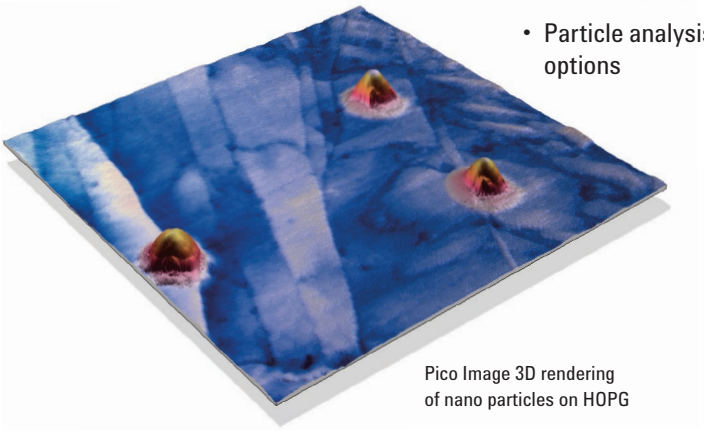
Post Processing Pico Image Software for Agilent AFM Systems

Data Sheet

Features and Benefits

- Modular AFM and SPM imaging and analysis software for universities, research laboratories, and industry
- Easy-to-use desktop publishing environment for fast and accurate metrology report generation
- Surface analysis workflow for full metrological traceability
- Real-time 3D imaging and flight path definition using OpenGL technology
- Intelligent filtering for high-quality imaging, plus metrological and scientific filters
- Comprehensive visual 2D and 3D analytical studies
- Calculation of 2D and 3D parameters in accordance with international standards (ISO)
- Multi-language support
- Particle analysis and statistics options



Pico Image 3D rendering of nano particles on HOPG

Overview

Pico Image surface imaging and analysis software is dedicated to Agilent AFMs and SPMs. It contains three levels for basic, advanced, and expert users. Standalone and network licenses are available.

The intuitive Pico Image desktop publishing user interface and comprehensive online help system guarantee ease of use. The surface metrology report is built visually, starting with multiple channel measurement files (for example, topography, amplitude, and phase) that can be correlated. Intelligent filters produce high-quality images, make hidden surface features visible, and separate different frequencies (such as very high frequencies, roughness, and waviness). Real-time 3D imaging provides excellent visualization. Videos of flight paths over a surface can be integrated into the perfect presentation.

Analytical studies generate all of the information needed to characterize a surface, a profile, or a series of profiles extracted from a surface. 2D and 3D parameters are generated in accordance with international standards. Unique features in Pico Image Advanced and Expert include the ability to generate sub-surfaces and work with them seamlessly as well as the ability to analyze multiple measurement datasets automatically by applying a template.

Options are available for the characterization of grains and particles and for generating statistics. Pico Image is the ideal analysis software package for use with Agilent AFMs and SPMs. It is integrated into our high-precision instruments.

Pico Image Basic

Pico Image Basic includes all of the features and functions required to build a basic surface analysis report on multi-layer measurement data that is input from Agilent AFMs and SPMs. The user can work in English, French, German, Italian, Polish, Spanish, Japanese or Chinese to build the analysis document. The document consists of a set of frames containing surfaces, profiles extracted from surfaces, the results of applying filters and other operators, analytical studies and 2D and 3D parameters. A measurement identity card, screen notes and illustrations including bitmaps, text blocks, arrows and frames can be added to a document. New steps can be inserted into the analysis workflow at any time and existing steps can be modified, with automatic calculation of all dependent steps. All frames in a document can be exported to a bitmap file and calculated parameters can be exported to an Excel-compatible .csv file for interfacing with 3rd party software and systems.

State-of-the-art surface visualization
Powerful surface visualization features include pseudo-colour images, photo simulations and 3D views with optional materials (gold, silver, bronze, copper, tin) to highlight surface features. Thanks to OpenGL technology it is possible to turn a 3D surface image, zoom in on details and amplify the Z axis in real time. Non-topographical layers in AFM or SPM measurement data files (for example, phase and deflection layers) can be overlaid on 3D topography layers. It is possible to record flight paths over a surface for integration into presentations.

