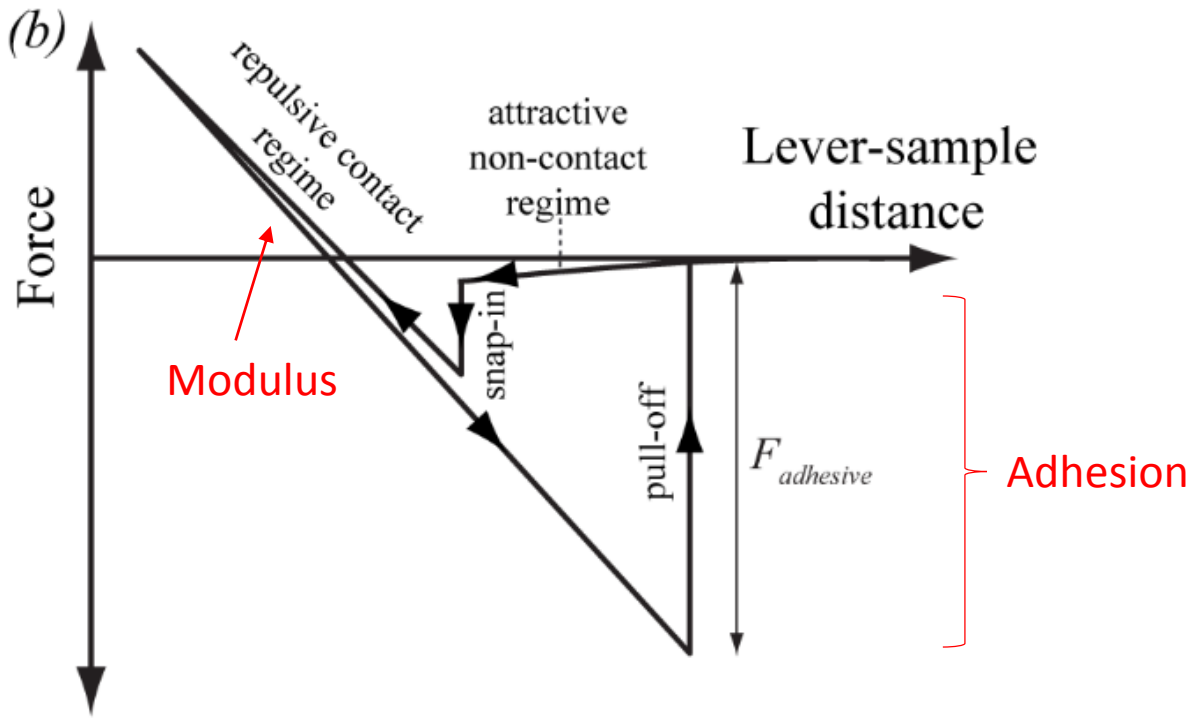



**Dynamic mode**
(AC or "tapping mode")

→ **RESONANT**
**(higher freq)**

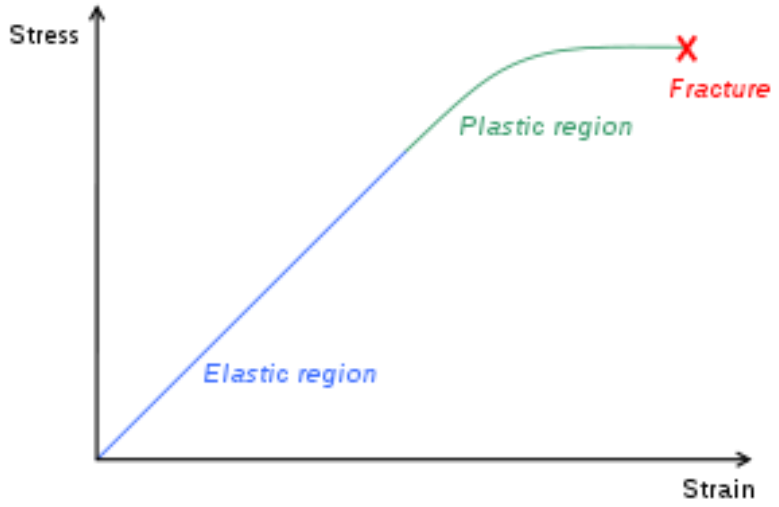


# Force curve/force spectroscopy



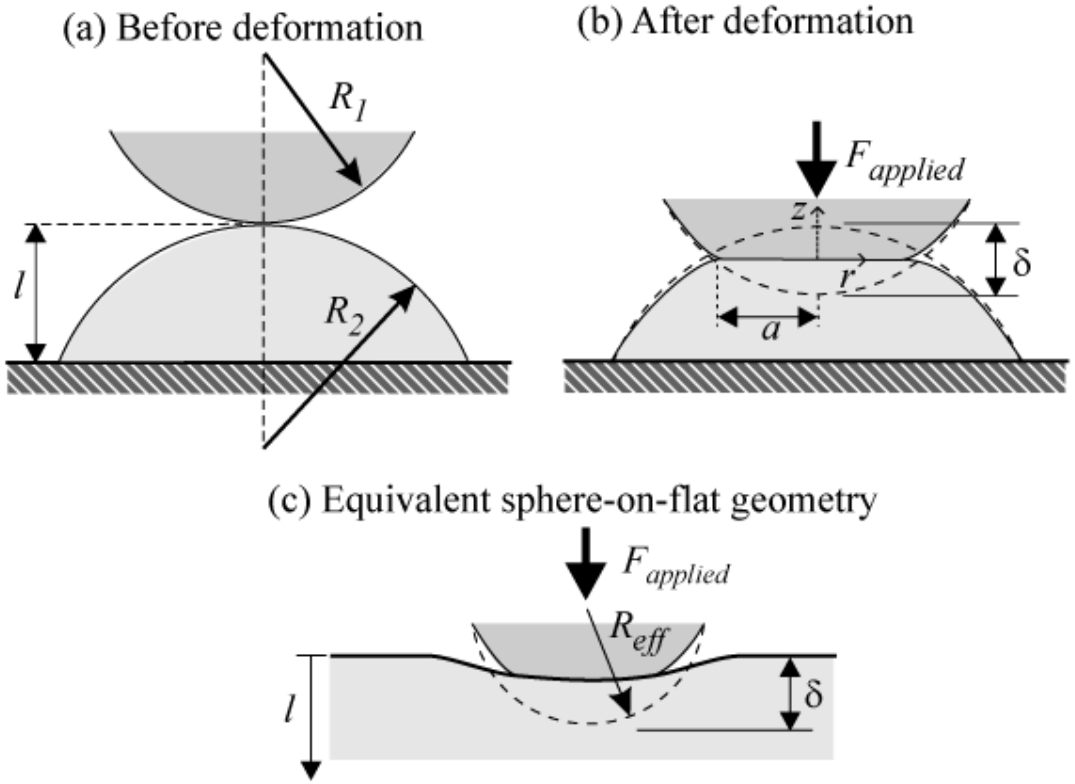
# *Static force curves contain important mechanical information on your surface*

- Static force curve measures the interaction (force) between your tip and sample as a function of distance (z)
- Operates in the elastic regime
- Contact mechanics models used to model interaction between tip and sample to measure:
  - Young's modulus
  - Adhesion/surface energy
- Hertzian contact mechanics: predict stresses and deformation that occur when two solid objects are brought into contact with each other
  - BUT….these models don't take into account van der Waals interactions between the tip and sample
  - Resort to DMT, JKR model that *do* take into account interactions between tip and sample



