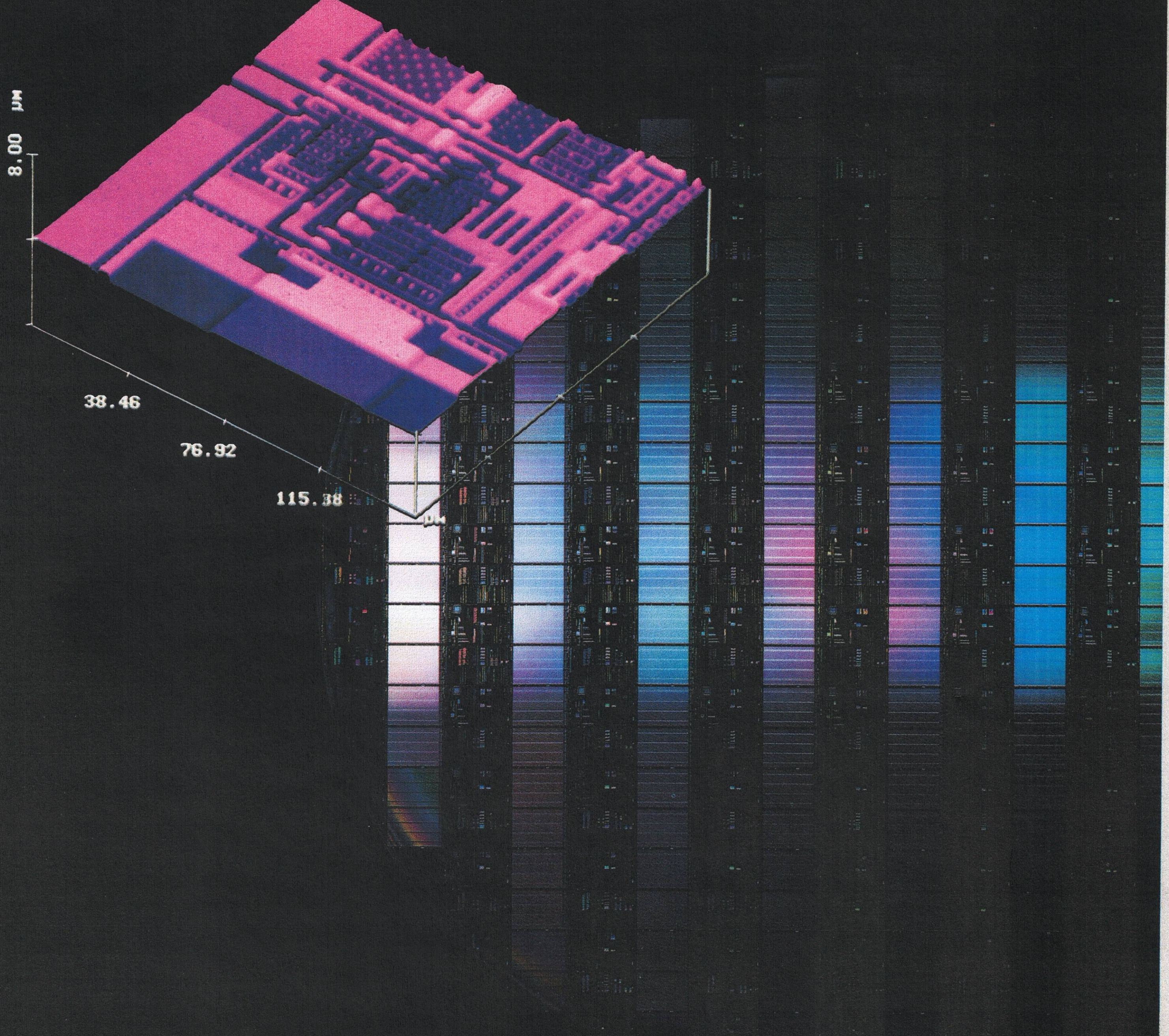
The NanoScope Large Sample Scanning Probe Microscope

