Lecture: P1_Wk4_L5
Modulus and Adhesion Maps

Ron Reifenberger
Birck Nanotechnology Center
Purdue University
2012
AFM enables a new class of experiments

What structural information can be obtained about the nanoscale object?
1. Position the tip above the nanoscale object

2. Perform basic Force vs. Displacement experiment

- Approach
- Loaded
- Withdraw
- Release

- Loading Force (nN)
- Jump to contact
- Indentation
- Adhesion
- z (Sample displacement)
A. Force vs. Time

B. Force vs. z-Displacement
The Idea: Modulus and Adhesion Maps

Preset Loading Force

jump to contact

lift off force $F(i,j)$

$z(i,j)$

Adhesion Map:

Modulus Map

Modulus $E(i,j)$

Topography Image

Write software that automatically measures quantities of interest.

Force vs. Time

- Loading Force (nN)
  - repulsion
  - attraction

Typically, a (128,128) image requires ~5-10 mins. to complete.
Simple Test (*circa* 1998):
**Au Bridge Connected to Contact Pads**

~20 nm thick Au contact pad

~10 nm thick Au bridge

Glass Substrate

---

State of the art (circa 2010):
Cellulose NanoCrystal (CNC) on mica

**Background:** Cellulose is a linear chain of glucose molecules \((C_6H_{10}O_5)_n\), \(n = 10,000-15,000\) linked together through an acetal oxygen* covalent bond. Multiple cellulose chains hydrogen bond to each other to form elementary fibrils, which collect into microfibrils called Cellulose NanoCrystals (CNC). CNCs are 5-50 nm in diameter and several micrometers in length and have regions that are disordered (amorphous-like) and highly ordered (crystalline).

**Problem:** What is the elastic modulus of an isolated CNC?

*Acetal oxygen: when two separate oxygen atoms are single bonded to a central carbon atom*
State of the art (circa 2011): Steps along the way

A) 744.19 mV

B) Thermal Tuning Spectra

C) Force-Displacement Curves on a Stiff Sample

D) Tip before Tip after

P1_Wk4_L5

R. Wagner, et al., Nanotechnology 22, 455703 (2011)
State of the art (circa 2011): Typical Data

State of the art (circa 2011): Modulus and Adhesion Maps

\[ \langle E \rangle = 8.1 \text{ GPa} \]

\[ \langle W_{132} \rangle = 116 \text{ mJ/m}^2 \]

\[ W_{132} = \gamma_{13} + \gamma_{23} - \gamma_{12} \]
Up Next: Lateral Force Microscopy