Lecture: P1_Wk5_L6
Image Artifacts

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Good Tips

D. Schaefer, PhD Thesis, Purdue University (1993)

Real Tips

Blunt tip

Broken tip


D. Schaefer, PhD Thesis, Purdue University (1993)
Tip Imaging Artifacts

**Double Tip**
- Tip
- Substrate
- Feature in substrate repeated in image

**Tip Dilation**
- Tip
- Substrate
- Image of feature in substrate broadened by tip “radius”

**Sharp Feature in Substrate**
- Tip
- Substrate
- Feature images tip

**Wide Tip**
- Tip
- Substrate
- Depth of feature in substrate inaccurate
Double Tip Image

Apparent width of small object

\[ x^2 = (R_{\text{tip}} + R_{\text{feature}})^2 - (R_{\text{tip}} - R_{\text{feature}})^2 \]

\[ x^2 = R_{\text{tip}}^2 + 2R_{\text{tip}}R_{\text{feature}} + R_{\text{feature}}^2 - R_{\text{tip}}^2 + 2R_{\text{tip}}R_{\text{feature}} - R_{\text{feature}}^2 \]

\[ x = 2\sqrt{R_{\text{tip}}R_{\text{feature}}} \]

apparent feature width \( \approx 2x = 4\sqrt{R_{\text{tip}}R_{\text{feature}}} \)
Summary: Tip Artifacts

Rule of thumb - any feature with a radius of curvature less than radius of curvature of tip is not accurately imaged.

Lesson: Choose a tip shape/cantilever consistent with what you are trying to accomplish.

<table>
<thead>
<tr>
<th>Mode</th>
<th>L(μm)</th>
<th>W(μm)</th>
<th>t(μm)</th>
<th>f₀ (kHz)</th>
<th>kₑ (N/m)</th>
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<tbody>
<tr>
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<td>400</td>
<td>30</td>
<td>2</td>
<td>18</td>
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<tr>
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<td>5</td>
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<td>50</td>
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<td>1</td>
<td>25</td>
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<td>3</td>
<td>70</td>
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<tr>
<td>Magnetic Force</td>
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<td>3</td>
<td>70</td>
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<tr>
<td>Under liquids</td>
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<td>30</td>
<td>0.16</td>
<td>37</td>
<td>0.05</td>
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</tbody>
</table>

Note: Typical values
Sometimes, special tip shapes are required

Scan Direction
Tip Care

**CONTAMINATION**
- Thin organic layers
- Oxide layers
- Particulates

**DRY CLEANING**
- UV (ozone) cleaning
- Heating (pyrolysis)
- Argon/Oxygen/Air plasma (glow discharge)
- Sputtering (UHV)
- Indenting into substrate
- CO\(_2\) “snow” – small dry ice particulates

**WET CLEANING**
- Chemical Etching
- Ultrasonic cavitation
- Passivation (coating)

**Tip Surface:**
- SiO\(_2\)
- Si\(_3\)N\(_4\)
- Au-coated
- Pt-coated

**Tip Shape:**
- Pyramidal
- Conical

Assumption: Cleaning the tip is equivalent to cleaning the whole cantilever.

Unknown tip morphology at the nanoscale?
Unknown microstructure at the nanoscale?
Microstructure of Metal Coating

Gold coated (Thermal Evaporation):

Gold/Palladium coated (Sputtered):
How do you know the tip is dirty?

1. Low resolution:

2. Large adhesive force observed:

Adhesion due to water (typical):

\[
F_{\text{capillary}} = \rho_{\text{Laplace}} A = \frac{R_{\text{gas}} T}{V_{\text{mol}}} \ln \left( \frac{\rho_{\text{vap}}}{\rho_{f}} \right) \pi R_{\text{cap}}^2
\]

\[
= \left( 4\pi \gamma R_{\text{tip}} \right) \left( \frac{h + R_{\text{tip}}}{0.52 \text{nm}} \right) \ln \left( \frac{\rho_{\text{vap}}}{\rho_{f}} \right) \approx 3 \left( 4\pi \gamma R_{\text{tip}} \right)
\]

Adhesive Force Histograms are a must!

3. Hysteresis in cantilever deflection vs. z data

Notes:
- BOPP=Biaxially-Oriented Polypropylene
- Image size: (2μm x 2μm)

Tests for Scanning Artifacts
(The $R^3C^2$ Rule)

• Repeat the scan – does it look the same?

• Reverse the scan direction, does the new image look like the original one?

• Rotate the scan direction; do the features rotate as expected?

• Change the scan size; do the size of features scale properly

• Change the scan speed; do the features remain stationary?

Useful if image processing software can subtract two images
Tip/Cantilever Recommendations

- Don’t store microcantilevers in plastic shipping cases without cleaning microcantilever before use.
- Use dedicated teflon or quartz beakers when cleaning (avoids leaching of plasticizers; acid leaching of pyrex).
- Use dedicated tools (tweezers, glass slides, etc.).
- Do not be afraid to clean your tweezers regularly.
- Ozone cleaning and Glow Discharge cleaning are relatively easy (no waste or protective equipment required).
- After cleaning, store tips in clean solvent.
- Under ambient conditions, hydrophobic tips seem to be better than “as-received” tips.
- When in doubt, throw it out!
Concludes Part I

Up Next: Part II - Dynamic AFM