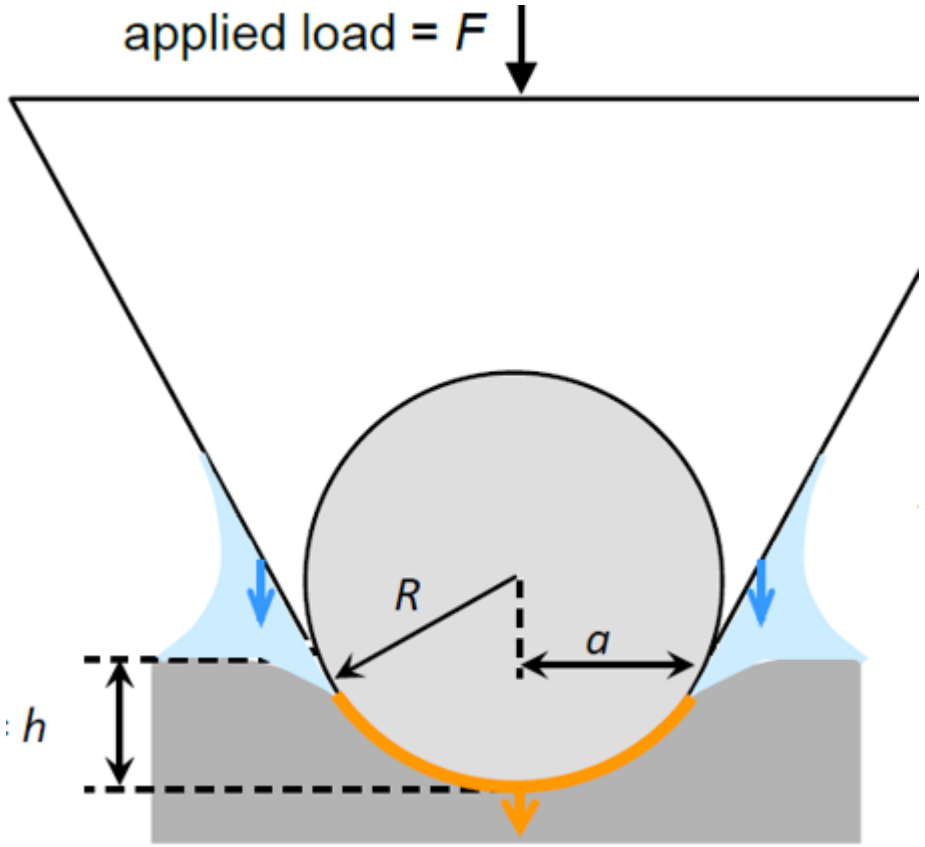
# Hertz analysis – model 2 lenses

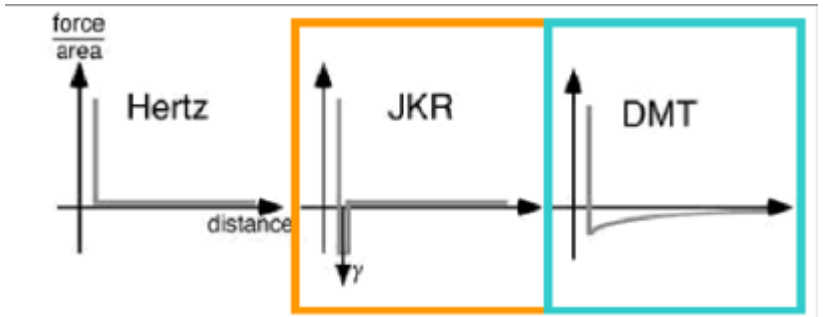
Studied interference fringes between 2 glass lenses, pressed together
Derived equations to model the observed behavior



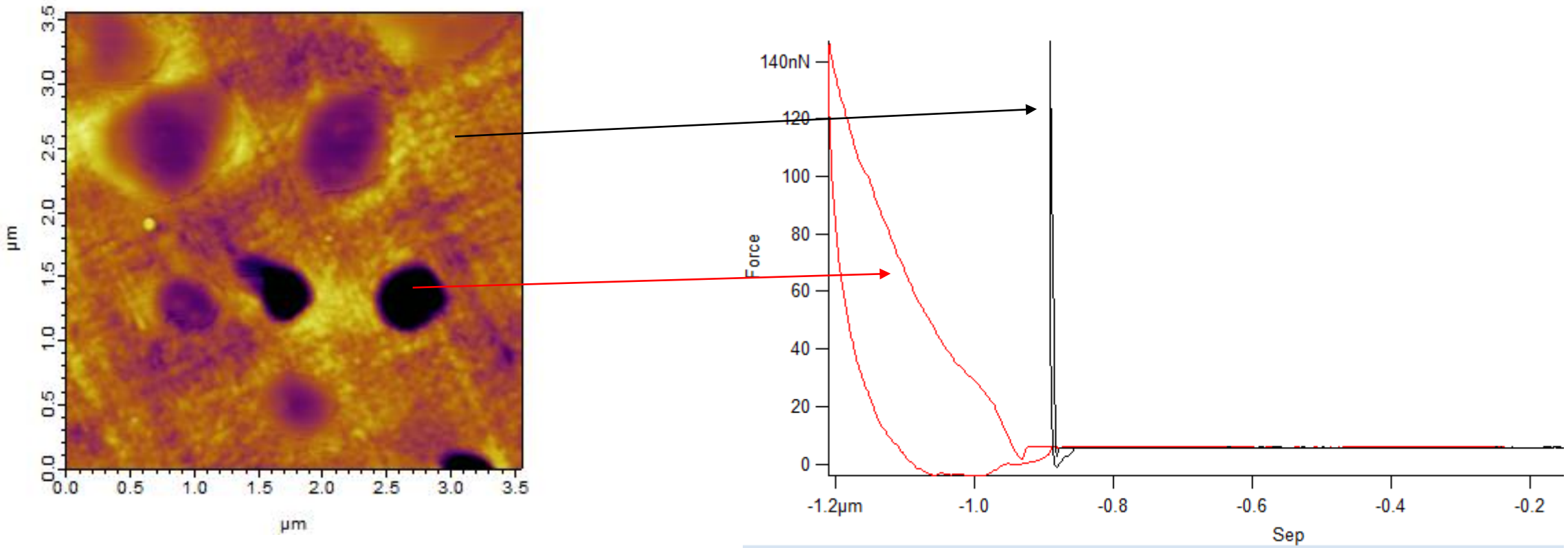

Contact between two spheres → region around contact deforms with center displacing by $\delta$
Circular contact area A is formed with radius a

