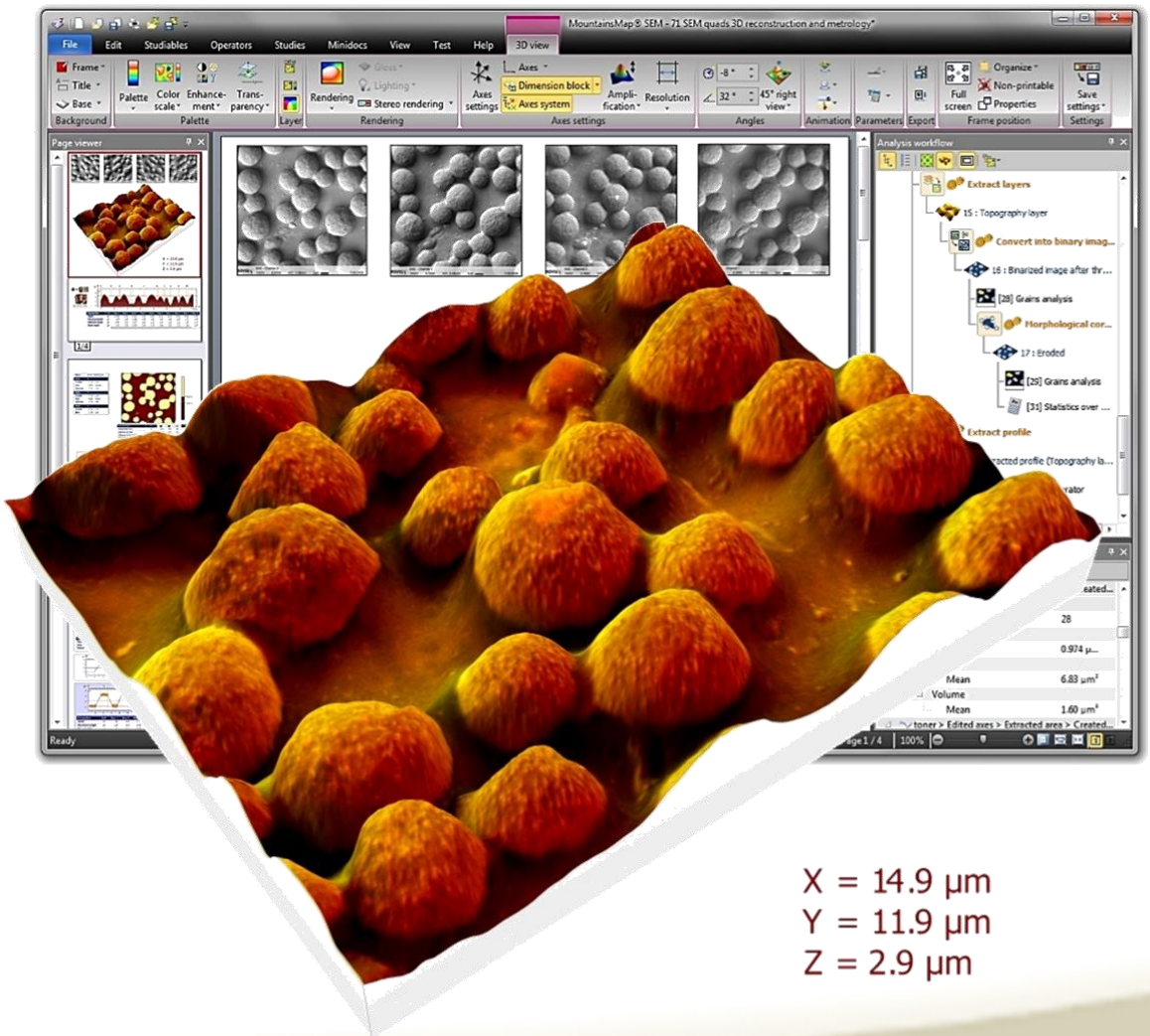
MountainsMap® SEM

Image enhancement, 3D reconstruction & metrology software

for Scanning Electron Microscopes

- 3D reconstruction from 2 or 4 SEM images in seconds
- Instant 3D enhancement of single SEM images
- SEM image colorization, enhancement and correction
- Measurement and dimensional analysis of raw and reconstructed features
- Surface metrology including roughness and grains & particles morphology
- Colocalization for correlative studies, including SEM/SPM, SEM/optical
- Easy publication of analysis results



