15-398 Introduction to Nanotechnology

Microscopy & Manipulation

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Today

- Examining the nanoscale
  - SEM
  - TEM
  - STM
  - AFM
- Manipulating atoms
  - STM
  - AFM

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A Bit of Microscopy History

Optical Microscope ~1700

SEM: 1942

Electrons: TEM 1931

1981: STM

1986: AFM

Time

www.prynearson.com/science.htm http://www.trincoll.edu/~alstrican/images/Instruments/ http://sibener-group.uchicago.edu

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Transmission Microscopy

- Light:
  - Max resolution 275nm
- Electrons
  - Max resolution <.1nm
- Why electrons are better?
  - De Broglie wavelength of e^-? h/mv
  - mv is controllable!

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Transmission Electron Microscope

Figure 9–22. Molecular Biology of the Cell, 4th Edition.

TEM

- Resolution: atomic
- Can determine 3-D structure
- Be careful of e^-- e^- interactions

Scanning Electron Microscope

Figure 9–29. Molecular Biology of the Cell, 4th Edition.

SEM

- Resolution: atomic
- Surface features
- Requires Vacuum
- Often must coat specimens

NASA nanotech group

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Comparing images

Figure 9–30 part 1 of 2. Molecular Biology of the Cell, 4th Edition.

Figure 9–30 part 2 of 2. Molecular Biology of the Cell, 4th Edition.

Scanning Probe Micrscopes

What might you measure?
How might you measure it?

STM

VOLUME 50, NUMBER 2 PHYSICAL REVIEW LETTERS 10 JANUARY

7 × 7 Reconstruction on Si(111) Resolved in Real Space

G. Binnig, H. Rohrer, Ch. Gerber, and E. Weibel
IBM Zurich Research Laboratory, 8803 Rüschlikon-ZH, Switzerland
(Received 17 November 1982)

STM cartoon

STM modes

- Constant-current mode
  - Measure height of probe to keep tunneling current same
- Constant-height mode
  - Measure tunneling current
  - Faster
  - Requires smoother surface
- Resolution
  - XY: 1nm, Z: .1nm

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World's smallest Billboard?

Xenon atoms

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STM images

STM of copper(111)

Can you identify:
-Spheres?
- waves?
-Valleys?
-Plateaus?

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Quantum Corrals

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1.2nm CNT

D. Carroll, Clemson U.

Si(111)

1000K

28K

J. Krim, North Carolina State University

RHK Tehcnology, Inc.

Atomic Force Microscope

Sample Surface scanned back and forth

AFM Modes

What forces act to attract? Repulse?

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Contact Mode

- Contact-mode
  - Interaction between tip and sample in "physical contact"
  - Can damage sample, esp bio materials
  - Forces in nanoNewtons
- Tapping Mode
  - Vibrate tip, measure freq of oscillation

Tapping Mode

Amplitude

Height

Phase Shift

Different Data -> different views

freeze fractured styrene-isobutylene-styrene a-b-a block copolymer film, from: http://www.psrc.usm.edu/mauritz/afm.html

Made from Si or Si_3N_4

Interpretting images

More artifacts

Subatomic resolution

Subatomic Features on the Silicon (111)-(7×7) Surface Observed by Atomic Force Microscopy

Franz J. Giessibl,* S. Hembacher, H. Bielefeldt, J. Mannhart

The atomic force microscope images surfaces by sensing the forces between a sharp tip and a sample. If the tip–sample interaction is dominated by short-range forces due to the formation of covalent bonds, the image of an individual atom should reflect the angular symmetry of the interactions. Here, we report on a distinct substructure in the images of individual adatoms on silicon (111)-(7×7), two crescents with a spherical envelope. The crescents are interpreted as images of two atomic orbitals of the front atom of the tip. Key for the observation of these subatomic features is a force-detection scheme with superior noise performance and enhanced sensitivity to short-range forces.

www.sciencemag.org SCIENCE VOL 289 21 JULY 2000

AFM Images

NaCl on Mica (5.6nmx4.8nm)

Hard Disk

Dip-Pen Lithography

Can Read and Write!

www.sciencemag.org SCIENCE VOL 283 29 JANUARY 1999

"Inks"

Soft Materials
- Small functional molecules
- SAMs
- Conducting polymers
- Biopolymers / macromolecules

Hard Materials
- Metal inks
- Sol precursor inorganic inks
- Nanoparticle catalysts

From Nanoinc presentation

Speeding up the process

Today

- Looking at (and modifying) the nanoscale
- SEM/TEM
- STM/AFM

- For Thursday: read chapter 3.

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