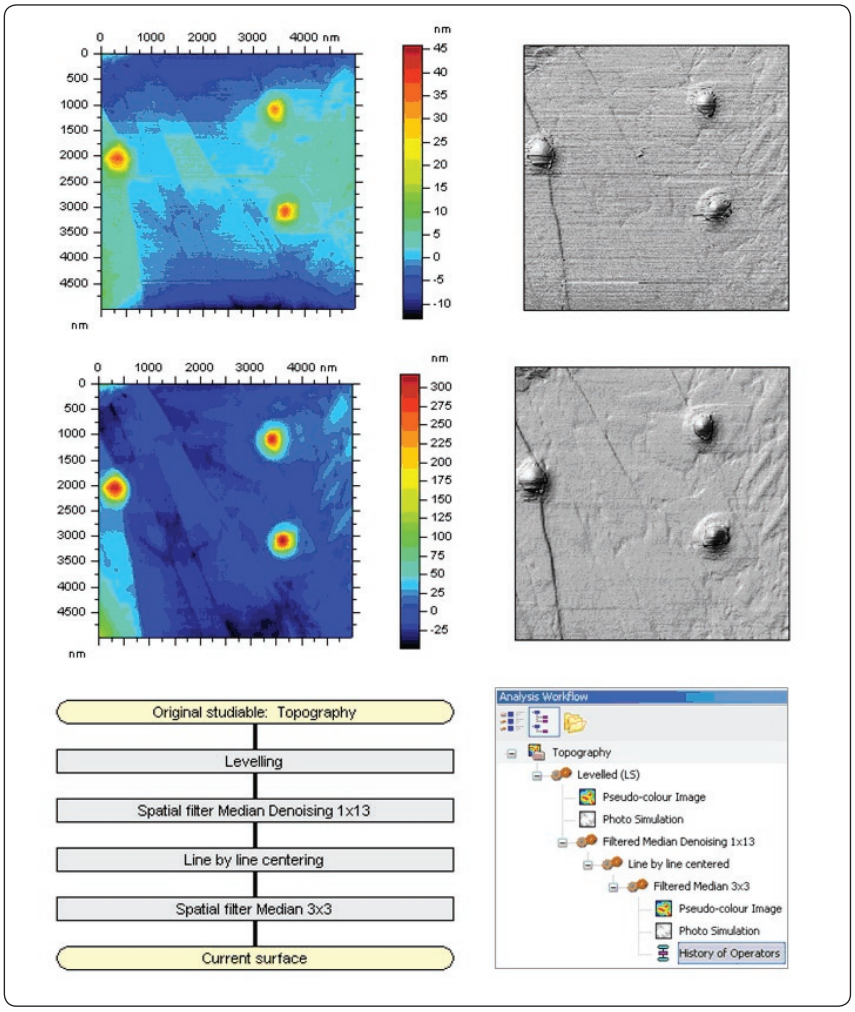


Figure 1. Spatial filtering to improve image quality.

High-quality images
Pico Image Basic contains many filters and other operators for pre-processing and cleaning up measurement data prior to analysis. There are functions for levelling, symmetry correction, axis relabelling, anomalous peak and valley removal, improved image resolution and retouching of aberrant points. Surfaces can be denoised and details (for example, edges) can be highlighted using spatial filtering. Surface and profile images can be improved by directly editing the FFT. The result is a set of higher quality images with more visible features.

Metrological filters
The best-fit form (pre-defined or calculated automatically as a polynomial) can be removed prior to the analysis of surface texture. The roughness and waviness components of a profile or surface are separated automatically using a Gaussian, spline or robust Gaussian filter with respect to a cut-off and end effects can also be managed automatically. (Figure 1.)

2D and 3D analytical studies
Pico Image Basic includes analyses of dimensions (distances, heights/depths, angles, areas, volumes and step heights) and spectral analysis. The bearing ratio curve and depth distribution histogram are calculated automatically, along with the material/void volume and thickness of user-defined vertical slices.

Conformity to international standards
3D height and functional bearing ratio parameters are calculated in accordance with the forthcoming ISO 25178 standard on areal surface texture and can also be calculated in accordance with the older EUR 15178 EN report if required. 2D parameters for raw and roughness profiles are calculated in accordance with ISO 4287.