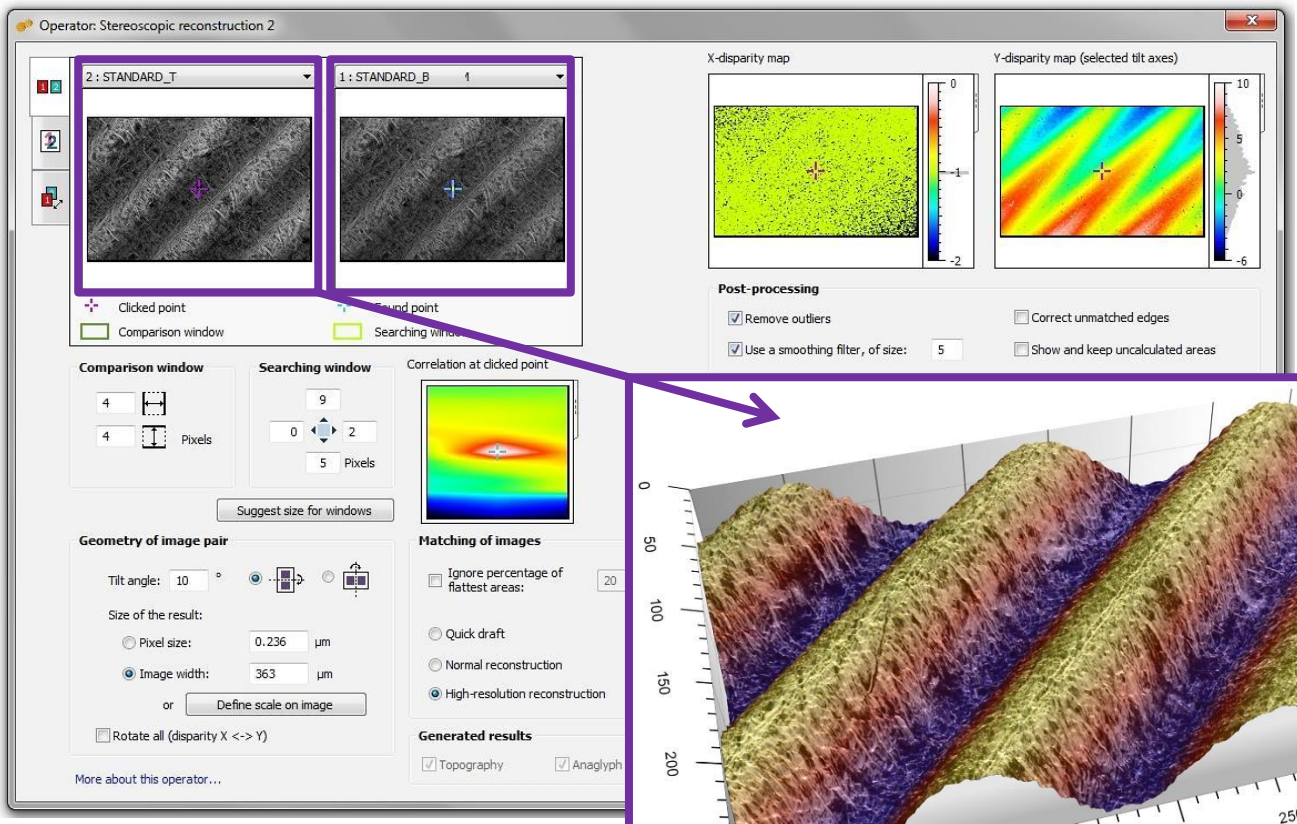
Mountains

Digital Surf

Superfast 3D reconstruction in a matter of seconds + surface metrology

3D from 2 images or anaglyphs

Reconstruct heights from two successive tilted scans of your sample using stereo photogrammetry reconstruction algorithms.

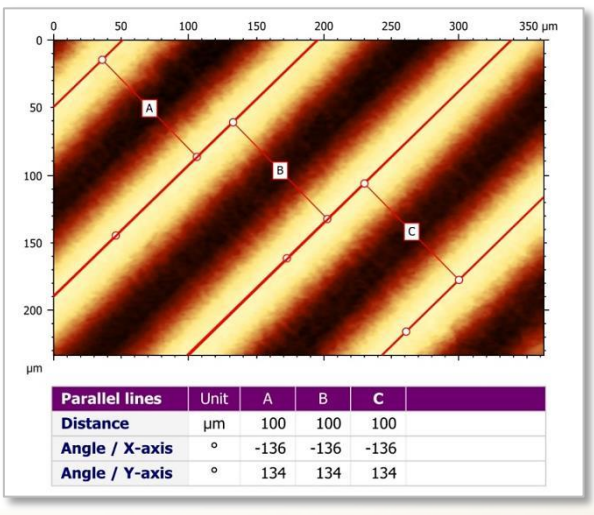


3D reconstruction in 3 seconds!

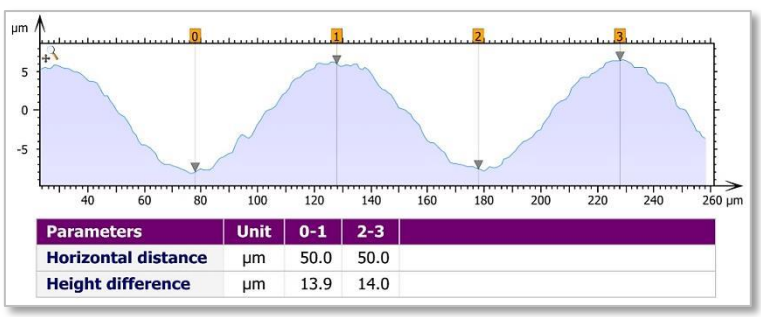
3D reconstruction from 2 SEM images of a periodic physical reference standard Click on "Suggest" and the reconstruction setup is suggested automatically. Several filters can be applied including outlier removal.

Metrology

Obtain good results from high quality stereo image pairs with the same details visible in both images.



Parallel lines	Unit	A	B	C
Distance	µm	100	100	100
Angle / X-axis	°	-136	-136	-136
Angle / Y-axis	°	134	134	134

