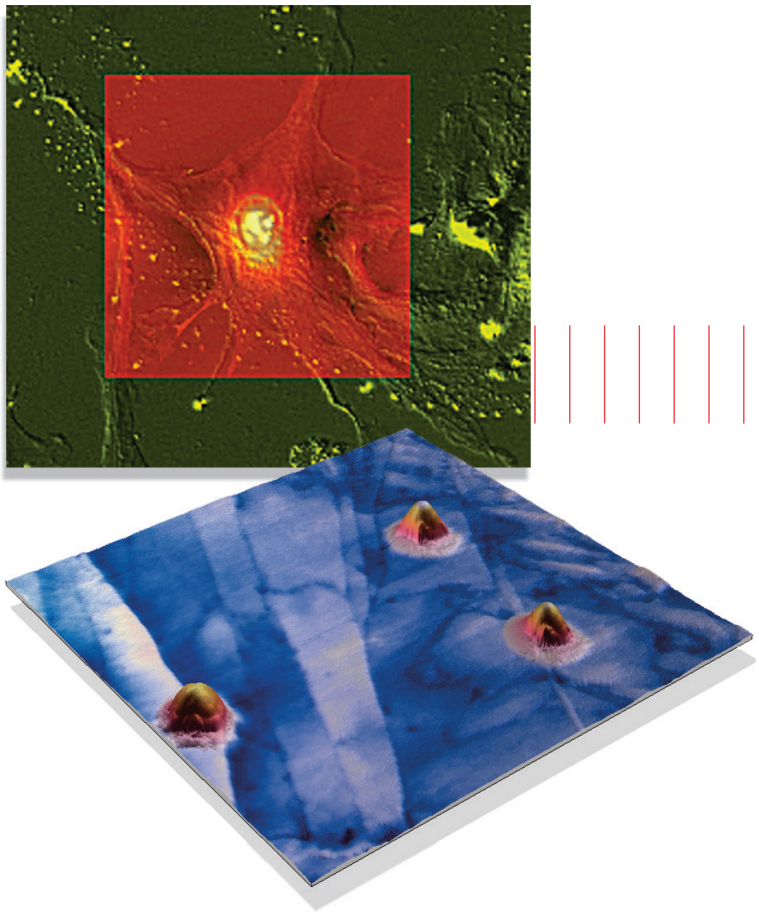
Post Processing Pico Image Software
for Keysight AFM Systems



Data Sheet

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights

Overview

Pico Image surface imaging and analysis software is dedicated to Keysight Technologies 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). Pico Image automatically assembles overlapping measurements made on a horizontal grid allowing multiple measurement to be stitched together into a single surface image. (Figure 4.) 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, image co-localization, the analysis of wavelets, and for generating statistics. Pico Image is the ideal analysis software package for use with Keysight 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 Keysight AFMs and SPMs. The user can work in English, French, German, Italian, Polish, Spanish, Japanese, Chinese or Russian 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. For easier integration into research and production, options for export of data in Word-compatible RTF format allow users to display data from parameters tables as actual tables.

State-of-the-art surface visualization

Powerful surface visualization features include pseudo-color 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.

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
- Grains/particles characterization, image co-localization, wavelets analysis, and statistics options

Cover images
Top: Co-localization of AFM and fluorescence cell images.
Bottom: Pico Image 3D rendering of nanoparticles on HOPG.

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 leveling, symmetry correction, axis relabeling, 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 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. Stereo rendering for visualization of data with 3D glasses is now available and animation can be exported in .AVI or compressed .WMV format.

Pico Image Advanced

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

Force Volume Curves

Advanced version features maps representing the value of a parameter calculated on each element of a force volume dataset. It can distinguish elements on series of profiles, series of spectrum or force curves - Different styles (color, line width, line style) can be associated with each element - A key clearly identifies what each element in the graph stands for.

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).

