Digital Instruments

Veeco Metrology Group

NanoScope® IIIa
Scanning Probe Microscope Controller

Unrivaled Experience and Design

Controller capability and performance are crucial to the productivity of any scanning probe microscopy (SPM) system. That's why Digital Instruments has always made our NanoScope controllers a central engineering focus. We pioneered, patented, and built the first fully digital controllers to provide the functionality, power, and adaptability required in this exploding field. This concept of flexible power gives our users a critical advantage, whether in research or industry.

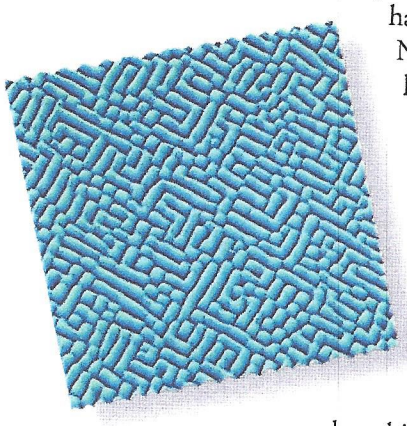


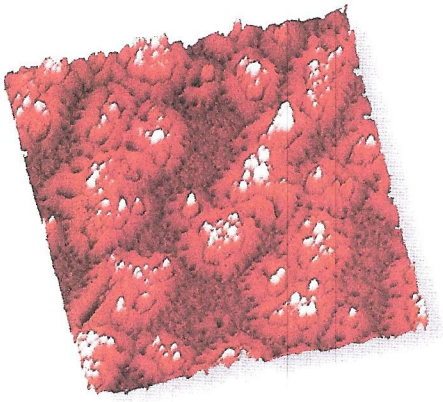
Image above: Undulating surface morphology of annealed $Si_{1-x}Ge_x$ epitaxial layers grown on silicon. This undulation is caused by mismatch strain, and varies with the fraction of Ge. 5µm scan courtesy A. Pidduck, D. Robbins and A. Cullis, Defense Research Agency, UK.

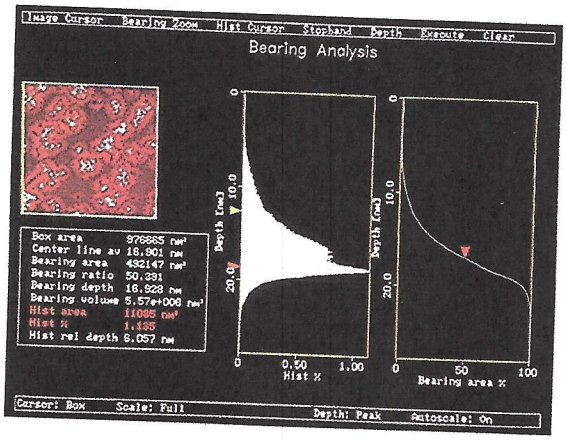
The NanoScope IIIa control system — the product of eight years of SPM design experience.

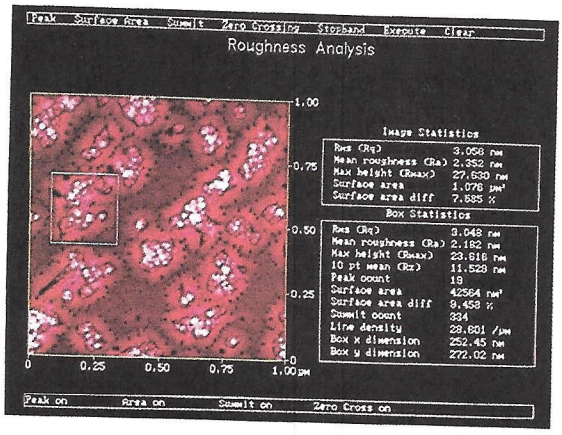
The NanoScope IIIa is the direct result of our experience gained in producing more than 3,000 SPMs. We've combined advanced analog and digital circuit designs with premium software and hardware to yield a uniquely powerful SPM controller. The NanoScope IIIa builds on our reputation for real-world productivity and our ability to meet the specialized needs of researchers with unique and custom applications.