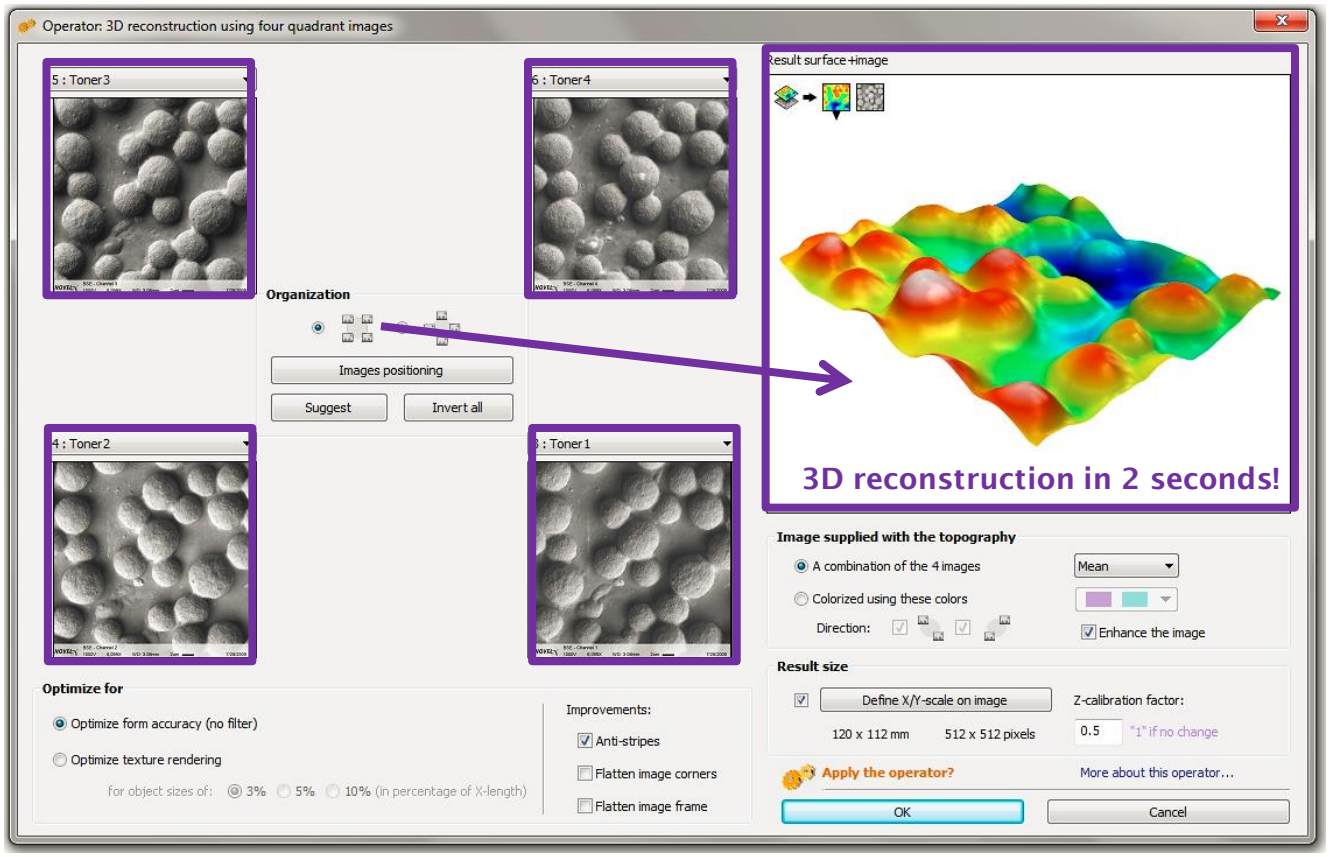


Parameters	Unit	0-1	2-3
Horizontal distance	µm	50.0	50.0
Height difference	µm	13.9	14.0

Measurements on the reconstructed surface correspond to reference standard dimensions.

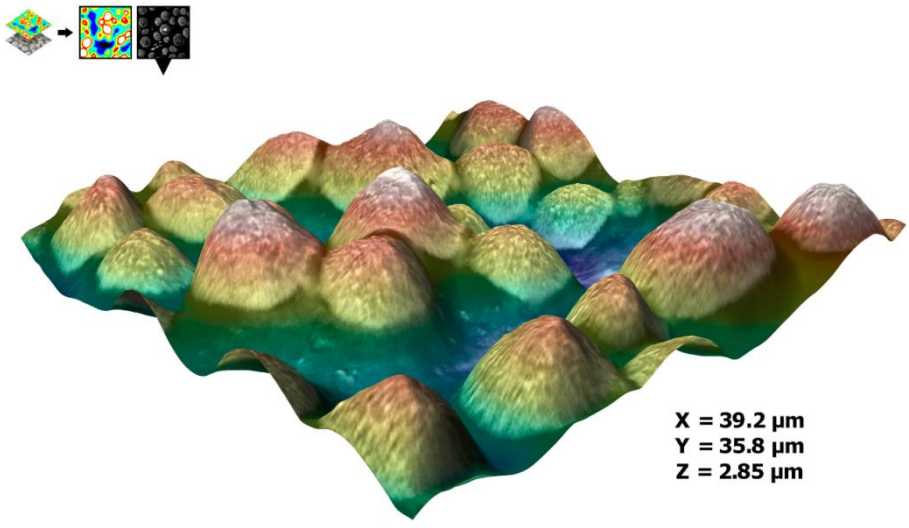
3D from 4 images

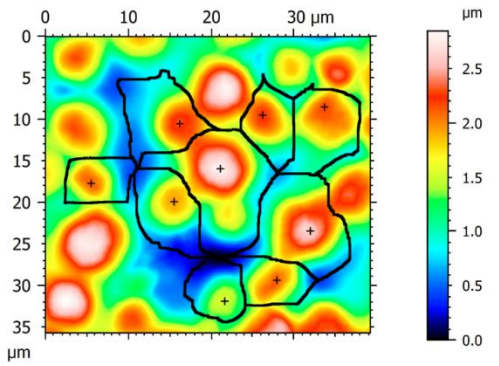
Reconstruct heights from a four image scan by a 4-quadrant backscattered electron detector using shape from shading algorithms.



Images courtesy of Keysight Technologies.

3D reconstruction of surface topography from 4 SEM images of toner particles. Again, click on "Suggest" and the reconstruction setup is suggested automatically.





Number of motifs	9		

Parameters	Stat.	Value	Unit
Height	Mean	0.389	µm
Area	Mean	69.9	µm²
Volume	Mean	3.48	µm³
Mean diameter	Mean	9.02	µm
Min diameter	Mean	7.32	µm
Max diameter	Mean	11.9	µm

Enhanced rendering can be achieved by overlaying the combined SEM image on the 3D color topography at a user defined transparency level.

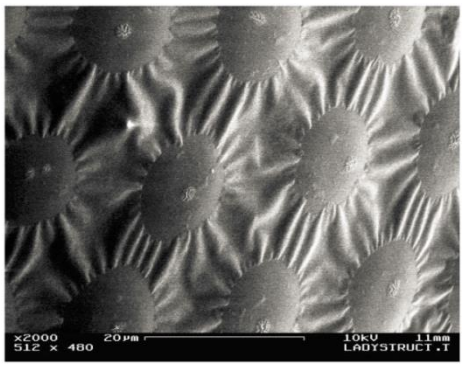
3D surface metrology can be carried out on reconstructed surfaces, for example morphological analysis of grains and particles* including volume (right).

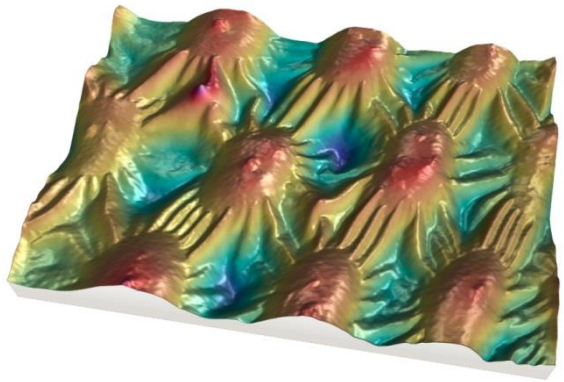
* Requires Grains & Particles optional module.

