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Materials Science and Engineering

Surface Roughness

Statistical descriptors that give average behavior of the *surface height*. For example, average roughness Ra; the root mean square roughness Rq; the skewness Ssk and the kurtosis K.

Extreme value descriptors that depend on *isolated events*. Examples are the maximum peak height Rp, the maximum valley height Rv, and the maximum peak to valley height Rmax.

Texture descriptors that describe variations of the surface based on *multiple events*. An example for this descriptor is the correlation length.

and their determination by AFM

E. Manias, MatSc 597F, Fall 2001

MATSE The Department of Materials Science and Engineering

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Surface Roughness Parameters

• Root-Mean-Square (RMS) Deviation of the Surface (Sq)

$$S_q = \sqrt{\frac{1}{M\,N} \sum_{j=1}^{M} \sum_{i=1}^{N} \eta^2(x_i, y_j)}$$

M: is a number of points of per profile (scan line)
N : is the number of profiles
η : amplitude at (x,y) point

• Skewness of Topography Height Distribution (Ssk)

$$S_{sk} = \frac{1}{M\,N\,S_q^3} \sum_{j=1}^{M} \sum_{i=1}^{N} \eta^3(x_i, y_j)$$

M, N and η : as above

for more roughness parameter definitions see the course's web site

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Surface Roughness Defined by AFM

- **Fractal:** measures surface roughness and determines the fractal dimension by superimposing a three-dimensional array of cubes on the three-dimensional image surface.

- **Grain size:** defines grain boundaries and displays histograms based on height and slope.

- **Power spectral density** (PSD): provides surface roughness data by computing the spatial power spectrum of the image.

- **Roughness:** calculates a variety of roughness parameters for the entire image and/or a sub-area (average, RMS, etc.).

- **Section:** allows Z data (height) to be plotted and measured in cross-section along any line drawn by the user across the image, similar to traditional profilometer measurements.

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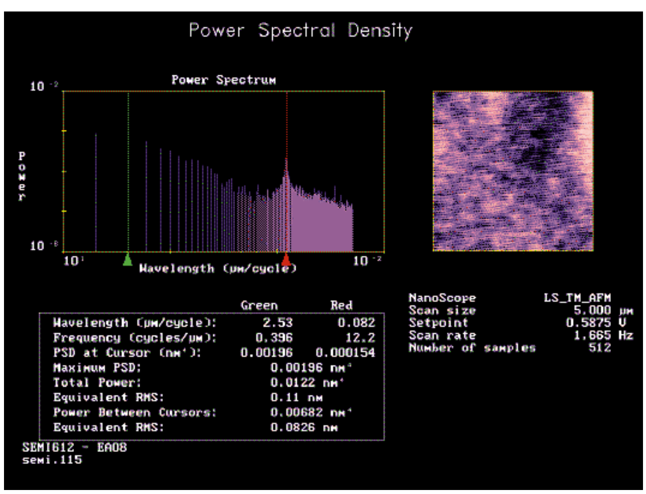
Power Spectral Density (PSD)

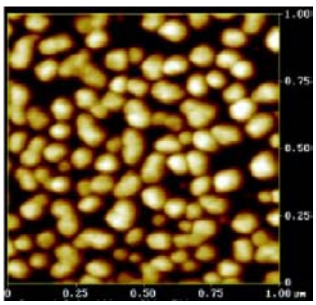


Power Spectral Density is becoming a widely accepted measurement for characterizing the spatial frequencies of the roughness on a surface. Here a 5 micron scan of epitaxial silicon shows a distinct peak at 0.82 microns.

Experimental elements that affect the estimated roughness parameters

The roughness parameters are estimated by the analyzing the topography scans of the sample's surface. Thus, everything that affects the "real" imaging of the topography will also affect the roughness estimation:

- all tip artifacts (and especially tip-shape convolution)
- how faithful to reality is the image (e.g. feedback quality)
- tip induced surface roughness (scratches, indentations, etc.)
- noise in measurement (especially at high (atomic, nm) resolution)



z-range	66.8nm
RMS	13.3nm
Ra	11.2nm
Surface Area	1.316 μm^2
Surf. Area Diff	31.0 %

Should all the AFM topography features be measured as roughness ?

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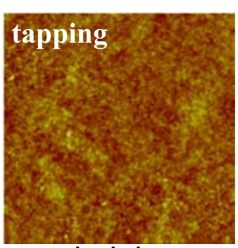
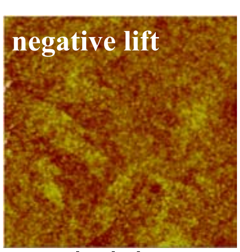
However, things are not so simple !