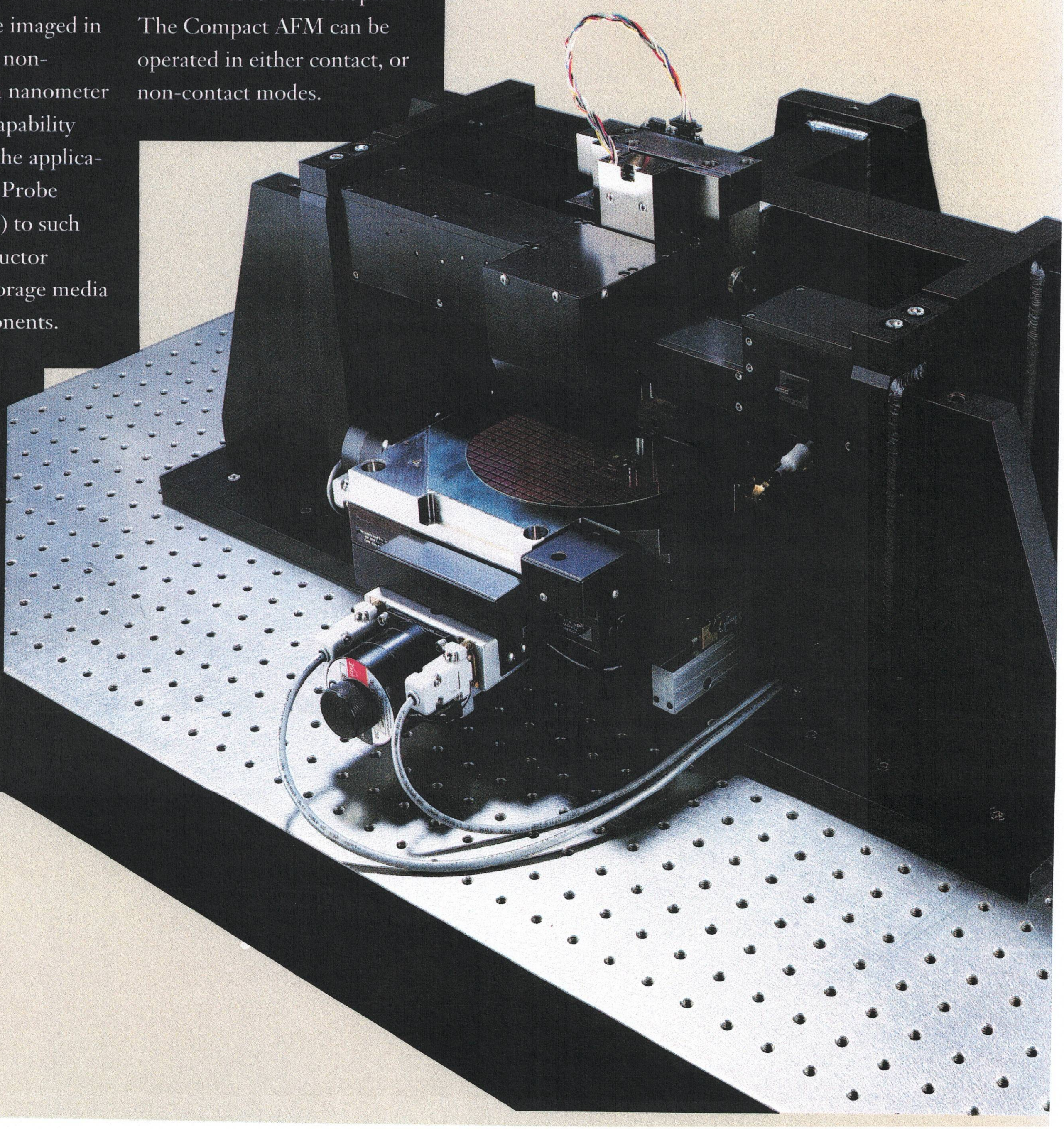


Overview

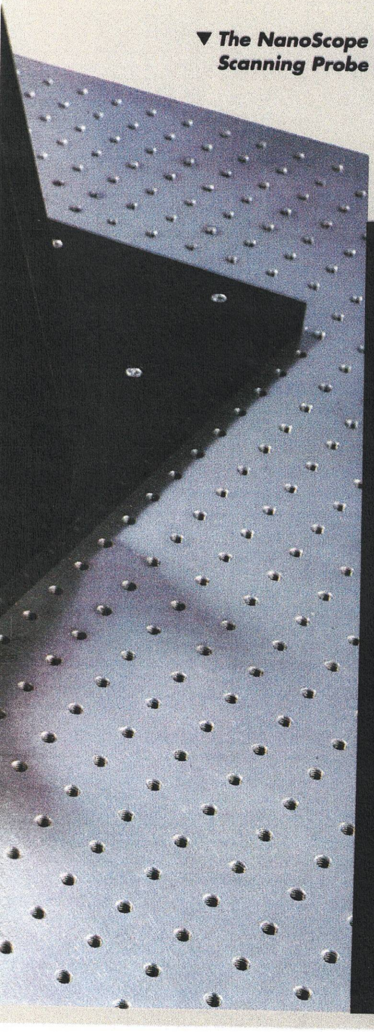
The expanded capability of the NanoScope Large Sample - Scanning Probe Microscope (LS-SPM) has revolutionized SPM technology. The NanoScope Large Sample system provides a user-friendly, automated platform for Atomic Force (AFM) and Scanning Tunneling Microscopy (STM) and eliminates the need to cut or break the sample. Now samples up to 14 inches in diameter can be imaged in three dimensions, non-destructively, with nanometer resolution. This capability further enhances the applicability of Scanning Probe Microscopy (SPM) to such fields as semiconductor manufacturing, storage media and optical components.

The outstanding feature of the NanoScope Large Sample SPM is an Atomic Force Microscope design that allows samples of an arbitrarily large size to be imaged. This design, called the Compact AFM, utilizes a unique probe deflection detection system that is small enough to be attached to a piezo scanner. This yields an instrument with much better frequency response characteristics than conventional Atomic Force Microscopes. The Compact AFM can be operated in either contact, or non-contact modes.

The Large Sample SPM features an automated sample stage, an integral 850X optical microscope and a software package that includes the ability to automatically collect data at up to 100 different points on the sample. The LS-SPM is compatible with Digital Instruments' NanoScope III Scanning Probe Microscope Control System, the state-of the-art in SPM control.



The NanoScope III System operates the widest range of SPMs in the industry ▲



▼ The NanoScope Large Sample Scanning Probe Microscope

System Description