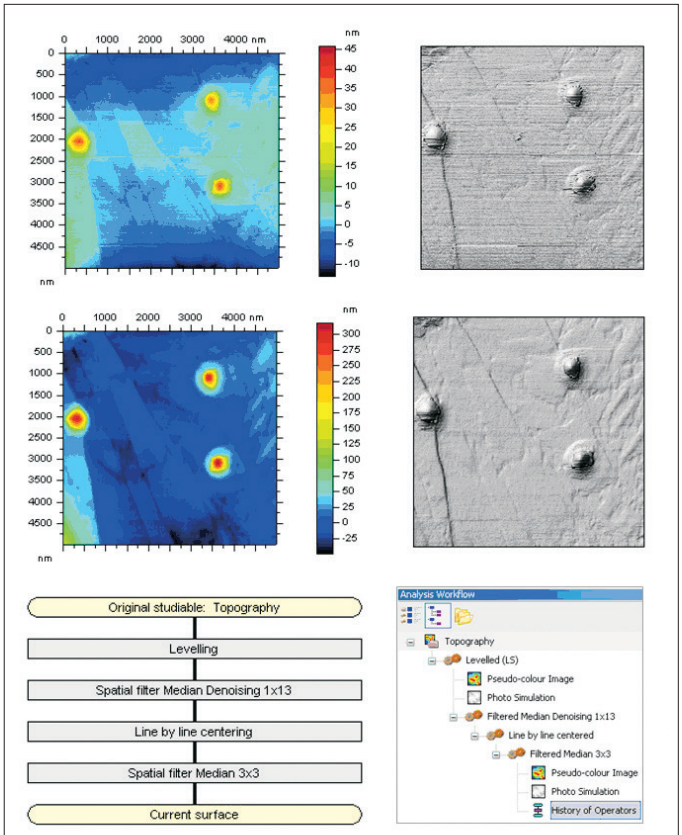


Figure 1. Spatial filtering to improve image quality.

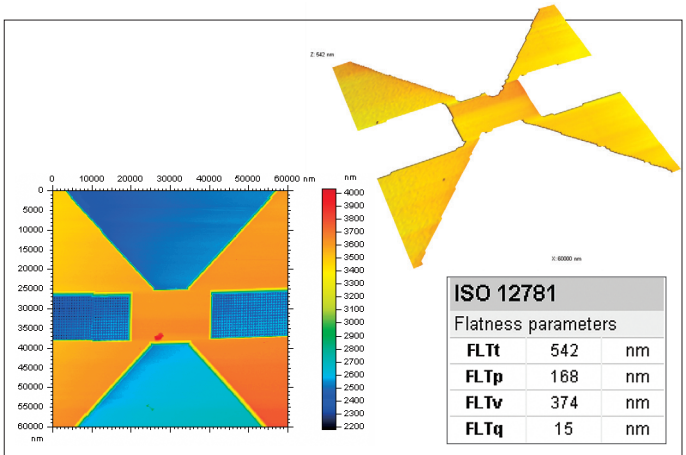


Figure 2. Calculation of ISO flatness parameters on a sub-surface of an IC resonator.

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.

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 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. Furthermore, multiple surfaces can be measured on a regular horizontal grid and can be stitched together into a single surface even if data on the x,y offsets between the surfaces is not available. And, Basic math functions (+, -, *, /, ^) can be applied to one or more surfaces. In addition, constants can be defined and used in formulae.

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.

Pico Image Options

Grains and particles option

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).

Image Co-localization option

The image co-localization option, which is included for Pico Image Expert, facilitates the study of various correlations by automatically co-localizing AFM and light microscope images of the same surface. (Figure 5.) Though this automated function provides precise registration, the size, rotation, and transparency of the co-localized images can be fine-tuned as needed.

Wavelets Analysis option

The wavelets analysis option lets users visualize and analyze the scale levels, from coarse to fine features on the images. Continuous wavelet decomposition methods allow visualization of the scales and spatial locations where phenomena occur on 2D profiles. Discrete wavelet filtering techniques enable users to decompose a 2D profile or 3D surface into a set of profiles or surfaces at different levels of scale; users can select the scale levels that will be included in the roughness profile (and thus the waviness profile).