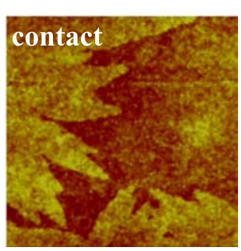


height

height



height



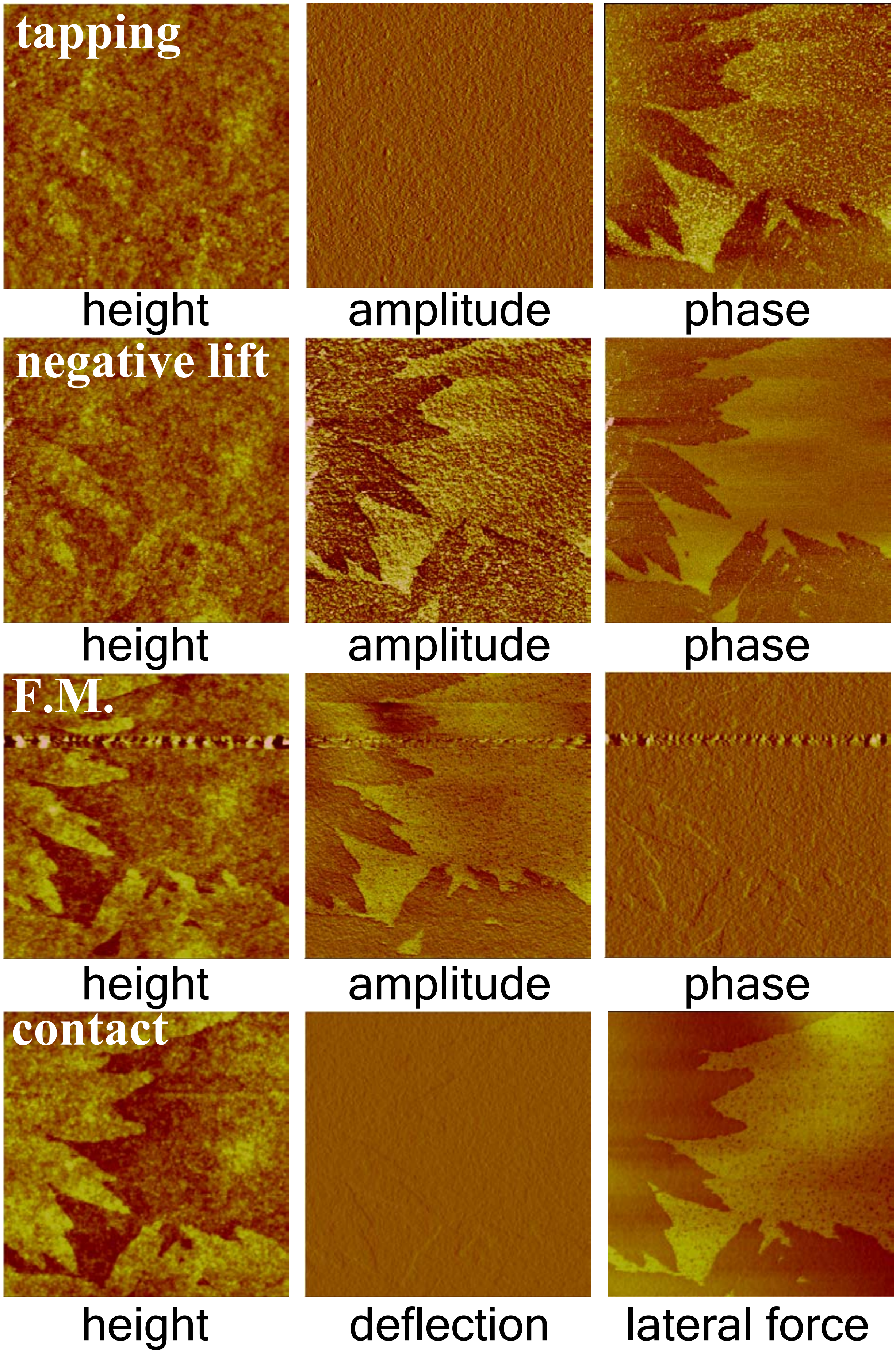
height

On the left is the same region of a polymer (PVA) surface, imaged under four different AFM modes by the *same* tip & cantilever.

It is obvious that the estimated surface roughness from each of these scans will be different

why?

Which image will provide the correct roughness parameter ?


tapping
height
amplitude
phase
negative lift
height
amplitude
phase
F.M.
height
amplitude
phase
contact
height
deflection
lateral force