Real-world Productivity — A Guiding Principle

Whether you are producing original research or making critical industrial measurements, in today's competitive world there is no substitute for real productivity. Productivity is measured by the number of samples you can analyze in a given time and the quality of the results you generate. The scientific literature attests to the success of our academic customers: our users produce the overwhelming preponderance of scientific papers presenting SPM data. Any way you look at it — total number of papers, papers per instrument or papers per year — our users are the most successful. And in industry, NanoScope throughput and quality of results are unmatched. No one comes close to our number of users, many of whom own multiple NanoScope systems.







NanoScope IIIa Specifications

Controller Electronics

- Digital Signal Processor (DSP) with a 20 MHz peak rate for arithmetic operations
- X, Y, and Z scanner drives with a ±220 volt range
- Three digital-to-analog converters (DACs) on each axis (nine total) independently control scan waveform, scaling, and offset
- Scan calibration maintained regardless of scan size or offset (other systems go out of calibration if their scans are offset, rotated or randomly sized)
- Calibrated data from both the trace and retrace lines of a scan simultaneously displayed and captured
- Display of both the up-to-down scan and down-to-up scan for protection against drift artifacts
- Four auxiliary DACs, three with ±10V outputs and one with ±12V and ±220V outputs, all with 16-bit resolution
- Two ±10 volt ADCs with 14-bit resolution and software-selectable filters; one input has four-way multiplexing (also see Hardware Options)
- Easy external access to NanoScope IIIa power supplies

Software Graphical User Interface (GUI)

- Flexible set of windowed menus and graphic displays for control of real-time and off-line features
- Operations and functions selectable by icon or menu

Real-time Control Software

The following real-time features can be modified while scanning:

- Adjustable scan rate, size and offset (Scan calibrations remain constant as these parameters are changed.)
- Samples per scan line (128, 256, or 512)
- Disable/enable slow scan axis motion (useful for optimizing feedback parameters along a single image line)
- Adjustable feedback parameters
  - LookAhead™ gain (proprietary technique which dynamically adjusts gain based on the previous scan line)
  - Integral and proportional gain
  - Set point (AFM)
  - Drive frequency and amplitude for oscillating tip modes

Images above: *The NanoScope IIIa provides accurate data and a very complete set of analysis tools. Three ways of looking at defects on an MBE (Molecular Beam Epitaxy) SiGe epitaxial film are shown.*

Top: *Surface Plot: This image clearly shows growth flaws that need to be corrected if the goal of a smooth film is to be reached. The NanoScope IIIa data display is very flexible so you can bring out the details of your images. 1µm scan.*

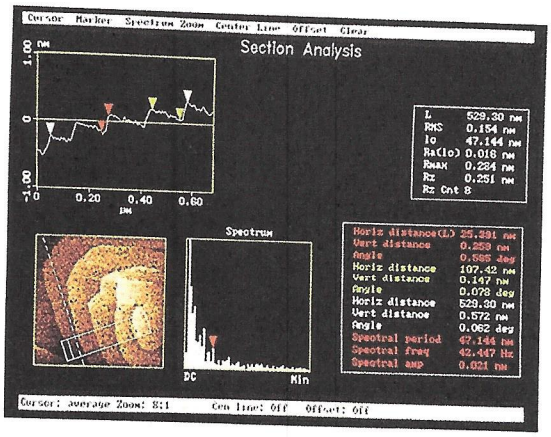
Middle: *Bearing Ratio: This is a standard method for assessing a surface texture (in this case, a measure of surface defects). Bearing area, ratio, depth and volume, as well as histograms, are all calculated automatically. 1µm scan.*