Instant 3D enhancement of single SEM images

3D enhancement

Single SEM images obtained using an oblique electron beam can be enhanced in 3D.



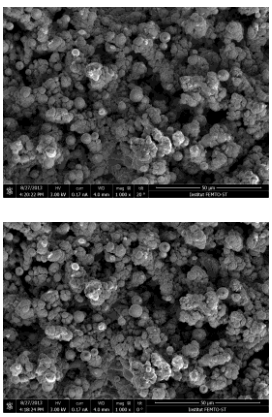


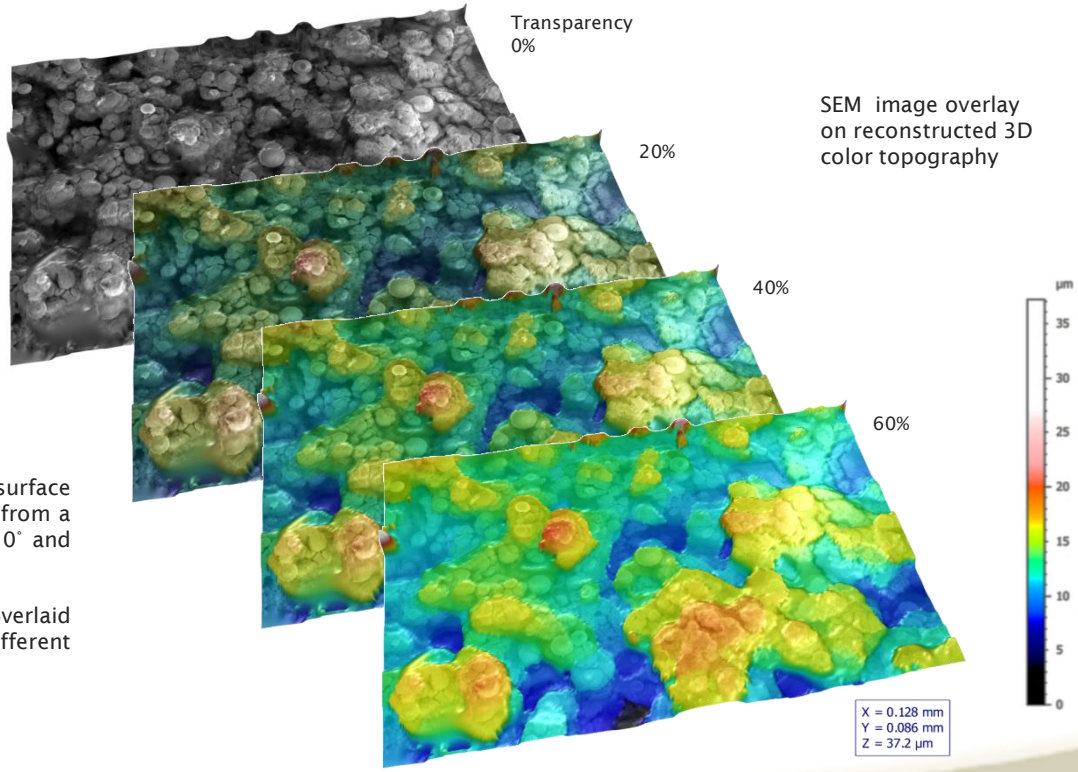
3D enhancement in 1 second!

3D enhancement of a single SEM image of a structure on a ladybug. (SEM image:Chris Supranowitz, University of Rochester).

Open up a new dimension in SEM image analysis!

- ✓ Zoom in on a 3D surface and rotate it in real time.
- ✓ Fly over features of interest on a surface and save your flight as a video for presentations.
- ✓ Choose the best lighting conditions.
- ✓ Level surfaces, flip them in the horizontal or vertical axis and rotate them in 1 degree increments.
- ✓ Select renderings.
- ✓ Set surface height amplification.
- ✓ Retouch any contaminated zones.
- ✓ Display contour diagrams and photo simulation.
- ✓ Extract 2D profiles from a 3D surface for visualization and analysis.





3D reconstruction of the 3D surface topography of a composite surface from a stereo image pair obtained at tilts 0° and 20°.

Here the grayscale SEM image is overlaid on the color coded topography at different transparency levels.

Assess Roughness, Waviness & Form

Advanced ISO 16610 filtering techniques and ISO 25178 3D parameters

MountainsMap® SEM makes it possible to separate the components of the reconstructed shape - form, waviness and roughness – in accordance with the latest international standards.

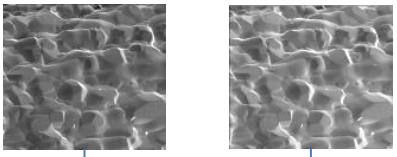
✓ Interactive best fit polynomial - isolates the form, with embedded sub-shape exclusion options (for example, exclusion of objects on top of a general shape).

✓ Latest ISO 16610 advanced filtering techniques to separate Waviness and Roughness.
- From Ra to the most popular standardized surface texture parameters: ISO 25178 3D, ISO 12178 flatness, ISO 4287 2D parameters.
- Even more parameters are available with the 3D Advanced Surface Texture optional module.

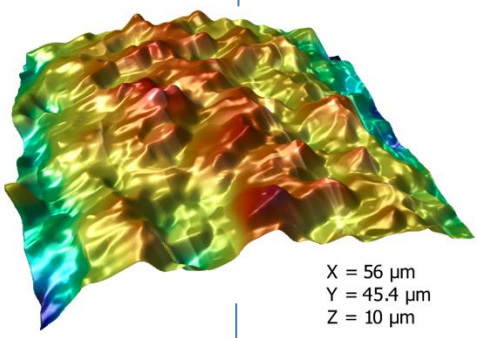
✓ Abbott-Firestone bearing ratio curve and depth distribution histogram.

✓ Wear volume assessment using before/after surface subtraction.