# Contact mechanics models with tip-sample interactions



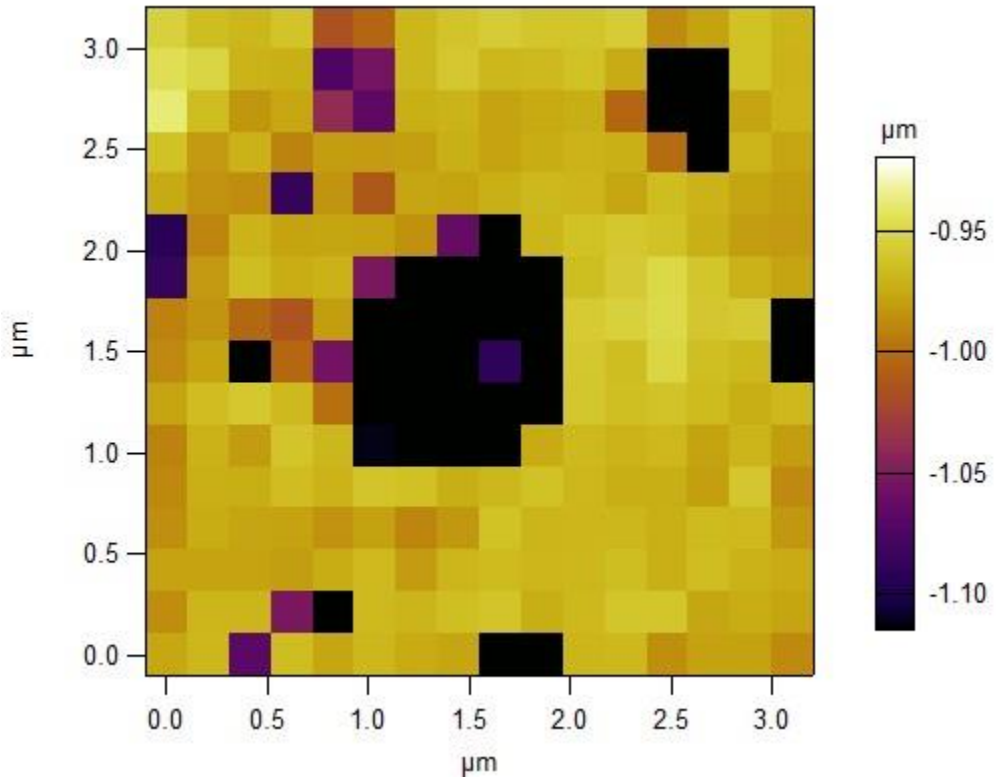



# Force curves on impact copolymer

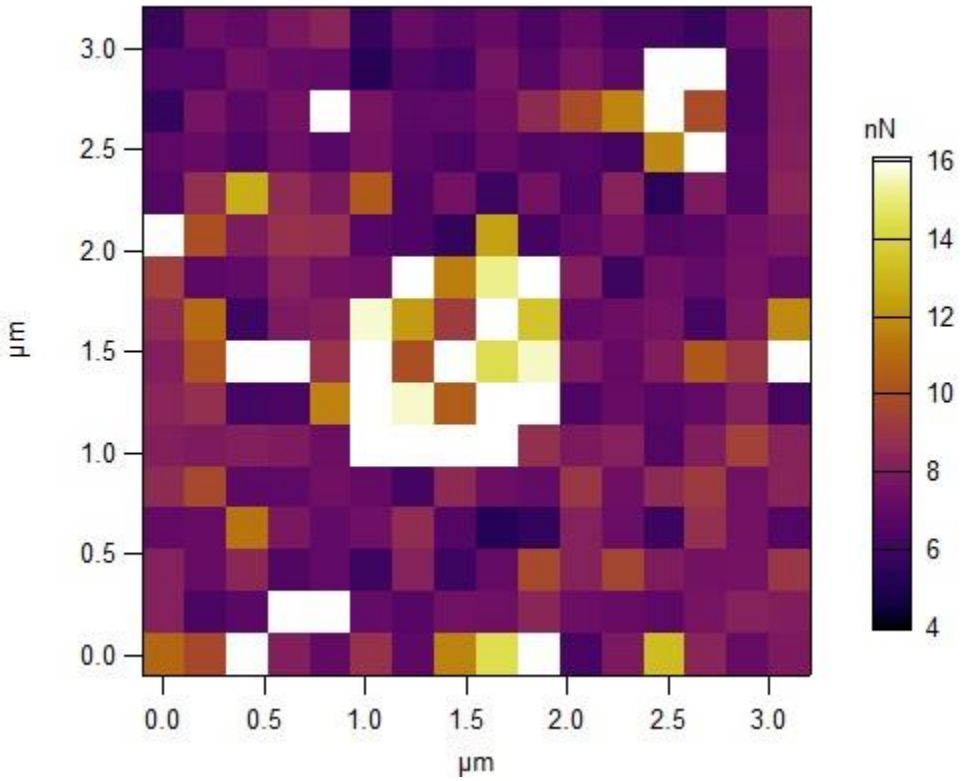


# *Create force maps…*

Height

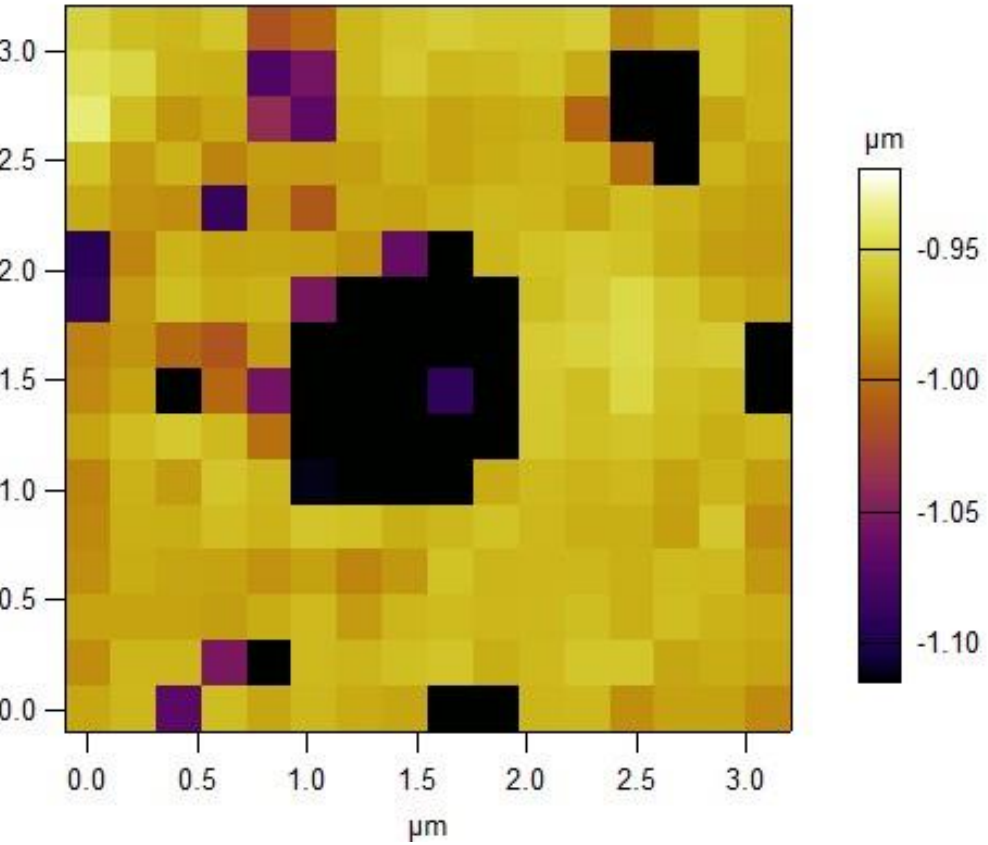



Adhesion

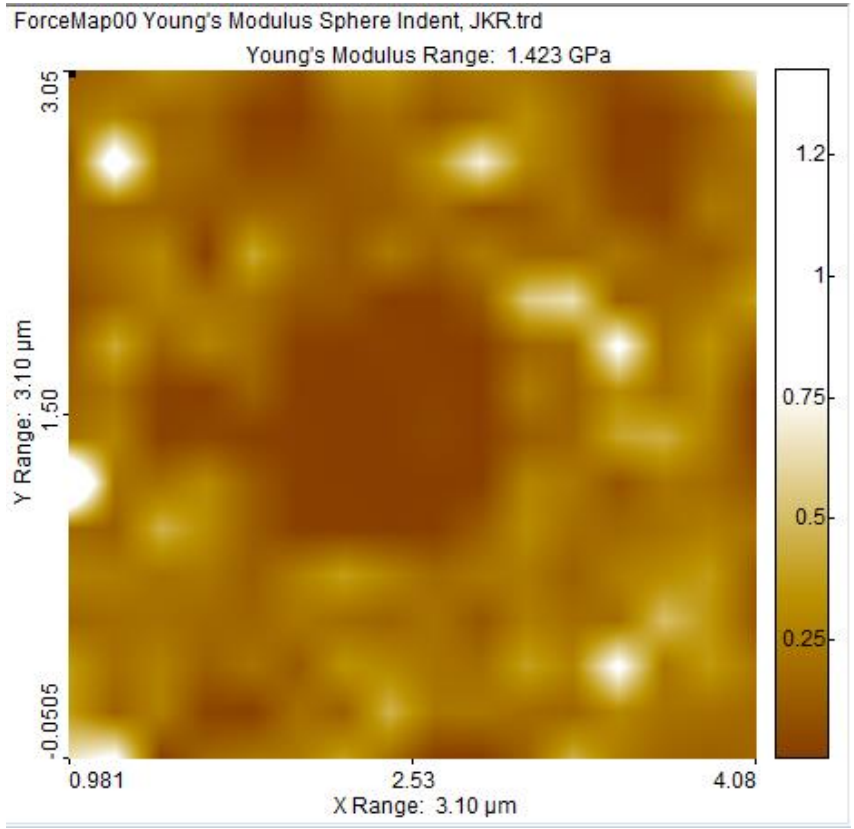