The NanoScope Large Sample Microscope, shown at left, is comprised of a superstructure, an automated XY (shown) or R-theta sample stage, a scanning probe microscope (SPM) stage, and an optical microscope coupled to a video camera. The superstructure, which constitutes the framework on which the other elements are mounted, is machined from Invar 36. This material was chosen for its high rigidity and desirable thermal and vibrational characteristics. These attributes are crucial to maintaining the mechanical stability necessary for the ultra-high resolution that is the hallmark of scanning probe microscopy.

The sample is translated by an automated stage that provides for six (XY stage) to eight (R-theta stage) inches of movement. The stage is equipped with one micron resolution glass linear encoders, and is operated closed-loop for maximum resolution and repeatability. The sample is mounted on an interchangeable chuck that secures the sample to the stage by either vacuum or mechanical means. Chucks for a variety of sample sizes and configurations are available upon request.

The scanning probe microscope stage is mounted on the rear crossmember of the superstructure and controls the vertical position of the SPM relative to the sample surface. The SPM stage is driven by a DC motor, operated closed-loop for maximum resolution. The scanning probe microscope is secured to the stage by a dove-tail mount that allows for easy exchange of microscopes.

The front crossmember of the superstructure is the housing for an optical microscope. This microscope allows the user to view either the sample surface or the SPM probe. Configured for a single objective with a field of view of approximately 200μ, the microscope provides approximately 850X magnification, via a high-resolution B/W CCD array coupled to a 13" video monitor. The video display is also provided with a moveable cross-hair for precise alignment of the probe to features as small as one micron.