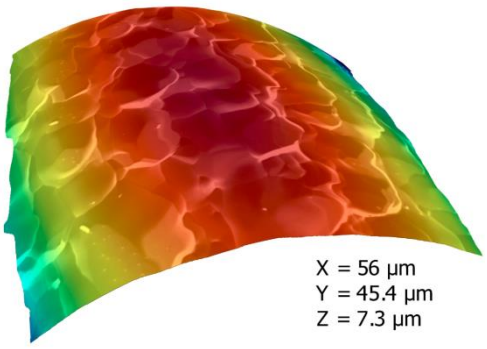
✓ Void/volume ratios within a surface slice.



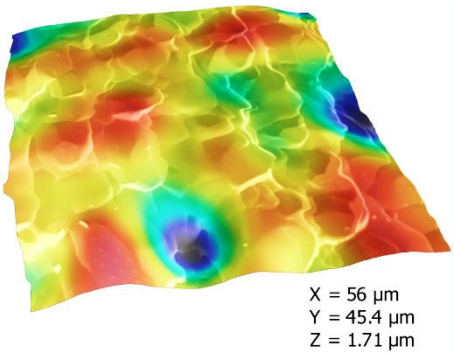
SEM image pair



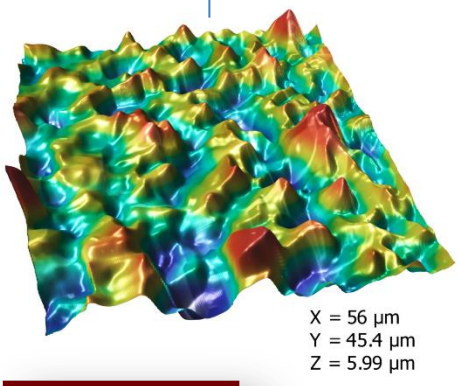
Primary surface obtained by 3D reconstruction



Form



Waviness



Roughness

ISO 25178		
Height Parameters		
Sq	0.279	µm
Ssk	0.238	
Sku	4.48	
Sp	1.60	µm
Sv	1.35	µm
Sz	2.94	µm
Sa	0.209	µm

ISO 25178 height parameters

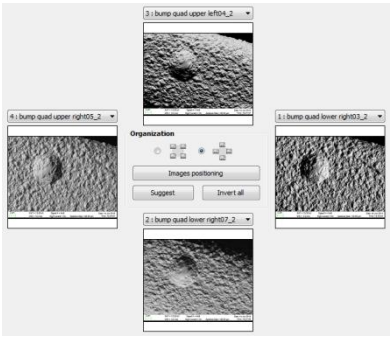
Analyze surface geometry

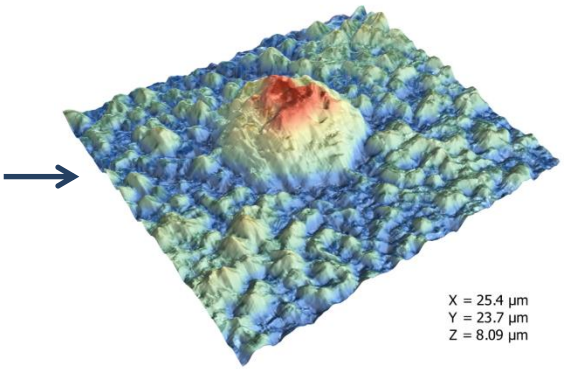
From basic measurements (distance, angles, volumes, steps) to dimensional analysis

Vertical geometry

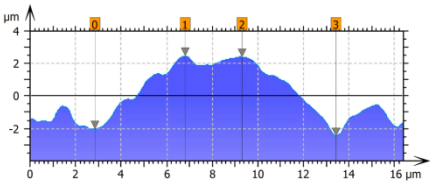
MountainsMap® SEM assures the fast and accurate analysis of surface geometry with tools for measuring:

- ✓ Distances.
- ✓ Angles.
- ✓ Areas of peaks and valleys.
- ✓ Volumes of bumps and holes.
- ✓ Material/void volume of vertical slices
- ✓ Step heights (surfaces & profiles).
- ✓ Coplanarity.

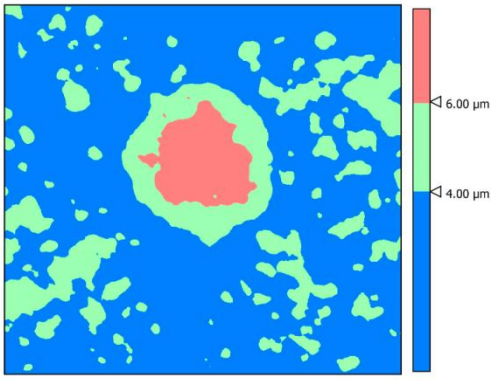




3D reconstruction from 4 SEM images of a bump on a copper grid.



Parameters	Unit	0-1	2-3
Horizontal distance	µm	3.96	4.12
Height difference	µm	4.51	-4.88
Slope	µm/µm	1.14	-1.18
Angle	°	48.7	-49.8



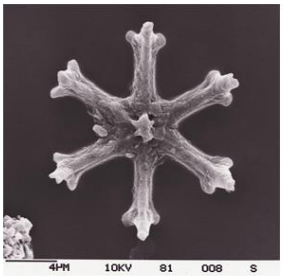
Parameters	Unit			
Projected area	%	71.2	23.5	5.30
Volume of void	%	13.3	87.8	97.4
Volume of material	%	86.7	12.2	2.60
Volume of void	µm³/µm²	0.532	1.75	2.04
Volume of material	µm³/µm²	3.47	0.243	0.0546
Mean thickness of void	µm	0.532	1.75	2.04
Mean thickness of material	µm	3.47	0.243	0.0546

Two example studies of vertical geometry. *Above*: interactive distance, slope and angle measurements on an extracted profile. *Right*: material and void volume of three interactively selected surface slices.

Images courtesy of LNE, French National Metrology Institute.

Horizontal geometry

Horizontal (x,y) profiles can be extracted from any SEM image and vertical (x,z) profiles (cross-sections) can be extracted from reconstructed surfaces. Geometric dimensions (including distances, radii, diameters and angles) can be calculated using autodimensioning and interactive tools.



Dimensions and angles from a microfossil SEM image.

Image courtesy of Dr. Hannes Grobe, Hannover, Germany, licensed under the Creative Commons Attribution 3.0 unported license.

