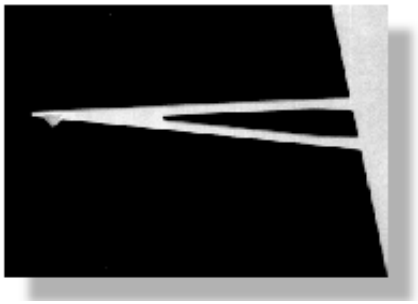
PENNSTATE

Contact (V-shaped) Cantilevers

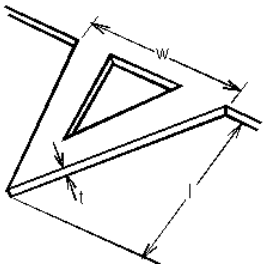


Cantilevers range from 100 to 200μm in length, 10 to 40 μm in width and 0.3 to 2μm in thickness

Integrated cantilevers can be made from silicon or silicon nitride. More than 1,000 tips can be made on a single Si wafer. V-shaped cantilevers are the most popular because they provide low mechanical resistance to vertical deflection and high resistance to lateral torsion

PENNSTATE

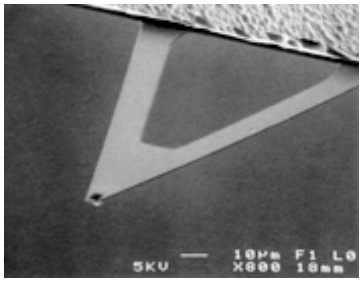
Contact (V-shaped) Cantilevers

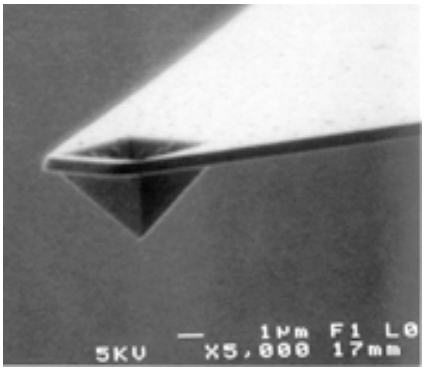


Cantilevers sizes range:
from 100 to 200μm in length (l),
10 to 40 μm in width (w), and
0.3 to 2μm in thickness (t)

PENNSTATE

Contact (V-shaped) Cantilevers



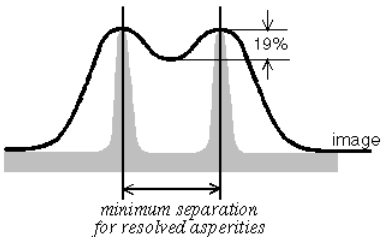


Si_3N_4

spring constants in N/m (or nN/nm)

PENNSTATE

Lateral Resolution



Lateral resolution determined by:
1. Step size of image
2. Maximum radius of tip

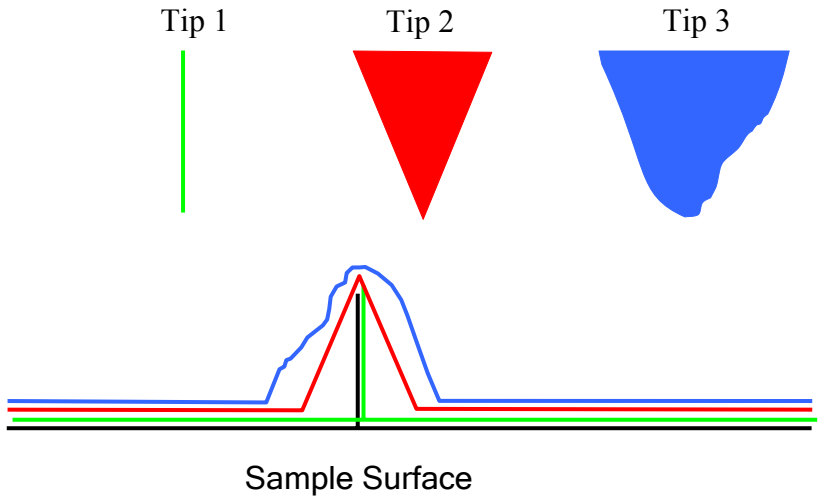
Typical Tips – R ~ 5nm giving a Lateral resolution of ~2nm
However, tips with single wall nanotubes with R ~ 1nm are being developed giving lateral resolution to ~0.05nm

Example:

Consider a scan with a 1µm x 1µm image taken with 512x512 data points. Such a scan has a step size (and lateral resolution) of 1µm/512 ~ 2nm.