These elements combine to make the Digital Instruments NanoScope Large Sample SPM an instrument of unmatched capability and performance.

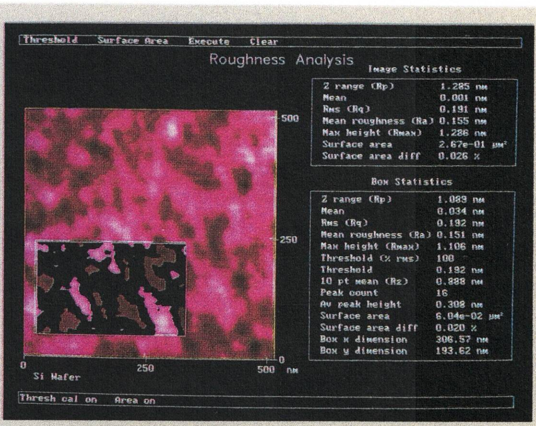
The Compact Atomic Force Microscope

The NanoScope Large Sample Scanning Probe Microscope system utilizes a unique atomic force microscope (AFM) design. This design, called the Compact AFM*, avoids many of the problems inherent in conventional AFMs.

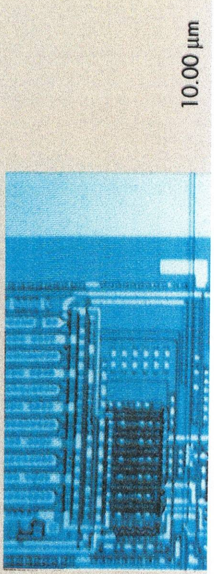
Scanning Probe Microscopes rely on piezo-electric scanners to provide the required raster motion. These scanners must be both highly accurate and capable of fast scan speeds. Currently, most commercially available atomic force microscopes mount the sample to the piezo scanner. The scanner's frequency response is highly sensitive to the sample mass. This limits most AFMs to samples of a relatively small size.

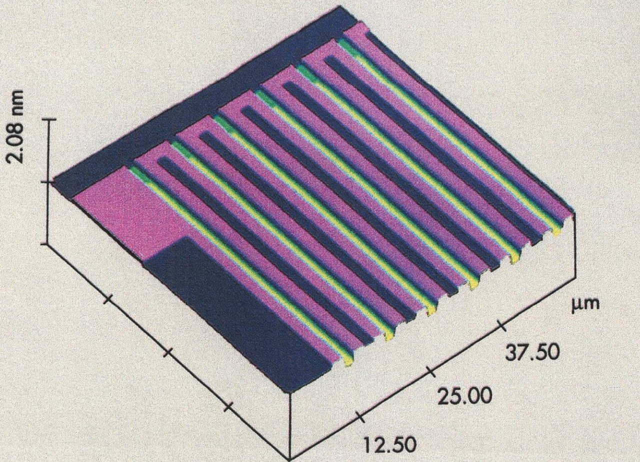
Digital Instruments' Compact AFM design, in contrast, scans the probe and detector rather than the sample. The Compact AFM utilizes a miniature diode-interferometer to detect the vertical deflection of the probe-bearing cantilever. As the probe is scanned it is deflected by features on the sample surface. Properly calibrated, this deflection signal versus the applied scan voltage is used to generate a three-dimensional image of the sample surface. Because the Compact AFM, rather than the sample, is attached to the scanner, the size and mass of the sample is irrelevant to the resolution and performance of the microscope. This capability represents a significant improvement in performance and applicability over conventional AFMs.