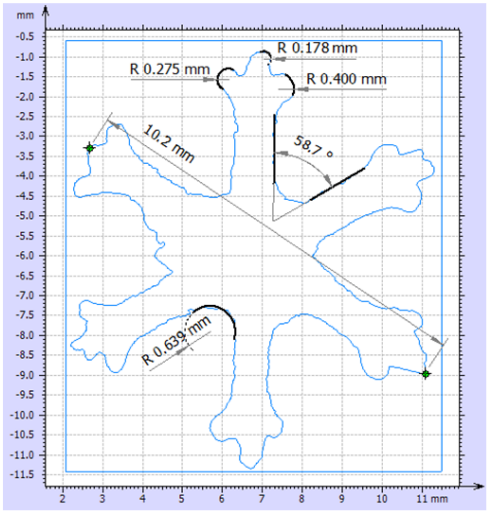


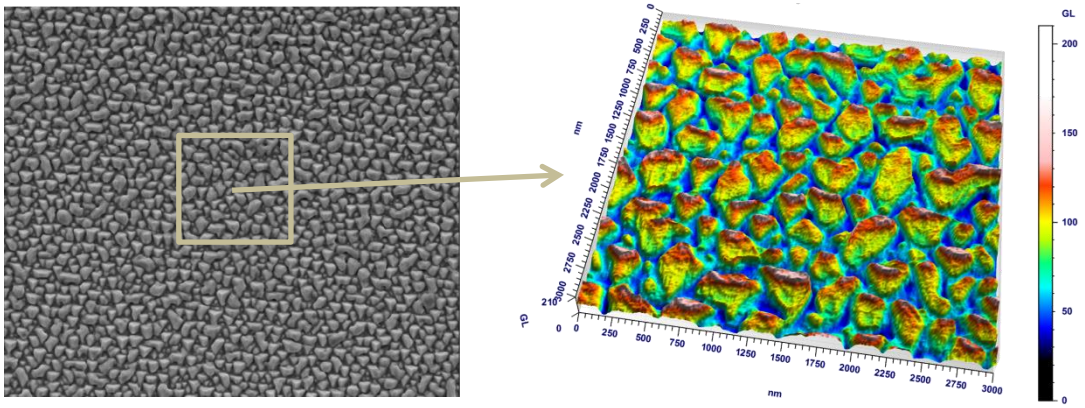
Image processing & analysis, the Mountains® way

Convert intensity levels into pseudo 3D to see more

Any SEM image can have its intensity signal interpreted as a height, producing a pseudo 3D image.

This is a good method for enhancing the visibility of discrete objects, for example grains and particles.

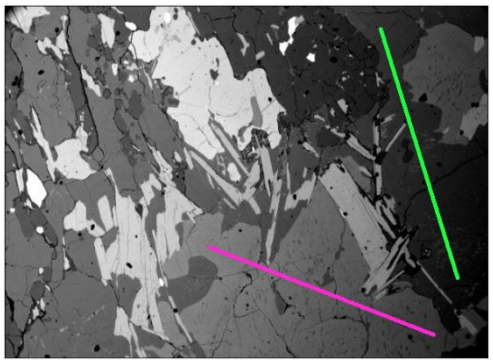
It also make it possible to carry out 2D grains and particles analysis on the x,y plane.



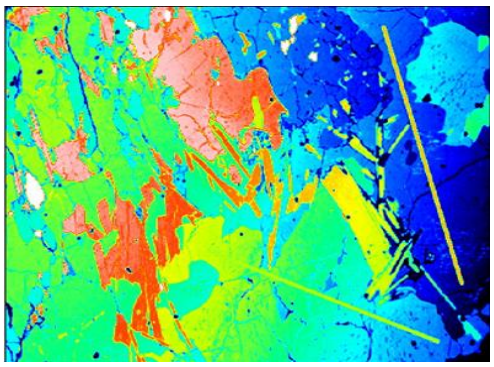
SEM image of grains and 3D intensity map of extracted zone

Gray level drift correction and surface composition metrics

Gray level drift on a SEM image means that the image cannot be used to obtain basic surface composition metrics. This can be rectified using gray level correction tools in MountainsMap SEM (convert the SEM image into a surface with intensity units on the z-axis and then apply the multi-plane form removal operator).

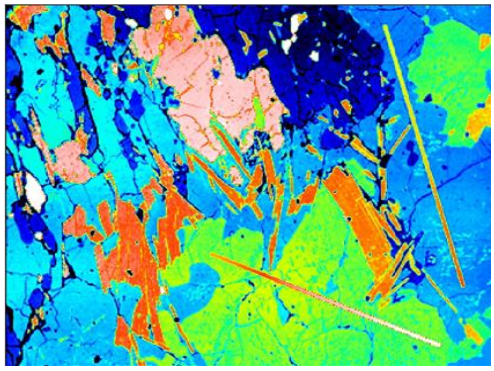


1. BSE SEM image with phase variation along the added colored lines due to gray level drift.



2. Simple colorization.

Gray level drift correction of a single BSE SEM image – before correction there is variation in two homogeneous phases along the colored lines – after correction each phase of the material is colored uniformly and it is possible to obtain compositional metrics. (SEM image courtesy of the School of Geosciences, University of Edinburgh.)



3. Uniform phase coloring after drift correction.

Colocalization

Combine data from different sources for correlative studies

It is possible to colocalize:

- images obtained by different detectors, for example secondary electron (SE) images and backscattered electron (BSE) images
- images obtained by different instruments, for example a SEM image and a 3D optical microscope image
- SEM images (or images obtained by another microscope with wide field of view) with 3D topography obtained by a scanning probe microscope or 3D optical microscope*.

Following colocalization of a SEM or other image with surface topography, it is possible to overlay the image on the 3D topography and study correlations.

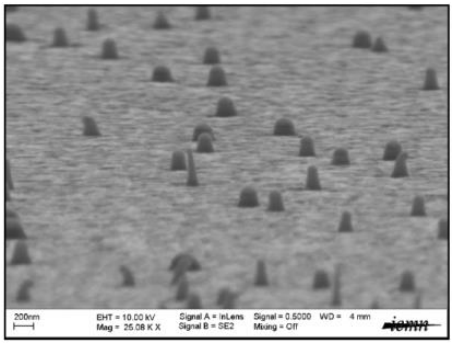
* Note: instrument compatibility depends on the configuration of installed MountainsMap® software. Optional extensions (SPM Extension and Spectrometry module) and upgrades provide compatibility with a range of different instrument types.

