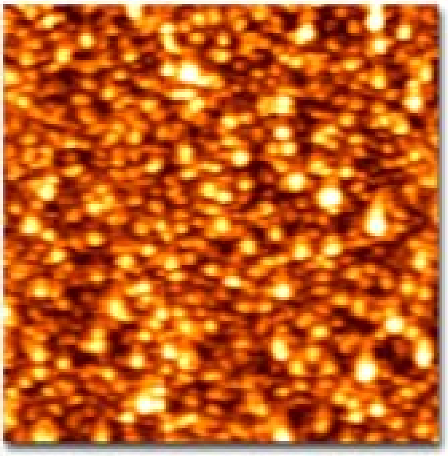
Atomic Force Microscopy for
Nano-Surface Texture / Roughness:

The atomic force microscope is ideal for quantitatively measuring the nanometer scale surface roughness and for visualizing the surface nano-texture on many types of material surfaces. Advantages of the AFM for such applications are derived from the fact that the AFM is nondestructive and it has a very high three dimensional spatial resolution.

Figure 1



This contact mode AFM image shows the grains at the surface of a metal bonding pad. The image size is 1.79 X 1.79 microns and the maximum height of a feature in the image is 29.2 nanometers.

Measuring the surface texture of samples with horizontal length scale of less than 10 microns and a vertical length scale of 100 nanometers is critical for many areas of science and technology. For example, surface texture can alter the optical properties of materials, control adhesive properties of polymers, effect the yield of processed silicon wafers, and control the density of stored magnetic materials.

AFM Comparison with Other Techniques

There are numerous analytical methods for establishing the surface roughness as well as the visualization of surface texture. Each of these methods has its own advantages and disadvantages.The following list briefly compares and contrasts these techniques.

Optical Methods

Optical methods have the advantage that they can measure surface properties very rapidly. However, the horizontal resolution of all optical methods is limited to the resolution of optical techniques, typically greater than ½ micron. Also, a limitation of optical methods is that they require an optically opaque sample. The following is a summary of optical methods:

Microscopes - Optical microscopes are excellent for visualization of surface texture but they do not allow direct measurement of quantitative surface roughness parameters.

Optical profilers - Optical profilers are ideal for rapidly measuring surface roughness parameters with a horizontal resolution that is greater than ½ microns. Large areas can be analyzed with optical profilers.

Scatterometry - Like other optical methods, scatterometry gives rapid surface roughness parameters of a surface area that is greater than 1 micron. However, this optical method is not a direct measure of surface topography and does not allow visualization of surface texture.

Electron / Ion Beam Methods

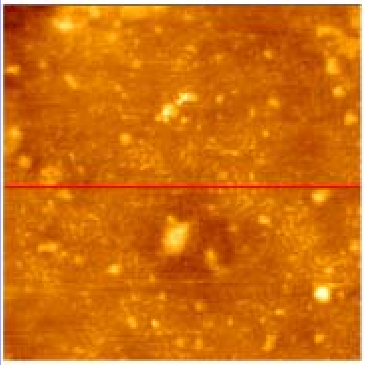
Electron and Ion beam techniques are capable of visualizing surface texture with horizontal resolutions of less than a nanometer. However, the beam techniques do not give quantitative three-dimensional surface topograms so it is difficult to get quantitative surface texture information. Also, because the contrast in beam techniques relies on the differing emission of electrons, beam techniques do not give contrast on flat homogeneous materials.

It is possible to get accurate surface roughness values using beam methods by cross sectioning a sample. However, cross sectioning can be difficult and the value may be changed by the cross sectioning process.

Mechanical Profilers

AFM technology is derived from the suface profiler. The primary difference between a profiler and an AFM is the loading force on the scanned probe. Because the loading force on an AFM is substantially smaller than a profiler, smaller probes can be used in an AFM. With a smaller probe, it is possible to visualize much smaller surface structure in an AFM than a profiler. Often an image from an AFM shows more detail than a profiler and the surface roughness can be much greater.

Figure 2



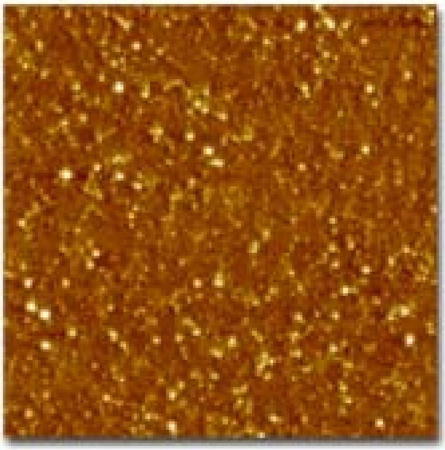
Ra:	*0.71*
Rq:	*0.90*
Rsk:	*0.45*
Rku:	*3.67*
Rz:	*4.63*

Line surface roughness of a polymer film showing a value for Ra of about .71 nm. There are larger features on the image, as large as 18.39 nm, but they are not included in the calculations of these line roughness parameters.

Examples of Sample Texture Measurements

Visualization: Often it is difficult to fully characterize surface texture without direct visualization of a surface. Atomic force microscopes are well suited for visualization of surface texture, especially when the surface feature sizes are far below one micron. Illustrated below is the surface texture of a piece of commercially available recording tape.

Figure 3



10 µm X 10 µm AFM image of commercially available magnetic tape showing the surface texture. The maximum Z scale on this image is 48.5 nm. Such images facilitate a visual inspection of surface roughness and texture.

Line Roughness: After acquiring an AFM image it is possible to measure the 1-D surface roughness on a line in the horizontal or vertical direction in the image. After identifying the line for the measurement, a computer calculates all of the relevant parameters. Below is an illustration of the 1-D surface roughness measured on a polymer film.

Area Roughness: Optimal characterization of surface texture is often expressed with area roughness calculations that are made on the entire surface. Surface roughness calculations are similar to line roughness calculations but they include data in the x and y plane of the surface.

Figure 4

This is a 1 µm X 1 µm image of a bare silicon wafer image with the Nano-R™ AFM system. The area roughness values shown are for the entire image.

Surface/Area Roughness Calculations

Surface and area roughness parameters are meant to help quantify the surface texture of a material. Initially such parameters were used for characteriz-ing machined surfaces, however; now they are used for characterizing all types of high technology and nano-materials.

Note: An excellent resource for the definitions of surface roughness parameters can be found on the web at the URL: www.predev.com/smg/parameters.htm

Sources of Error in Area/Surface Roughness Measurements

There are two primary potential sources of error in using an AFM for measuring surface textures. The first is the probe geometry and the second is the length scale of the measurement.

Probe Geometry: The surface texture that is measured with an AFM depends on the geometry of the probe tip. If the probe tip is larger than the features causing the surface texture, then the surface roughness measurements will appear smaller than they should be. This possible source of error is avoided by using the sharpest possible probe.

Length Scale: Within the image used for the surface/area roughness calculation there must be an adequate sampling of the features giving rise to the surface texture. As a result, it is possible to get a different surface texture when the scan size is changed. This problem is avoided by using the same size scan range when surface roughness on several samples is being compared.