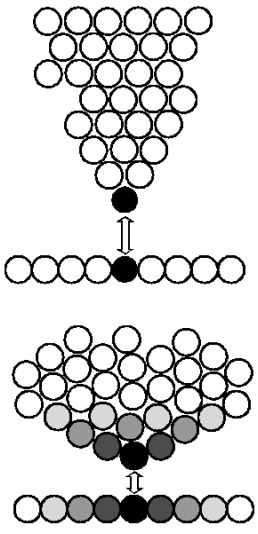
PENNSTATE

Influence of the Tip Geometry on Imaging Surface Features



PENNSTATE

Influence of the Tip Geometry on Imaging Surface Features



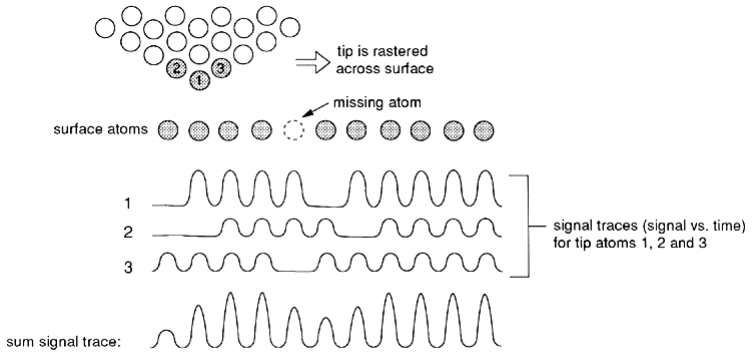
STM (top) gives true atomic scale resolution because only the atom closest to the surface interacts with the closest atom on the sample (sensitivity $\sim r^{9}$).

For AFM (bottom) the dependence of the closest atom of the tip interacting with the closest atom of the sample is much weaker and **longer range**. The result is that several tip atoms interact simultaneously with the atoms in the surface.

PENNSTATE

Real Atomic Resolution

Can atomic defects be 'seen' in the AFM image?



PENNSTATE

Real Atomic Resolution

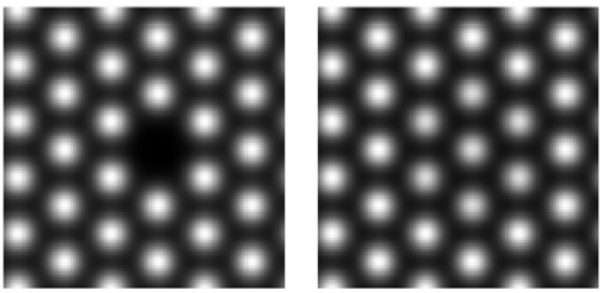
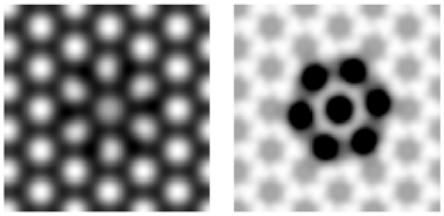


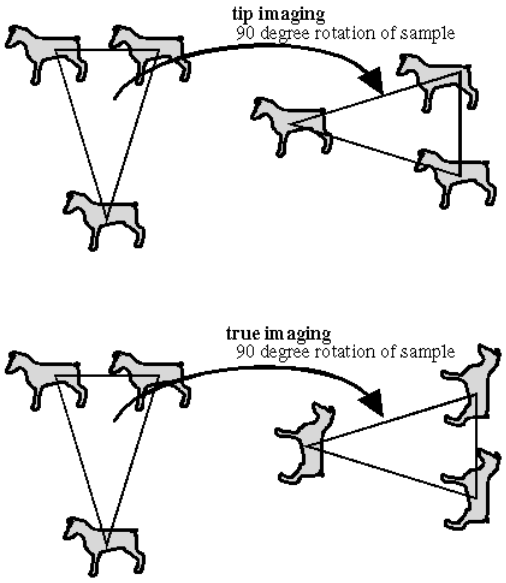
Figure 3.1: *AFM images of a fcc lattice with an atomic vacancy. (left) When the scanning is carried out with a single-atom tip the vacancy is clearly imaged. (right) When the same surface is scanned by a 7-atom flake-like tip, having its atoms in registry with the atoms of the lattice, the vacancy disappears and an imaginary atom is imaged instead.*



same sample as above, imaged with a 7 atom flake-tip, now rotated by 14° (left) and 22.5° (right)

PENNSTATE

Tip-Shape Artefacts



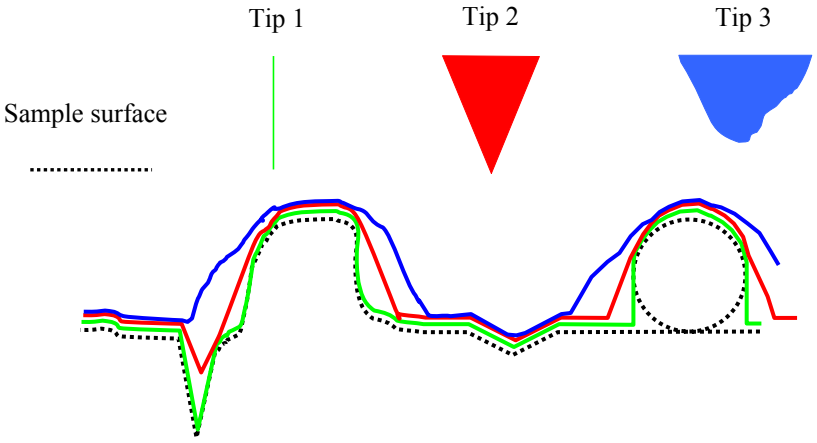
If a shape is repeated throughout the image.

