DI
Dimension AFM
User Training

Basics of AFM Technique

MINT Center
Introduction

• Scanning Probe Microscopy
  – STM (Scanning Tunneling Microscopy, invented 1981)
    • Tunneling Current between sample and tip highly sensitive to gap distance $z$.
    • Sample needs to be conductive.
  – AFM (Atomic Force Microscopy, invented 1986)
    • Measure forces exerted on the cantilever/tip assembly
    • Can measure on any sample (conductive/non-conductive)

Key features of AFM:
• Can measure in air, liquid, vacuum
• Choice of tip yields a variety of information on the sample surface (topographic, magnetic, friction, elastic properties)
• Ease of use (commercially available tips)
• Video-rate scanning speed
The Idea

Binnig, Quate, and Gerber invented the AFM in 1986.

Basic Principle

PSPD = Position-Sensitive Photo-Detector
The Scanner

Scanner is made of piezoelectric material (e.g. PZT, Lead Zirconium Titanate).
The Dimension 3000 AFM
Measurement Modes

• Contact Mode
• Tapping Mode
• Non-Contact Mode

Lennard-Jones Potential between atoms / molecules
Cantilever Characteristics:

Probe Characteristics:
- radius of curvature less than 10 nm;
- tip height 20..25 µm;
- full tip cone angle less than 30°.

SEM images of the silicon cantilever.

Specifications

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
<th>Typical</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cantilever length, l±5, µm</td>
<td>125</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cantilever width, w±3, µm</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cantilever thickness, µm</td>
<td>3.5</td>
<td>4.0</td>
<td>4.5</td>
</tr>
<tr>
<td>Resonant frequency, kHz</td>
<td>265</td>
<td>325</td>
<td>400</td>
</tr>
<tr>
<td>Force constant, N/m</td>
<td>20</td>
<td>46</td>
<td>75</td>
</tr>
</tbody>
</table>
SPM – A Powerful Tool

Primary Imaging Modes
• Contact AFM
• Tapping / Non-Contact AFM (oscillation mode)

Secondary Imaging Modes
• Lateral Force Microscopy (LFM)
• Magnetic Force Microscopy (MFM)
• Conductive AFM (CAFM)
• other
Pentacene Imaged with AFM

First-time observation of individual atoms in a molecule!

CO-terminated Gold Tip

Gross et al., Science 325, 1110–1114; 2009
Artifacts

• The fact that the AFM data is taken by a tip with a finite size introduces imaging ‘artifacts’ that may significantly alter the resulting ‘image’.

• Great care has to be taken to identify possible artifacts in the measured data and consider them for image interpretations!
Artifacts

Dull or Dirty Tip
Artifacts

Double- / Multiple Tips
Artifacts

Contamination from Sample Surface
Artifacts

Optical Interference
Never take an AFM image at face value! Very often interpretation is needed!