Pico Image Advanced

Pico Image Advanced contains all Pico Image Basic features as well as several additional features.

Analysis of a series of profiles and force curves
Pico Image Advanced can convert a surface into a series of profiles. The mean, min, and max profiles in a series can be highlighted, a movie mode for walking through the profiles is provided, and control charts, scatter plots, and histograms can be calculated for selected parameters. In addition, force curves (deflection in V or nm versus distance in nm, or force in nN versus distance in nm) are calculated with respect to a series of profiles.

Studying segmented surfaces
There are two ways of generating a sub-surface in Pico Image Advanced, either by deliberately managing non-measured points (for example, during thresholding) or by surface segmentation. All operators and studies can be applied seamlessly to the sub-surfaces, including parameter calculation (Figure 2).

More 3D parameters and other features
Pico Image Advanced provides a more complete set of 3D parameters with ISO 25178 spatial, hybrid, functional volume, and feature parameters, as well as EUR 15178 EN spatial, hybrid, functional volume, and functional indices parameters. Surface isotropy and the three main surface directions are calculated in the texture direction study. It is also possible to compute the similarity of different surfaces.

Pico Image Expert

Pico Image Expert is a complete surface analysis package that contains all Pico Image Basic and Advanced features, plus several additional features.

Advanced analysis features
Features in Pico Image Expert include the ability to overcome instrument range limits by stitching several measurements together, surface contour diagrams, and a graphical representation of the ISO 25178 functional volume parameters. The interactive Abbott-Firestone curve makes it easy to determine what depth corresponds to a given bearing ratio and what the bearing ratio is at a given depth.

Fractal analysis of a surface or profile displays a scatter plot using the enclosing boxes method or the morphological envelope method. It calculates the fractal dimension, the slope of the regression line, and the correlation coefficient of the regression line.

A plot based on the autocorrelation function shows the isotropy, periodicity, period, and direction of period on a surface. The values of the dominant wavelengths on a surface or a profile are displayed in the averaged power spectrum density plot. In addition, the network of micro-valleys or furrows on a surface can be vectorized and the max depth, mean depth, and density of the furrows can be calculated with respect to a threshold.

The set of 3D parameters is further extended to include ISO 12781 flatness parameters. The set of 2D parameters is extended to include ISO 4287 parameters for waviness profiles and other 2D parameters.

Contour analysis
2D contour analysis in Pico Image Expert measures vertical, horizontal, and diagonal distances on a profile, straightness, or shape deviation in accordance with ISO 1101, the radius of an arc, and the angle between two line segments. It calculates the point of intersection of two segments and extends the segments to the point of intersection.

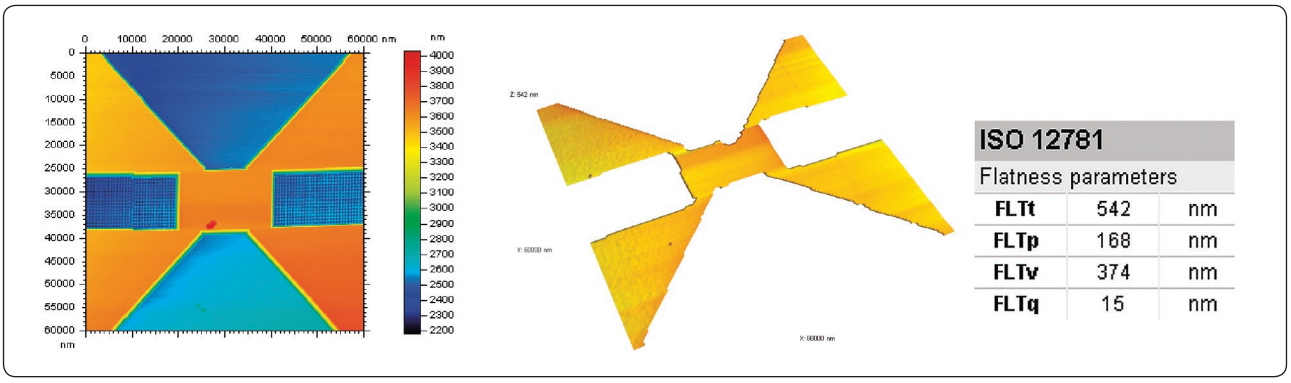


Figure 2. Calculation of ISO flatness parameters on a sub-surface of an IC resonator.