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).

Keysight AFMs and SPMs

The 9500 AFM seamlessly integrates revolutionary new Nanonavigator software, a new high-bandwidth digital controller, and a state-of-the-art mechanical design to provide unrivaled scan rates of 2 seconds/frame and truly astonishing ease of use. In addition to completely redefining the user experience for atomic force microscopes, this intelligently conceived system delivers the superior performance and flexible functionality that scientists and engineers have come to expect from Keysight. New NanoNavigator software, whose workflow-based graphical user interface (GUI) makes the system noticeably easy to use. The new software's Auto Drive feature, for example, automatically and optimally sets parameters within seconds. The Keysight 9500 system offers a large, closed-loop AFM scanner with atomic resolution, industry-leading environmental control, ultra-high-precision temperature control. A new high-bandwidth, FPGA-based digital controller ensures high-speed operating precision and eliminates the requirement for additional external control boxes.

The 7500 AFM establishes new performance, functionality, and ease-of-use benchmarks for nanoscale measurement, characterization, and manipulation. This next generation system extends atomic force microscopy, offering a large, closed-loop AFM scanner with atomic resolution, industry-leading environmental control, ultra-high-precision temperature control, an unrivaled range of electrochemistry capabilities, and much more. The clever, compact design of the 7500 gives researchers quick, convenient access to their samples. A half-dozen of the most used AFM imaging modes are supported by the system's standard nose cone, which can easily be interchanged with specialized nose cones as needed, extending the 7500's capabilities effortlessly.

The 7500 inverted light microscope (ILM) system combines the power of the high-resolution 7500 AFM with the direct optical viewing capability of an ILM. The system offers unparalleled performance and ease of use for imaging in fluids. It extends AFM utility in order to encompass studies of single molecules, polymers, cell membranes, whole cells, and much more. Atomic force and optical fluorescence, FRET, darkfield and brightfield microscopy data can be obtained simultaneously.

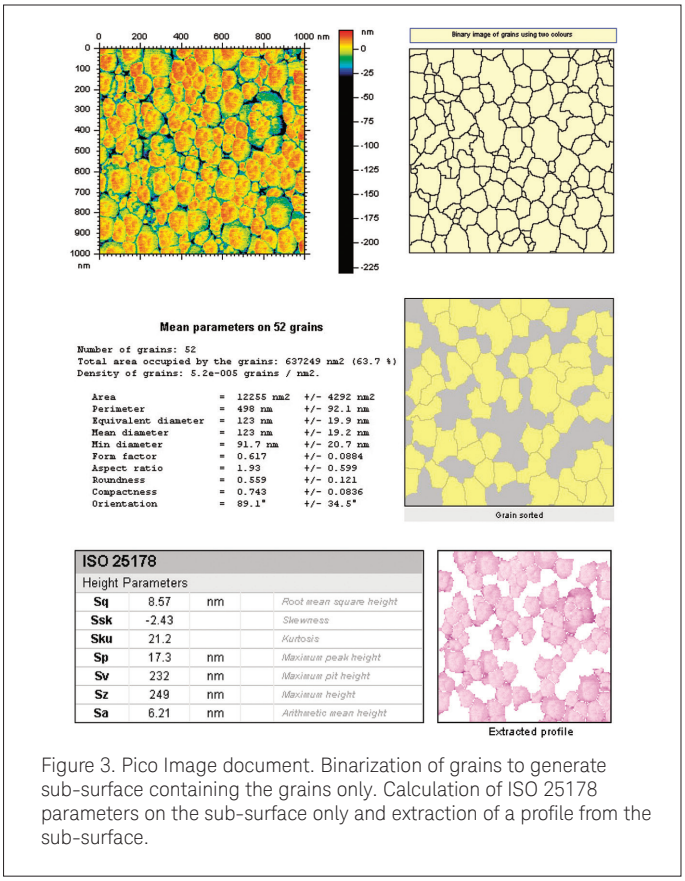


Figure 3. Pico Image document. Binarization of grains to generate sub-surface containing the grains only. Calculation of ISO 25178 parameters on the sub-surface only and extraction of a profile from the sub-surface.