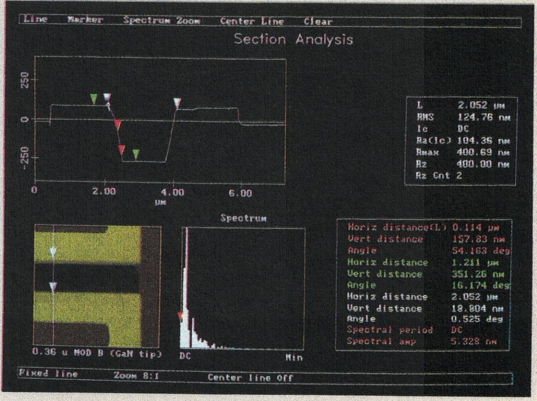
*Patent #5,025,658



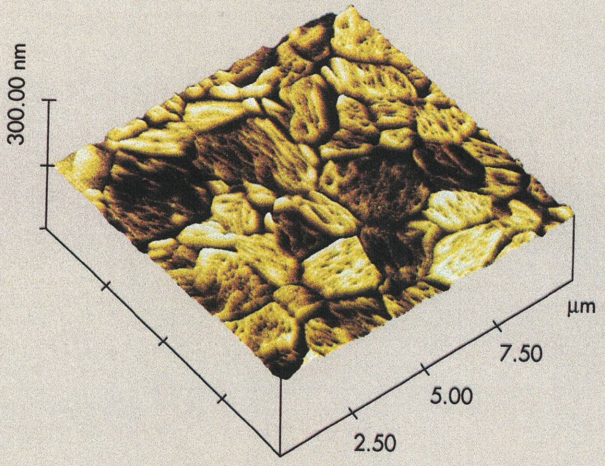
Surface roughness measurement of a bare Si wafer: *Force Microscopy is the only technique which provides the lateral spatial resolution to adequately measure microroughness at the angstrom scale. This roughness relates directly to issues such as gate oxide integrity. Note the 1Å RMS roughness.* ▲



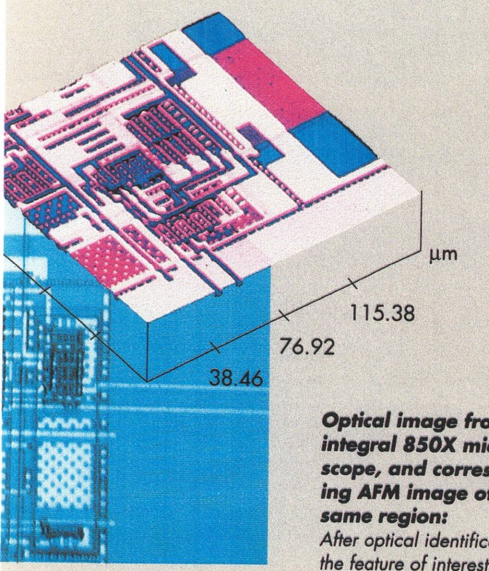




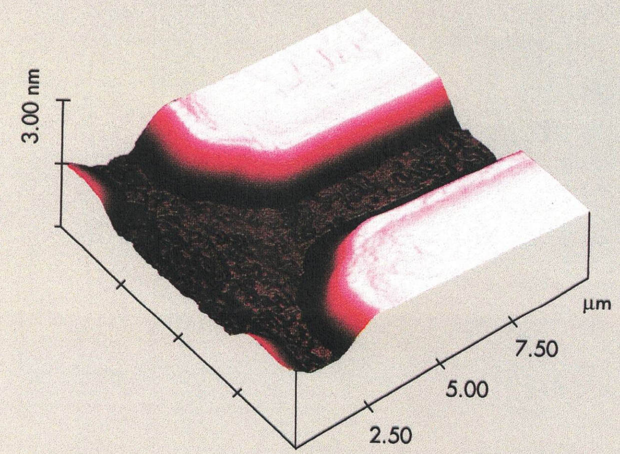
3D image and cross-section of a phase shift mask: *The combination of large sample capability and ultra-high resolution makes the LS-SPM invaluable in the development of new lithography processes.*



Aluminum and copper grains on Si:
The size of the grains on traces and contacts significantly affects the reliability of integrated circuits. ◀



Optical image from the integral 850X microscope, and corresponding AFM image of the same region:
After optical identification, the feature of interest is automatically translated under the SPM probe. ◀