# *Create stiffness maps with different models*

Height map




JKR modulus map




✓ JKR modulus for rubber: 8MPa

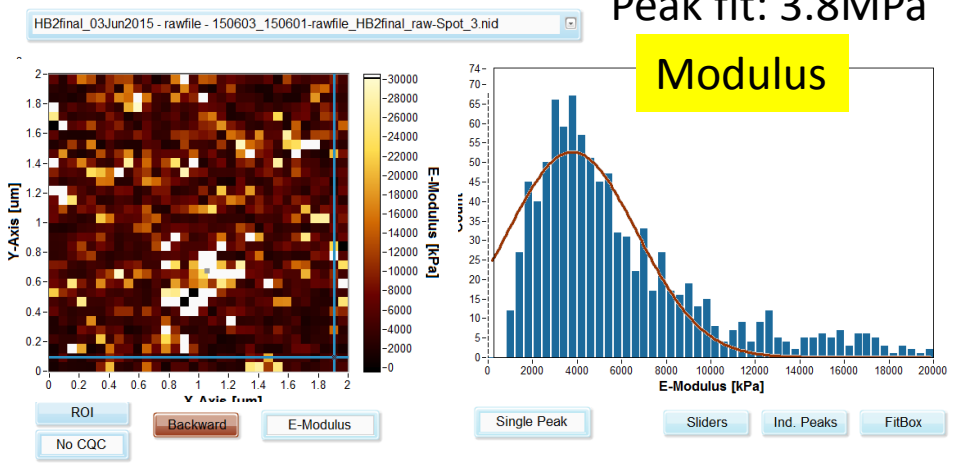
✗ JKR modulus for PP: 270 Mpa

# 2 Rubbers cured for different amounts of time: fit with JKR model

SurfaceChar

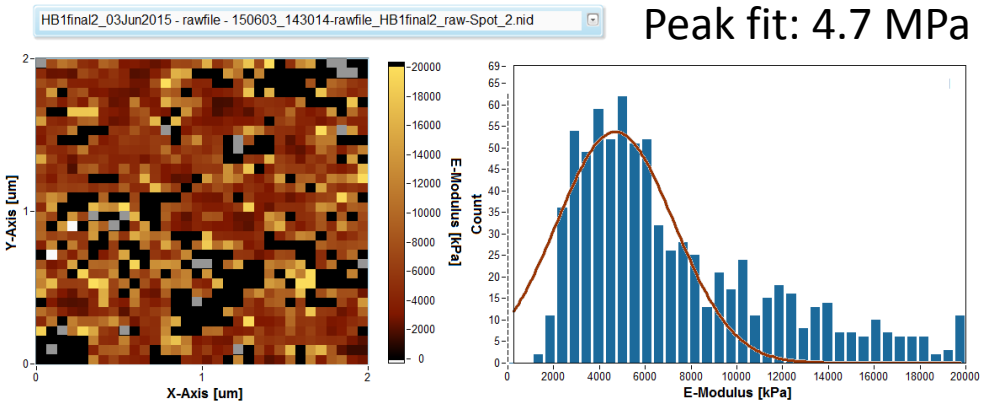
Rubber #1

Peak fit: 3.8MPa