Pico Image Options

Grains and Particles option
Grains and particles can be identified using two methods. The first method binarizes a surface and separates it into grains, particles, bumps, indentations, and so forth against a background with respect to a threshold. The second method identifies grains based on segmentation of a surface into motifs.

Statistics can be generated either for all or for individual grains and particles, including area, perimeter, equivalent/mean/min/max diameter, form factor, aspect ratio, roundness, compacity, and orientation. Grains and particles can be sorted into two subsets with respect to a threshold value for a selected parameter. A histogram can be generated showing the distribution of grains and particles with respect to a parameter. It is also possible to visualize the topography of grains and particles.

Other features include calculation of the volume of islands or hillocks on a surface above a user-defined threshold height. The following parameters are calculated on the islands: number, mean volume, mean height, mean surface area, and mean height/surface ratio. In addition, a peak count distribution (PCD) histogram shows the number of peaks or the number of grains and particles per unit of surface area.

It is also possible to display and analyze 3D motifs on a surface. A segmentation by watersheds algorithm partitions the surface into significant hill or dale motifs and locates their peaks or pits. Watercourse lines and peaks/pits are shown graphically. Average height, area, and volume parameters are calculated for all motifs, closed motifs, or open motifs. They can also be calculated for individual motifs. Filtering and pruning criteria can be adjusted to merge small or insignificant motifs into larger ones (Figure 3).