Non-contact AFM image of unbaked photo-resist:
The non-contact AFM is the only instrument capable of non-destructively imaging soft samples and steep side-walls. ▲

Semiconductor Applications

The introduction of the NanoScope Large Sample SPM has opened new realms for the application of scanning probe microscopy to the semiconductor industry. The unique ability of the scanning probe microscope to provide ultra-high resolution, non-destructive, three-dimensional imaging of sample surfaces, from nanometers to over 100 microns demonstrates the power that SPM holds as a metrology tool. This potential to provide new failure analysis and defect characterization capabilities has been compromised by the requirement for relatively small samples. This requirement has limited the applicability of the SPM in the semiconductor industry. The full wafer capability of the NanoScope Large Sample SPM removes this limitation.

The figures at left illustrate some typical applications of the Large Sample Scanning Probe Microscope in the semiconductor industry.

These include:

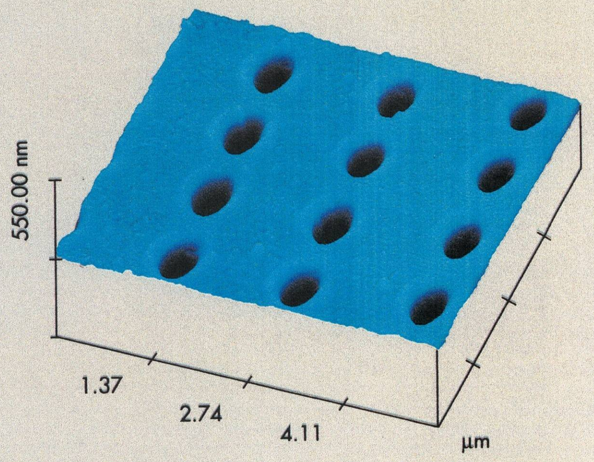
- Surface Roughness
- Defect Imaging
- Characterization of Sub-Micron Geometry Structures
- Gate Oxide Integrity
- Mask Development
- Characterization of Deposited Layers
- Critical Dimension and Defect Characterization on Resist

The NanoScope Large Sample SPM's combination of ultra-high resolution, full wafer capability, and ease-of-use make it the perfect tool to provide solutions to many of the problems facing IC metrologists.

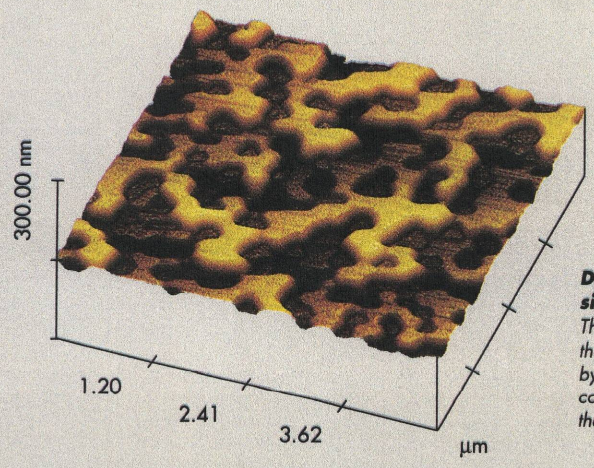
Other Applications

The NanoScope Large Sample Scanning Probe Microscope has also proven invaluable in many areas outside of the integrated circuit industry. The ability to image large samples on a scale from a few nanometers to over 100 microns on samples as diverse as storage media to binary optics has created a wave of new applications for Scanning Probe Microscopy. The pictures at right illustrate a few of the applications for which the Large Sample SPM has provided the critical capabilities of ultra-high resolution and large sample capability.