Bottom: *Surface Roughness: Another way of measuring surface texture is to calculate roughness. With the NanoScope IIIa software, RMS, mean, max, peak height, line density and other parameters are automatically calculated. 1µm scan.*

- Selectable AFM feedback modes
  - Topography
  - LiftMode™
  - Oscillating cantilever phase and amplitude
- Selectable STM feedback modes
  - Image at a constant height while monitoring current
  - Image at a constant current while monitoring height
- Selectable STM operating bias
- Variable input attenuation from 1X to 8X (for AFM TappingMode)
- Image display of a scan from either or both the trace (left-to-right) and retrace (right-to-left)
- Oscilloscope display of a scan from either or both the trace and retrace
- Selectable data units (e.g.; drive volts or scan length)
- Enhanced data display with choice of 24 color tables
- Continuously adjustable dynamic range of Z drive voltage (55V to 440V)
- Support for nonstandard microscopes and accessories
- Highpass and lowpass filters for incoming AFM data
- Immediately restart a scan from top or bottom of scan area
- Lithography programs with more than 20 commands
- Interleave™ mode for collection of different types of data simultaneously
  - Distinct feedback attributes for the main and interleaved scan lines (useful for measuring topography and magnetic force simultaneously, for example)
- True multitasking:
  - Reliably analyze previously-recorded data while simultaneously gathering new data and storing the new data to disk
- Data capture features
  - Continuously capture data from successive scans of the same area
  - Auto scan for successively capturing user-selected areas in a linear or square array
  - Multiple plane-fitting options
  - Automatic data capture for calibration
  - File-naming options

Real-time features adjustable between scans:

- Up to three types of data (512x512 points) displayed simultaneously from the same scan on all available channels, for example TappingMode, amplitude of oscillation, and magnetic force
- Contact AFM Force curve measurement capability for analyzing and setting tip-sample forces
- Automatic cantilever-drive frequency tuning for TappingMode and other oscillating tip modes
- Automatic multiple image scan and capture with programmed translation between scanning sites
- Scanning tunneling spectroscopy (STS) mode analyzes current as a function of bias or height
- Current imaging tunneling spectroscopy (CITS) mode provides commands to create arrays of STS data
- Force imaging equivalent to CITS, but produces an array of force curves instead of STS data (requires V4.2 software)
- Leakage and amplifier offset measurements for STM



One of the important capabilities of SPM is the ability to make direct three-dimensional measurements. In this cross sectional image of an InP spiral growth center, the height and width of the terraces is measured directly and the height data is averaged in specific rectangular areas. 1µm scan.

Image Processing and Other Off-line Functions

- Highly-automated AFM scanner and STM head calibration
- Data viewing modes (all can be customized)
  - Top view: two-dimensional plot
  - Line plot: a series of linear sections in three-dimensional perspective
  - Surface plot: a three-dimensional plot with adjustable height and slope shading with selectable light angle
  - Parameter view: any combination of scan parameters can be displayed with the image
- Data analysis functions and parameter choices
  - Autocovariance: automatically calculates and displays auto-covariance values for the image data
  - Bearing: plots and analyzes the distribution of surface height; can be applied to entire image or sub-areas
  - Compare: allows comparison of bearing results for two or more images plus a composite view
  - Depth: a comparison command that accumulates depth data within a specified area and known reference point; best applied when rapidly comparing similar features on the same area of different samples, such as on large numbers of patterned silicon wafers
  - 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
  - Section: allows Z data to be plotted and measured in cross-section along any line drawn by the user across the image
- Data modification functions
  - Contrast: enhancement using statistical algorithms to emphasize features
  - Convolution: highpass, lowpass or user-assignable 3 x 3 kernel filter
  - Erase scan lines: removes noisy scan lines from an image
  - Flatten auto: eliminates image bow using least squares polynomial fit
  - Flatten manual: similar to flatten auto but allows user to eliminate non-flat areas from calculations
  - Gaussian: applies a user-specified Gaussian filter to X or Y
  - Geometric: provides powerful nonlinear highpass and lowpass filtering using adjustable geometric convolutions
  - Highpass: replaces each data point in the image with a weighted difference between the data point and each of its nearest eight neighbors
  - Invert: inverts the image data along the Z axis
  - Lowpass: replaces each data point in the image with the weighted average of the 3 x 3 cell of points surrounding the point
  - Median: replaces each data point in the image with the median value of either a 3 x 3 or 5 x 5 cell of surrounding points to remove spike noise
  - Plane fit auto: calculates a least squares fit of a polynomial surface of selectable order (either X or Y), and then subtracts the result from the data
  - Plane fit manual: allows a vertical or horizontal line (or portion thereof) placed anywhere on the image to specify the position for the calculation of the best-fit polynomial
  - Resize: changes the number of pixels per line in captured images to 128, 256 or 512
  - Spectrum 2D: transforms images into a two-dimensional fast Fourier transform (FFT) plot, then allows the user to selectively pass or remove specific frequencies
  - Subtract images: subtract one image from another
  - Zoom: expands selected areas of a captured image for visual examination with more detail
  - Parameter: rescales the Z range and scan size of a captured image
- File handling capabilities
  - Simultaneously display up to 24 images for searching and selecting
  - Copy, delete, move, rename
  - Make, change or delete directory
  - Delete all, rename all