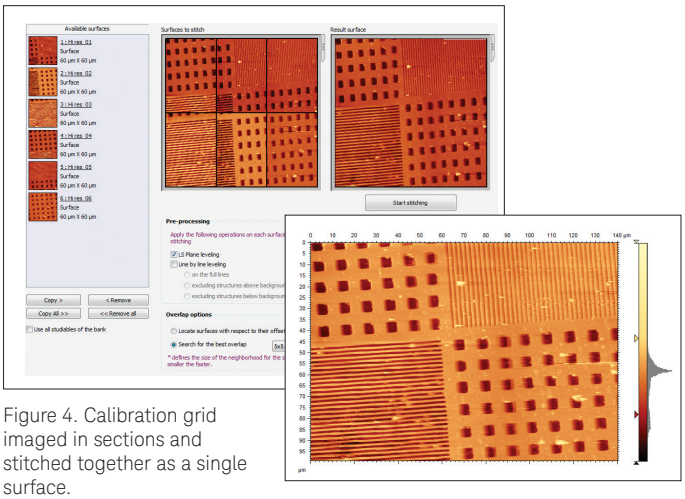


Figure 4. Calibration grid imaged in sections and stitched together as a single surface.

The Keysight 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 Keysight 5500ILM 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. Its advanced design allows the AFM to sit on top of an inverted microscope and under the illumination pillar, resulting in better optical contrast for the images.

The Keysight 5600LS utilizes a fully addressable 200mm x 200mm stage and a low-noise AFM design to perform high resolution imaging of large samples in air or smaller samples in liquid, and under temperature control. The programmable, motorized stage enables fast, accurate probe positioning for imaging and mapping large and small specimens alike.

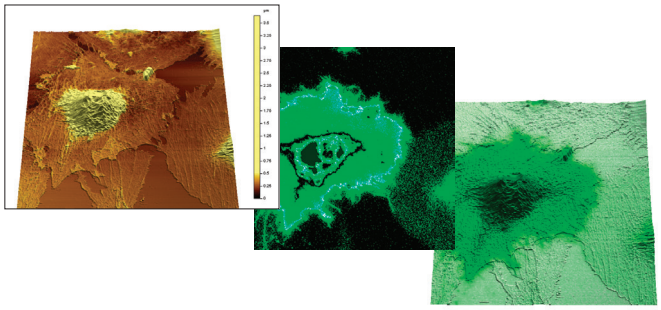


Figure 5. ECV cell. (Left) AFM image. (Center) Fluorescence image. (Right) Co-localized image.

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).
3-D Analysis	Create a 3 dimensional projection of the data using the detection signal as the out of plane extrusion. Topography, phase, amplitude, current, or any AFM channel can be plotted in a 3D image. Manipulation of the 3D projection (orientation, amplification, scale, color palette provide infinite variability and high quality output for inclusion in other documents. Scale customization. Edit lighting and projector positions and save settings for reuse or other surfaces. Stereo rendering for visualization of data with 3D glasses. Export animation in .AVI or compressed .WMV formats
Line Correction and Line Removal	Correct or delete unexpected lines in images.
Spatial Filtering	Apply one of several filters to the data (denoise, smoothing, Gaussian, or Mexican hat) to emphasize data trends that can be hidden in high spatial frequency artifacts.
Form Removal	Remove substrate or scanner artifacts to show true response of the topography/Z-channel data. Cylinder, Sphere, or higher order polynomial enable extraction of defect free surface data.
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. Application of an analysis document template to multiple measurement data files to generate one analysis document per measurement. Export analysis reports in PDF and RTF (Word compatible) formats. Ribbon customization feature.
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, Apply styles to different elements in series of profiles.
Online help	Help on all functions, contextual help, glossary, and metrological information.

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). Apply basic math functions to one or more surfaces.
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 with or without offsets.
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, power spectrum density and interactive parameter maps on force curves.
Operators	Morphological filtering, join two profiles, profile subtraction (compute similarity between two profiles), symmetries, form removal, re-sampling, autocorrelation, and inter-correlation.
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).