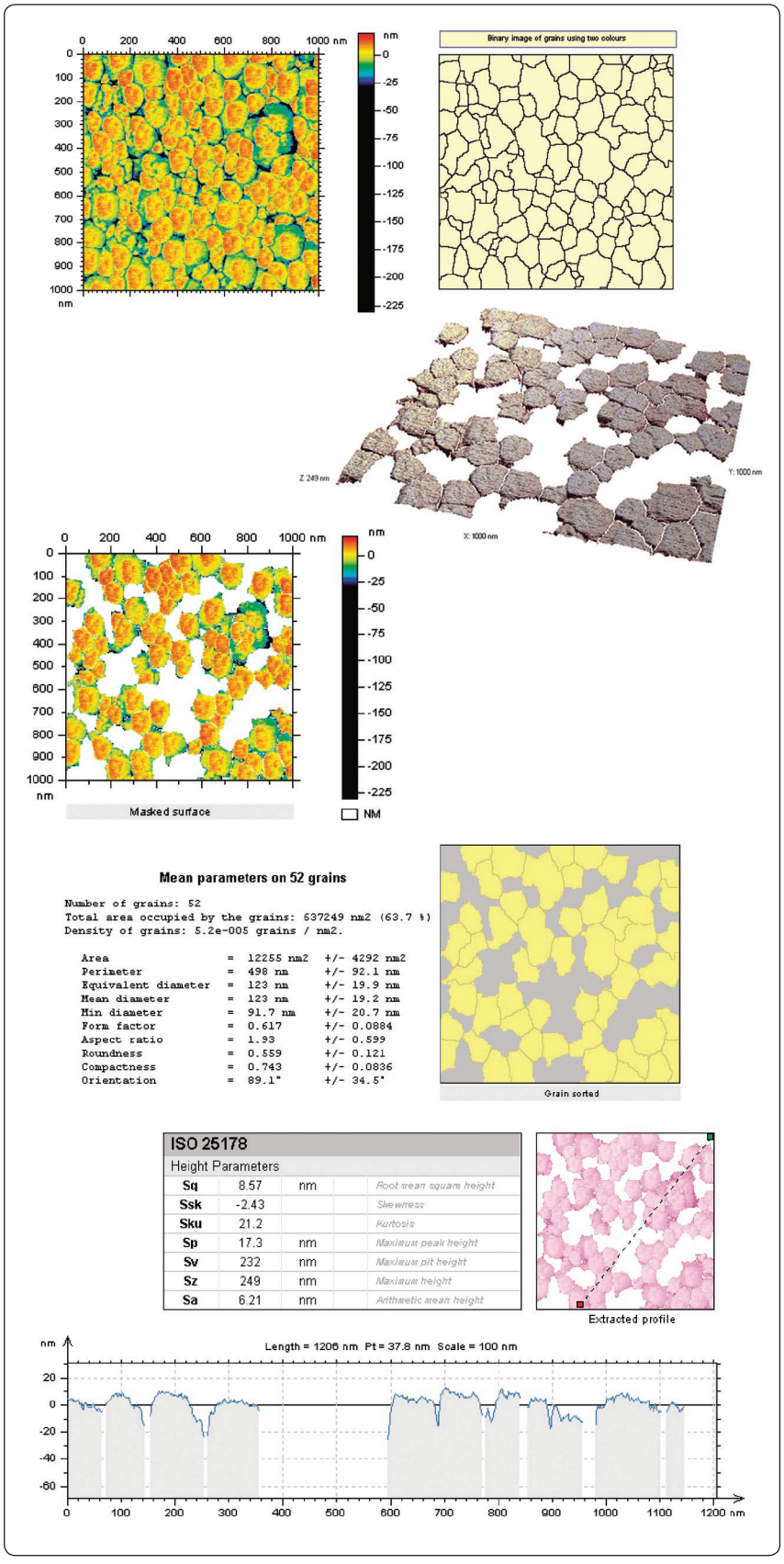


Figure 3. Pico Image document. Binarization of grains to generate sub-surface containing the grains only. Calculation of ISO 25178 parameters on the sub-surface only and extraction of a profile from the sub-surface.

Statistics option
The statistics option is used to generate statistics on one or more populations consisting of a set of documents. Statistics include a summary by parameter (min, max, mean, standard deviation, lower quartile, upper quartile, and median) together with control charts, histograms, box plots, and scatter plots for selected parameters. (Figure 3).

Agilent AFMs and SPMs

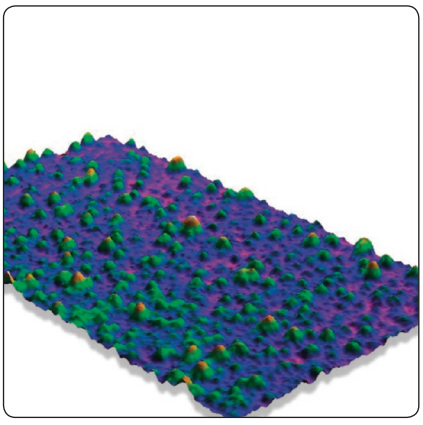
The **Agilent 5500** is an ideal multiple-user research system. The intelligent, modular design of this exceptional microscope permits the simple integration of numerous imaging modes and easy-to-use, application-specific sample-handling plates. The 5500 sets the industry standard for environmental and temperature control, enabling leading-edge *in situ* experiments in air and liquid.

The **5500 LS** microscope stage enables fast, accurate probe positioning for imaging and mapping large specimens at atomic-scale resolution. This large, motorized stage allows users to precisely locate and identify an area of interest and, with the coordinates stored, automatically reposition the sample rapidly and accurately for further study.

The **5500 inverted light microscope (ILM)** adapter combines high-resolution AFM imaging with the direct optical viewing capability of an inverted light microscope to provide both atomic force and optical microscopy data. This system's advanced design allows the atomic force microscope to sit on top of an inverted microscope and under the illumination pillar, resulting in better optical contrast for the images.

The **Agilent 5400** is a high-precision instrument engineered to provide superb ease of use and versatility. This scientific-grade microscope at a remarkably affordable price and comes with its own curriculum, making it an outstanding choice for education as well as research.

The **Agilent 5100** is a high-resolution system that provides excellent imaging capabilities in an easy-to-upgrade package. The 5100 offers researchers many of the same features as Agilent's sophisticated 5500 microscope at an entry level price. Since user requirements often grow, the Agilent 5100 is fully upgradeable to the 5500.