Menu-Accessible Utilities

- Color table editor for modification and creation of color tables
- Autocalibration: calibrates scanners and heads using a sample with known dimensions
- Print: allows images to be printed with several options
- Compatible with PostScript® printers (Several color and black and white printers are available through Digital Instruments.)
- ASCII export and import: converts a binary file to and from ASCII format for use with other software
- TIFF export: creates and stores an industry-standard TIFF (Tagged Image File Format) file for use with applications such as desktop publishing
- TIFF import: displays a TIFF 5.0 format file on the display monitor
- IBM import: converts an IBM STM to NanoScope file format

Hardware Options

- Analog-to-digital converter package (ADC5)
  - Five fully independent, ±10 volt ADCs (requires V4.1 software for use with force curves, V4.2 for imaging)
  - Front panel BNC connectors for frame and line synchronization pulses
- Signal access module (SAM)
  - Access to every input and output signal between the controller and the microscope (12 input and 12 output)

Computer

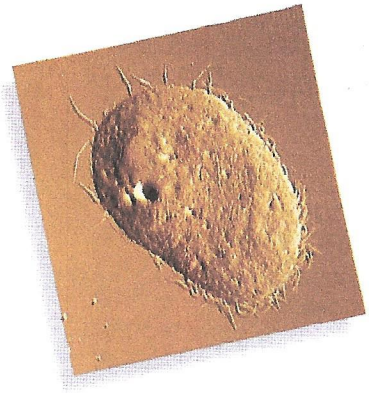
We provide a premium, server-quality computer system with all NanoScope controllers. As computer technology advances, we periodically revise the computer specifications. Please call Digital Instruments for current specifications. All systems include separate display and command monitors for a cleaner interface.

Facilities Requirements

- Space: 30 in. x 60 in. (75 cm by 150 cm) table
- Power: 1500 W (Please specify voltage and frequency.)
- Weight: 180 LB (36 Kg)

Compatibility With NanoScope Products

- Fully-compatible data between NanoScope *E*, NanoScope III, and NanoScope IIIa
- Compatible with our complete line of SPMs, including all Dimension™, MultiMode™, BioScope™, and future products.
- NanoScope II images importable to the NanoScope IIIa format
- NanoScope *E* and NanoScope III controllers upgradable to NanoScope IIIa



This TappingMode scan of the protozoan, Tetrahymena, shows its cilia-covered body and mouth structures. The sample was dried onto a glass slide and scanned; no other preparation was required. 50µm scan courtesy C. Mosher and E. Henderson, BioForce Laboratory and Iowa State University.

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