Rotate sample and image again. If tip shape is dictating the image, the image will appear nearly the same as shown in the top.

If the image is a 'true' image, the image will be rotated.

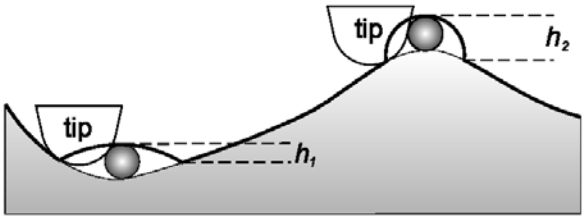
PENNSTATE

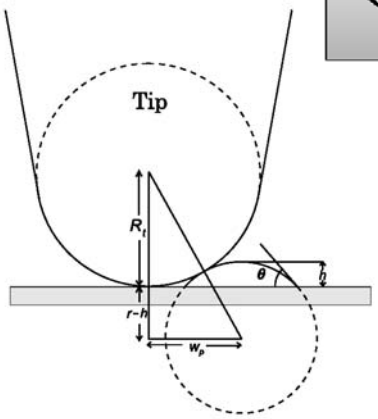
Influence of the Tip Geometry on Imaging Surface Features



PENNSTATE

Influence of the Tip Geometry on Imaging Surface Features





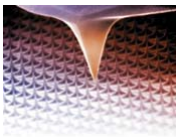
$$r = \frac{w_p^2}{2h} + \frac{h}{2} - R_t = \frac{w^2}{8h} + \frac{h}{2} - R_t$$

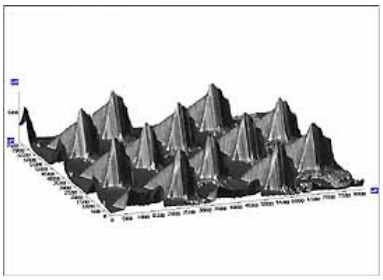
$$\cos\theta = 1 - \frac{h}{r}$$

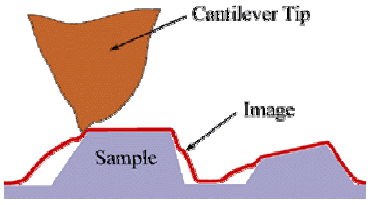
$$V_c = \frac{1}{3}\pi r^3(1 - cos\theta)^2(2 + cos\theta)$$

PENNSTATE

Tip Evaluation Samples



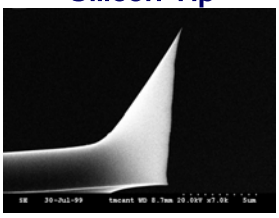




PENNSTATE

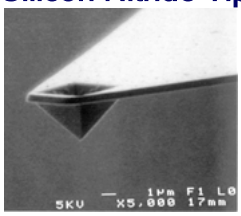
Tip Selection (contact AFM)

Silicon Tip



- Good for deep narrow features
- Can be electrically conducting
- Used for Tapping Mode™

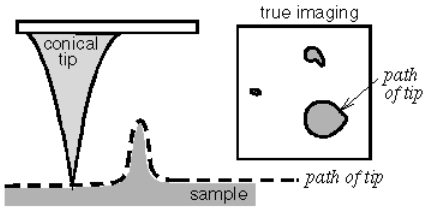
Silicon Nitride Tip



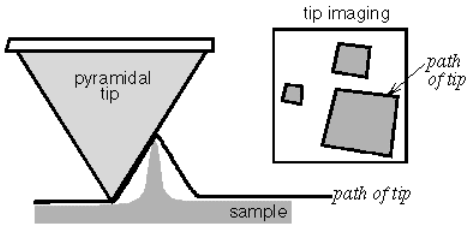
- More mechanically robust
- Good for LFM
- Smaller resolution than Si

PENNSTATE

Tip Selection (contact AFM)



Si Tip can image shaper features, but also wears more rapidly

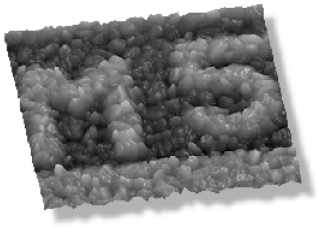


There will be more image artifacts with a Si_3N_4 tip, but will not wear and is better suited for LFM than Si

PENNSTATE

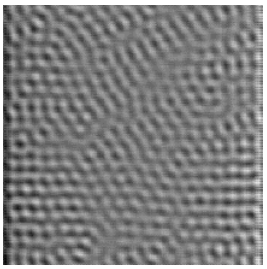
Software Interventions

- Introduce artificial light sources
- 3-dimensional rendering
- Color tables
- Curvature enhancement algorithms
- Retouch areas of bad data
- Filtering “environmental noise”
- Magnify or reduce the vertical scale
- Fourier Transform
- Low-Pass/High-Pass Filtering …



3-D rendering of a semi-conductor surface

Narrow band pass filter



BE VERY CAREFUL !!!!