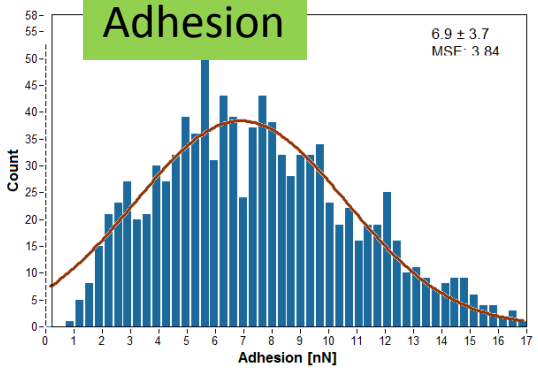

Rubber #2

Peak fit: 4.7 MPa



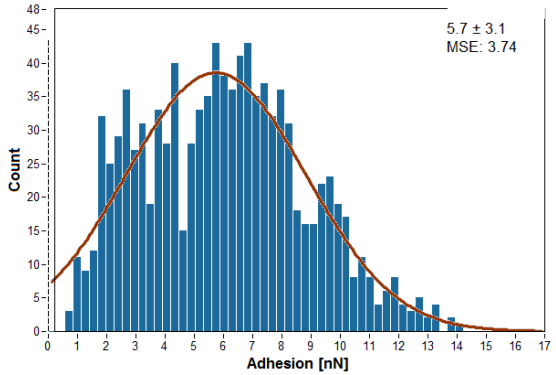

"stiffening"

Peak fit: 6.9nN




"less sticky"

Peak fit: 5.7nN



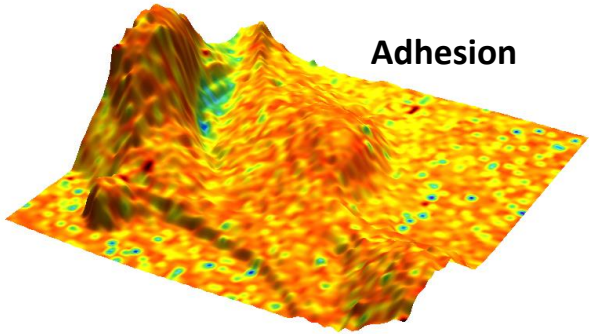

Data from Nanosurf

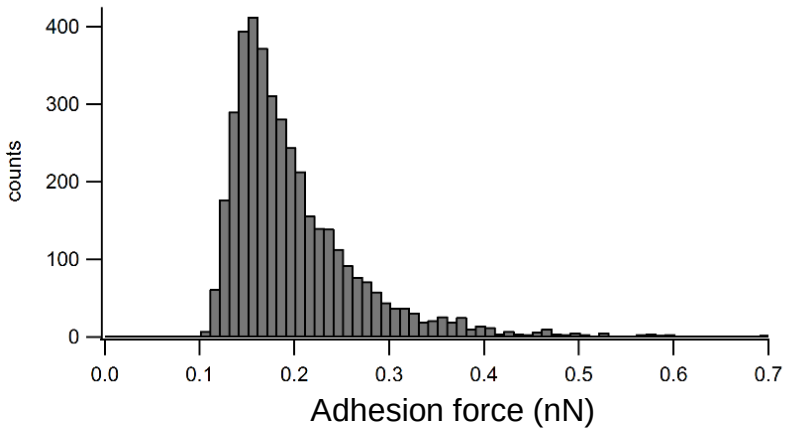
*SHOCON lever (0.12N/m, 155nm/V sensitivity)*