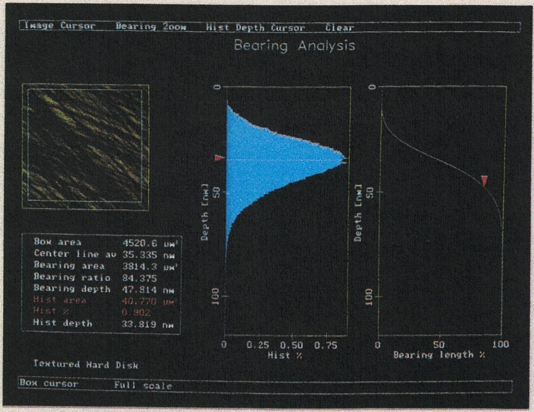
For example, the storage media industry has found the resolution and accuracy of the scanning probe microscope invaluable in performing critical dimension and surface roughness measurements. The SPM has become the standard instrument in the disk drive industry for characterizing texture and wear on magnetic disks. No other non-destructive technique provides the lateral and vertical resolution necessary to measure everything from the pole tip recession on thin film heads, to the surface roughness of carbon overcoats. This level of resolution and accuracy, coupled to the Large Sample SPM's ability to image samples as large as a 14 inch video disk master, makes the LS-SPM a metrology tool of unprecedented capability.



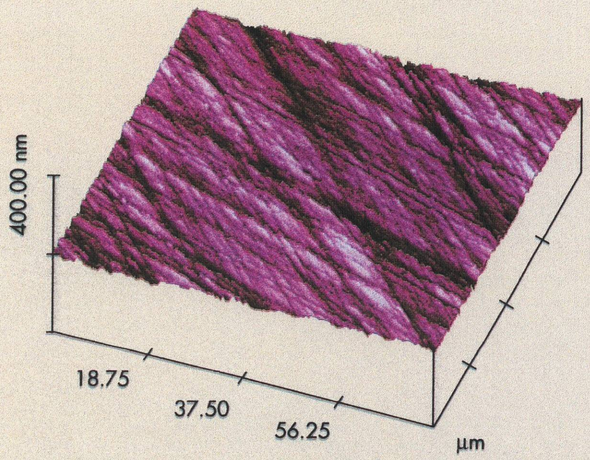
Bits on a 14 inch video disk master: *SPM provides the accuracy crucial for critical dimension measurements on optical media. The NanoScope LS-SPM is the only instrument capable of imaging samples up to 14 inches in diameter.* ▲

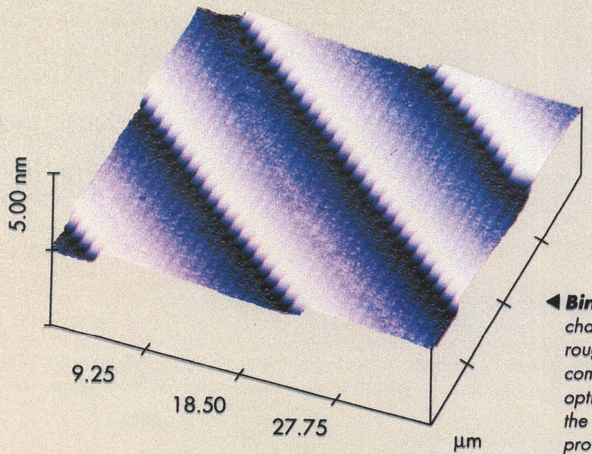


Deposited cobalt silicide film on Si: *The off axis nature of the Si is displayed by the plate-like construction of the film.* ◀



3D image of a hard disk, and surface height distribution curves for the same area: *Only the SPM has the spatial resolution necessary to accurately characterize the texturing on magnetic hard disks.*





◀ ***Binary Optic:*** *The ability to characterize coatings and roughness on full-sized optical components is crucial to the optics industry. The LS-SPM is the only instrument capable of providing the necessary angstrom resolution, large sample capability, and non-destructive imaging capability.*

Conclusion

The NanoScope Large Sample Scanning Probe Microscope System provides a significant advance in SPM capability. The combination of large sample compatibility, an integral optical microscope, automated sample translation, programmability, and ease of use make the LS-SPM an instrument of unprecedented performance. Furthermore, the Large Sample SPM has been designed as an upgradeable platform. New SPM configurations and techniques can be added by the simple expedient of upgrading the drive software. These features make the NanoScope Large Sample Scanning Probe Microscope unmatched in capability and versatility.