Co-localization Option Features

Expert levels	
Studies	Co-localize images of the same surface measured by different instruments in order to study correlations.
Operators	Co-localize simultaneous AFM topography/phase/deflection image with one or more fluorescence images or co-localize a confocal microscope topography image with a SEM image. Fine tune the size and rotation of the overlaid image if required, together with its transparency.

Wavelets Option Features

Basic, Advanced, and Expert levels	
Studies	Continuous wavelet decomposition — visualize the scales and spatial locations where phenomena occur on 2D profiles.
Operators	Decompose a 2D profile or 3D surface into a set of profiles or surfaces at different levels of scale — select the scale levels for inclusion in the roughness profile and hence the waviness profile — use Coiflet, Daubechies, Discrete Meyer, Spline and Symlet wavelet families (wavelet spline filtering is an advanced filtering technique defined in ISO 16610).

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 Feature Overview

	Basic	Advanced	Expert
Fast high quality multi-channel imaging with overlays	No	●	●
Powerful clean up and metrology filters	No	●	●
Force curve analysis	No	●	●
Comprehensive analytical studies of geomety and texture	No	◕	●
Integration of ISO and National (ASME, JIS, DIN, etc.) standards	No	◕	●
3D Fourier analysis	No	◑	●
Sub-surface analysis using new ISO 25178 algorithms	n/a	●	●
Fast analysis report creation	No	●	●
Stitching	No	No	●
Grains, particles, and islands analysis	Option	Option	Option
Statistics	Option	Option	Option
Co-localization of topography on fluorescene images	Option	Option	●
Wavelets filtering and analysis	Option	Option	Option
Force volume analysis	No	●	●

● All of features. ◕ 75% of features. ◑ 50% of features. ◔ 25% of features.

Pico Image Specifications

Instrument compatibility	Keysight 5500, 5500ILM, 9500, 7500, 7500ILM, 5600LS
Operating system	Windows 7, Vista, XP, and 2000; PicoView
Hardware requirements	Pentium 4 or dual core, 4 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, Russian and Chinese
Software levels	Basic is standard with 5500, 5500ILM, 5600 7500 & 7500ILM, Advanced and Expert is optional for the 5600LS, 7500, 7500ILM and 9500

KEYSIGHT TECHNOLOGIES

Unlocking Measurement Insights

AFM Instrumentation from Keysight Technologies

Keysight Technologies offers high precision, modular AFM solutions for research, industry, and education. Exceptional worldwide support is provided by experienced application scientists and technical service personnel. Keysight's leading-edge R&D laboratories are dedicated to the timely introduction and optimization of innovative, easy-to-use AFM technologies.

www.keysight.com/find/afm

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at:
www.keysight.com/find/contactus

Americas

Canada	(877) 894 4414
Brazil	55 11 3351 7010
Mexico	001 800 254 2440
United States	(800) 829 4444

Asia Pacific

Australia	1 800 629 485
China	800 810 0189
Hong Kong	800 938 693
India	1 800 11 2626
Japan	0120 (421) 345
Korea	080 769 0800
Malaysia	1 800 888 848
Singapore	1 800 375 8100
Taiwan	0800 047 866
Other AP Countries	(65) 6375 8100

Europe & Middle East

Austria	0800 001122
Belgium	0800 58580
Finland	0800 523252
France	0805 980333
Germany	0800 6270999
Ireland	1800 832700
Israel	1 809 343051
Italy	800 599100
Luxembourg	+32 800 58580
Netherlands	0800 0233200
Russia	8800 5009286
Spain	0800 000154
Sweden	0200 882255
Switzerland	0800 805353 Opt. 1 (DE) Opt. 2 (FR) Opt. 3 (IT)
United Kingdom	0800 0260637

For other unlisted countries:
www.keysight.com/find/contactus

Published in USA, July 2, 2016
5989-7596EN REV A
www.keysight.com