Example 1: colocalization of SEM SE and BSE images

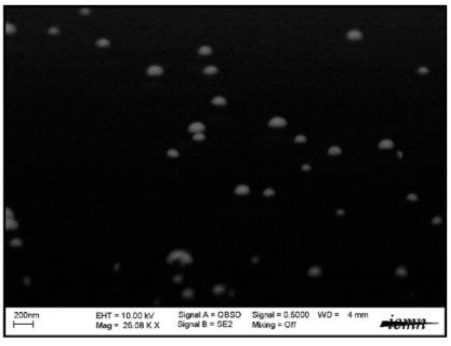
During the vapor-liquid-solid growth of silicon nanowires the diffusion of gold from the catalyst is monitored because it affects nanowire growth.

Here the SE (secondary electron) image (1) and BSE (backscattered electron) image (2) are colocalized in Mountains® 7 and the BSE particles are colored to obtain the composite image (3).

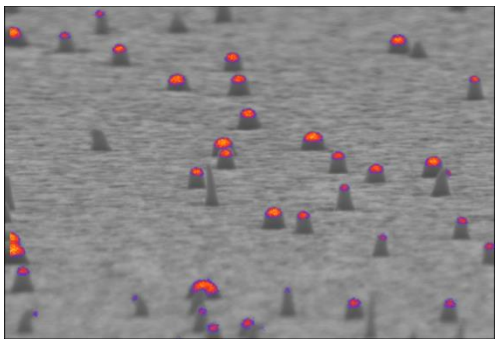
The composite image shows that some nanowires have lost their gold droplets.



① SE image



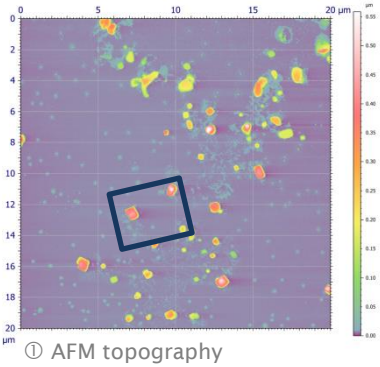
② BSE image



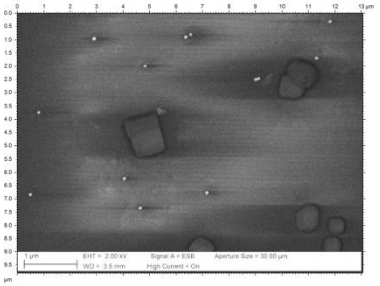
③ Composite image obtained by colocalization and overlaying the BSE image on the SE image.

Images courtesy of IEMN, Lille, France.

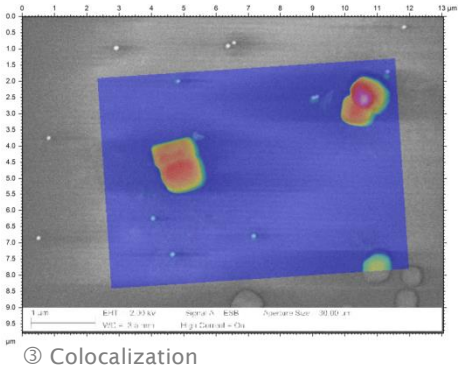
Example 2: colocalization of SEM image with atomic force microscope (AFM) 3D topography



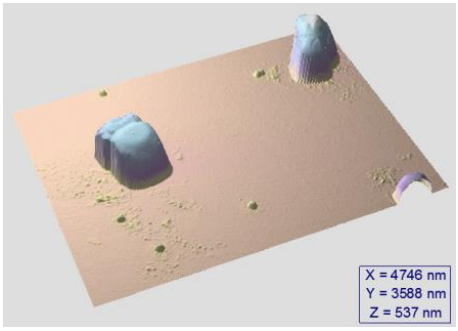
① AFM topography



② BSE image



③ Colocalization



④ Overlay: BSE image on AFM topography

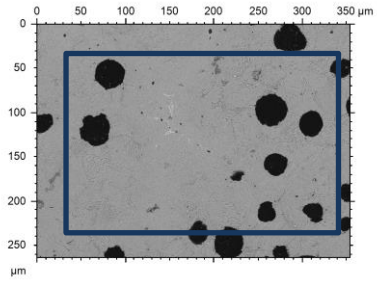
Co-localization of SEM images with 3D surface topography data obtained by AFM facilitates the study of feature morphology.

Here a zone extracted from an AFM topography image of nanostructures (1) is colocalized with a BSE image (2) to obtain a composite image (3). Then the part of the BSE image that coincides with the extracted zone is overlaid on the 3D surface topography at a selected transparency level (4).

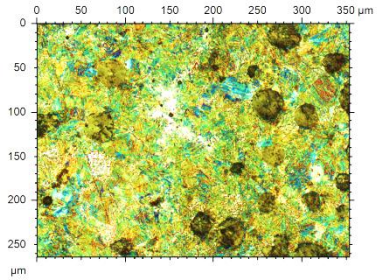
Requires SPM Extension optional module (provides compatibility with scanning probe microscopes including AFM's).

Images courtesy of LNE (French National Metrology Institute).

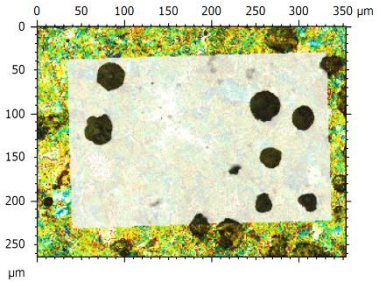
Example 3: colocalization of SEM image with optical microscope image



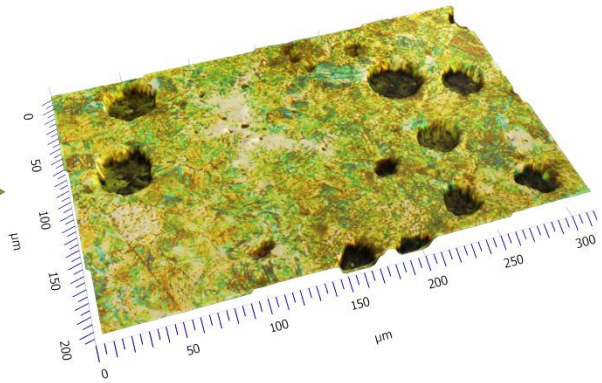
SEM image



Color image



Colocalized images



Overlay of color image on SEM image

Co-localization of cropped SEM image with color optical microscope image. The SEM image is converted into a pseudo 3D image with z axis in intensity units (not shown). Overlaying the optical microscope image on the pseudo 3D image highlights surface features and chemical structure.