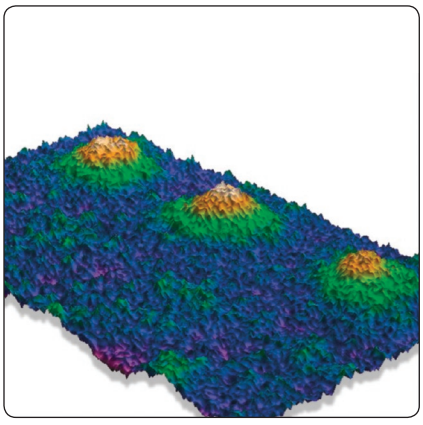


Figure 4. PZT film on Si. Topography (left) and KFM (right) image. A 10V pulse was deposited at three places on the sample and was then imaged with a 70Kz conductive cantilever.

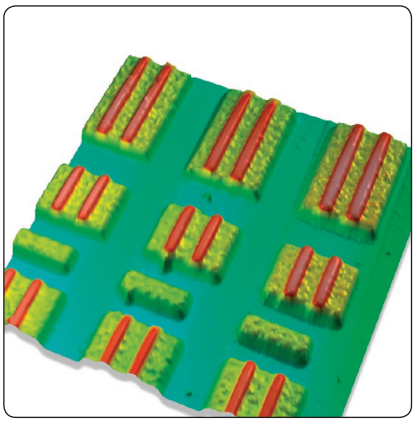


Figure 5. KFM image of a SDRAM imaged with a 70Kz conductive tip.

General Features

Basic, Advanced, and **Expert** levels	
Units	Metric or imperial
Measurement data input	Multilayer files (topography, phase, current, deflection, friction, force, input-signal control layer)
Document builder	Frame-based desktop publishing style user interface, mini-doc (pre-defined analysis sequence or macro) definition, page viewer, analysis workflow, document fine-tuning with automatic recalculation, password protection, palette manager, document preview, and PDF output (using third-party PDF printer)
Data export	.csv (Excel) text export; .jpg, .bmp, .gif, and .png image export
Illustrations	Bitmap import, bitmap cut and paste, text block, screen note, user info, company logo, framing, arrows, date, page number, palette for color-coded vertical scale, study captions, and measurement identity card
Online help	Help on all functions, contextual help, glossary, and metrological information
Advanced and **Expert** levels	
Document builder	Application of an analysis document template to multiple measurement data files to generate one analysis document per measurement
Illustrations	Pass/fail messages based on tolerance settings for selected parameters

3D Surface Analysis Features

Basic, Advanced, and **Expert** levels	
Studies	Pseudo-color image, photo simulation, 3D view of any layer (Z axis amplification %, level of detail %, XY scale markers, standard views, flight path definition, animated view, export animation to video file), flight path library, superimpose any layer (e.g., phase) on 3D topography, Abbott-Firestone curve (depth distribution), material/void volume and thickness of vertical slices, volume of a peak/hole, coordinates of a point, distance between two points, measurement of an angle, step height measurement (in respect to one or more reference and measurement zones), and frequency spectrum
Operators	Summary of last operator, operator history, leveling, line correction, mirror with respect to X, Y, or Z axis, zoom, rotation, align texture with X or Y axis, separation of roughness and waviness components of surface (Gaussian, spline, and robust Gaussian filters, cut-off, optional management of edge effects), profile extraction, thresholding, re-sampling, re-touch surface points, form removal, editing of axes (axis name, length/spacing, offset, unit type, unit), spatial filtering, Fourier Transform modulus, and filter by direct editing of FFT
Parameters	ISO 25178 height and functional bearing ratio parameters; EUR 15178 EN height and functional bearing ratio parameters
Advanced and **Expert** levels	
Studies	Texture direction (isotropy and three main directions)
Operators	Introduction of non-measured points using some operators, surface partitioning (segmentation by watersheds and Wolf pruning algorithms, generation of segmented sub-surfaces for analysis), morphological filtering (using combinations of dilation, erosion, opening, and closing filters), fill in non-measured points, and surface subtraction (for surface similarity computation)
Parameters	ISO 25178 spatial, hybrid, functional volume, and feature parameters; EUR 15178 EN spatial, hybrid, functional volume, and functional indices parameters
Expert level	
Studies	Contour diagram, interactive Abbott-Firestone curve, graphical study of volume parameters, fractal analysis (scatter plot using enclosing boxes or morphological envelope methods), power spectrum density, measurement of wrinkles, vectorization of micro-valleys network, texture isotropy, and periodicity
Operators	Autocorrelation, intercorrelation, and surface stitching
Parameters	ISO 12781 flatness parameters