# *Forcemaps on cells*

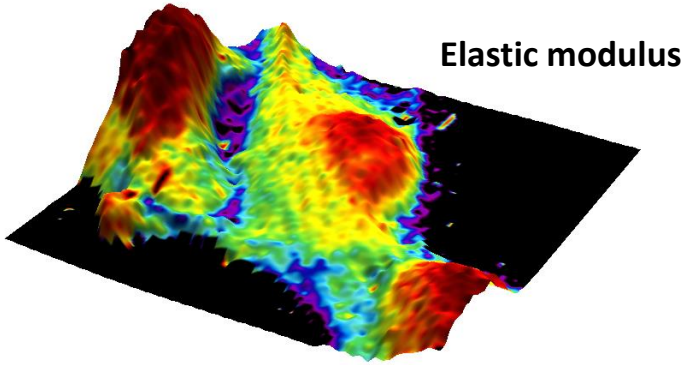
SurfaceChar

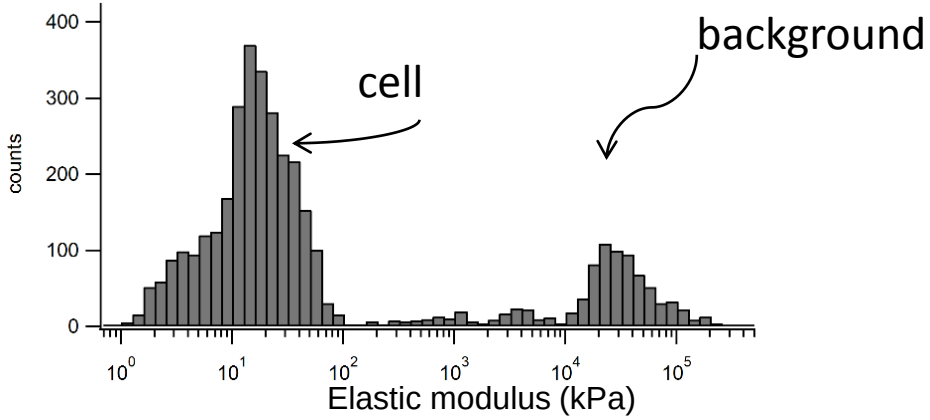
Epithelial cells



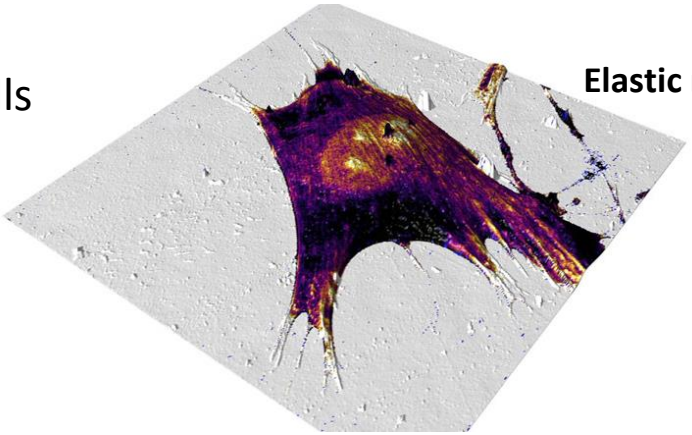



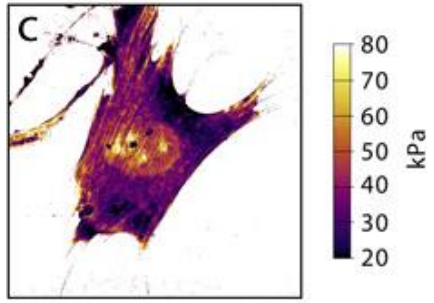

Data from nanosurf




Fibroblast cells

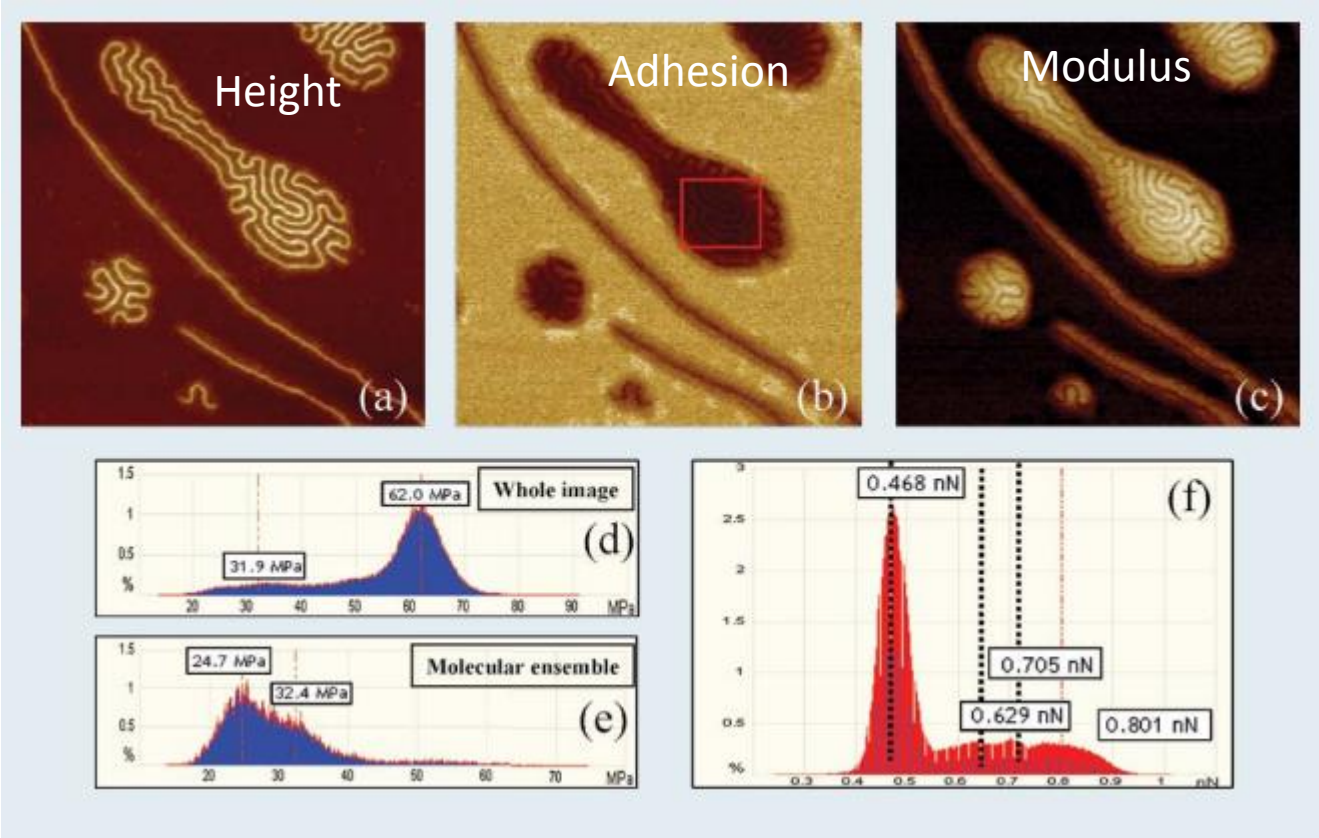



Data from Asylum Research (online image gallery)

# Forcemaps on polymer brush

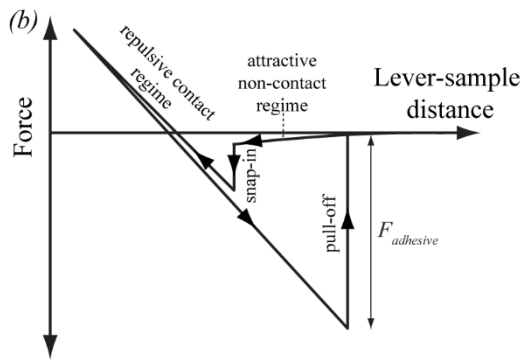
Polybutylacrylate




Data from Bruker Nano (AN128)

# *Force spectroscopy – current state of the art*

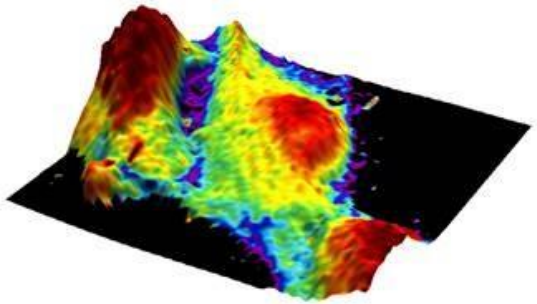
- Impressive control over all features of force curve:
  - Separating out parameters for approach and retract
  - Customizable parameters: triggers, hold (creep) segments, frequencies, etc.
- Main contact mechanics models are commercially available for fitting
  - DMT, JKR, Sneddon, Hertz are all standard parts of force analysis packages
- Wide range of spring constants for commercial cantilevers
- Speed, speed, speed
  - Force volume now done with real time acquisitions speeds



# *Challenges of force spectroscopy*

- Useful tool to measure stiffness and adhesion force in your sample
- End up with large data sets!
- Analysis can be a real hurdle
  - Real-time analysis with limited set of models
  - Need user-friendly ways to use different models within the same image
    - Heterogeneous materials – all materials may not be suitable for DMT analysis
  - Need to have familiarity with method and analysis for rational analysis
- Truly <u>quantitative</u> measurement with force curves still a challenge because of uncertainties in:
  - Tip shape calibration
  - Spring constant determination
  - Contact mechanics model assumptions

Courses in
Atomic Force Microscopy/
Scanning Probe Microscopy



Hooke College of
Applied Sciences

Dalia Yablon, Ph.D.

www.hookecollege.com

To register for future webinars or if you missed one of our past webinars,
access the recorded presentation and related resources.
Our webinars provide insightful information and innovative approaches to microanalysis
that apply to a wide range of industries.

**www.mccrone.com/webinars**