2D Profile Analysis Features

Basic, Advanced, and **Expert** levels	
Studies	Profile curve, Abbott-Firestone curve (depth distribution), coordinates of a point, distances between multiple pairs of points, step height measurement (multiple steps, automatic, ISO 5436-1, or manual method), height/depth and area of peak/hole, and frequency spectrum
Operators	Summary of last operator, operator history, leveling, zoom, thresholding, re-touch profile points, editing of axes (axis name, length/spacing, offset, unit type, unit), and filter by direct editing of FFT
Parameters	ISO 4287 amplitude, spacing, material ratio, and peak parameters for raw profile and for roughness profile
Advanced and **Expert** levels	
Operators	Create a series of profiles and fill in non-measured points
Expert level	
Studies	Roughness and waviness profile curves, interactive Abbott-Firestone curve (depth-bearing ratio, bearing ratio-depth correspondence), fractal analysis, morphological envelopes, contour analysis, and power spectrum density
Operators	Morphological filtering, join two profiles, profile subtraction (compute similarity between two profiles), symmetries, form removal, re-sampling, autocorrelation, and intercorrelation
Parameters	ISO 4287 amplitude, spacing, material ratio, and peak parameters for waviness profile; other 2D parameters for raw, roughness, and waviness profiles

2D Series of Profiles Analysis Features

Advanced, and **Expert** levels	
Studies	Series of profile curves (highlight mean, min or max, movie mode), Abbott-Firestone curve (depth distribution for each profile in a series), force curve analysis (deflection (V or nm) versus distance (nm), force (nN) versus distance (nm)), step height measurement (multiple steps, automatic, ISO 5436-1, or manual method for each profile in a series), control charts, scatter plots, and histograms
Operators	Summary of last operator, operator history, leveling, zoom, extract profile, conversion of a series of profiles into surface, and fill in non-measured points
Parameters	ISO 4287 amplitude, spacing, material ratio, and peak parameters for raw profile and for roughness profile
Expert level	
Operators	Symmetries, series re-sampling, add/remove profiles from a series, and profile shifting (feature re-alignment)
Parameters	ISO 4287 amplitude, spacing, material ratio, and peak parameters for waviness profile; other 2D parameters for raw, roughness, and waviness profiles

Grains/Particles Option Features

Basic, Advanced, and **Expert** levels	
Studies	Peak count distribution, surface motifs analysis (segmentation by watersheds algorithm, hill and dale statistics), statistics on islands (with respect to threshold height), colored binary image, statistics on an individual grain/particle, and statistics on all grains/particles
Operators	Binarization (grains/particles and background), binarization by segmentation of surface into motifs, binary masking (superimpose grains/particles only on surface image), grain/particle sort with respect to selected parameter, and morphological operations (dilation, erosion, opening, closing)

Statistics Option Features

Basic, Advanced, and **Expert** levels	
Studies	Specify one or more populations (sets of documents) for study, statistical summary by parameter (min, max, mean, standard deviation, lower quartile, upper quartile, median), control charts, histograms, box plots, and scatter plots

Pico Image Specifications

Instrument compatibility	Agilent 5100, 5400 and all 5500 platforms
Operating system	Windows Vista, XP, and 2000; PicoView
Hardware requirements	Pentium 4 or dual core, 1 GB RAM, 200 MB free space on HDD, 32-bit OpenGL-compatible accelerated graphics card with 1280 x 1024 true-color resolution, and USB port for protection key
Supported languages	English, French, German, Italian, Polish, Spanish, Japanese, and Chinese
Software levels	**Basic** (standard with the Agilent 5500, 5400, 5100 platforms), **Advanced** and **Expert** (optional for the Agilent 5500, 5400 and 5100 platforms)

AFM instrumentation from Agilent Technologies

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