Images courtesy of Carl Zeiss.

Highly intuitive desktop publishing environment

Full metrological traceability, automation, fine tuning on the fly

Visual analysis reports

In MountainsMap® SEM you build a visual analysis report frame by frame, page by page, working in a comfortable desktop publishing environment. Frames contain 3D and other views of surface data, the results of applying filters, analytical studies, ISO and national parameters, measurement identity cards, comments and illustrations. You can navigate to any frame in a report by selecting it in the page viewer.

Smart user environment

The smart user environment - with logical top-down organization of all functions and contextual object-oriented ribbons – means that you can go from idea to action with minimum effort. A full screen mode provides maximum comfort when you are carrying out a specific analytical study. Furthermore you can work in your own language thanks to the fact that the user interface - including expanded graphical tooltips that provide a first level of help – is available in ten languages (EN, FR, DE, ES, IT, PL, BR, JP, CN, KR). In addition, a complete reference manual (EN, FR, DE, JP) with illustrations and examples can be accessed simply by pressing the F1 key.

Full metrological traceability

Every analysis step is recorded in a hierarchical analysis workflow to assure full metrological traceability. Analysis steps in the workflow can be fine tuned at any time. All dependent steps are recalculated automatically.

Powerful automation features

Once an analysis report has been completed it can be applied as a template to automate the analysis of multiple measurement data files. In addition common sequences of analysis steps can be saved in a library for insertion into future analysis reports to save time.

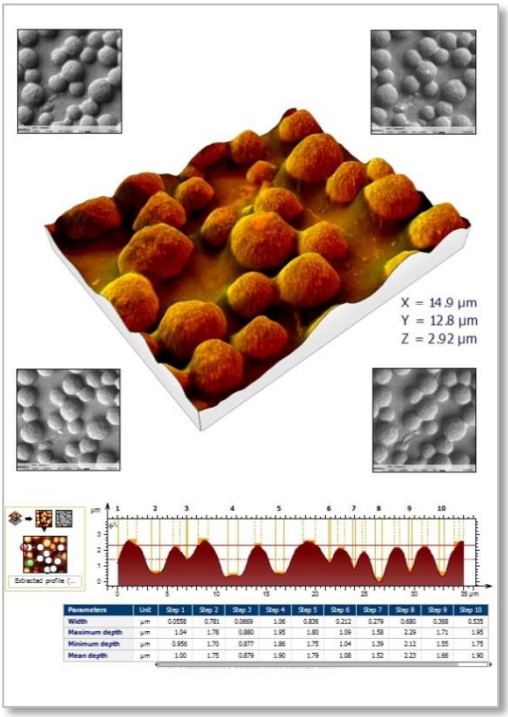
Pass/fail with tolerancing

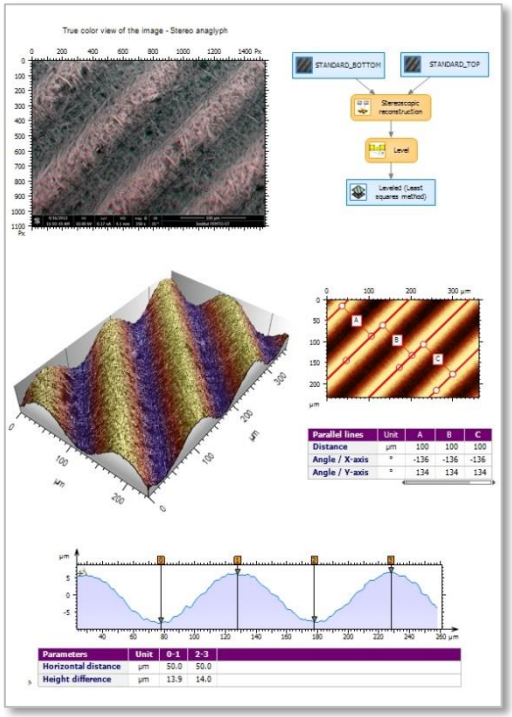
Pass/fail criteria with tolerances can be defined for any parameter. Green/red pass fail traffic lights are displayed automatically and the parameter value and tolerance limits are shown graphically.

Data export

Frames and pages can be exported as bitmaps up to 1200 dpi for poster sessions. Finished reports can be exported in PDF and RTF formats for easy circulation.

All numerical results, including pass/fail status, are accessible in the Results Manager panel and can be exported in Excel-compatible text files for interfacing with 3rd party software, including quality management software.





MountainsMap® SEM Optional Modules

For advanced and specialized applications

Expand your MountainsMap® SEM with a wide selection of optional dedicated modules:

- Grains and Particles Analysis – for quantifying grains and other isolated surface features and generating statistics
- 3D Advanced Surface Texture – more 3D surface studies, parameters and filters
- 3D Fourier and Wavelets Analysis – analysis of process-surface interactions from spatial frequency analysis
- 4D Series – monitor surface changes over time or experiment conditions
- Statistics – monitor parameters on multiple static/dynamic surface data populations
- Advanced Contour Analysis – comprehensive form deviation analysis
- 2D Advanced Surface Texture - advanced 2D profile studies and filters
- SPM Extension – work with data from scanning probe microscopes including atomic force microscopes (AFM's), magnetic force microscopes (MFM's), current sensing atomic force microscopes (CSAFM's), scanning tunneling microscopes (STM's), scanning near-field optical microscopes (SNOM's)
- Spectrometry – visualize and analyze hyperspectral data (obtained by EELS, EDX, Raman, FT-IR and other spectrometers/microscopes)

Please see the back page for a summary of the main features in each module. Three of the modules are highlighted in the next two pages.

Grains and particles analysis module

Study isolated surface features

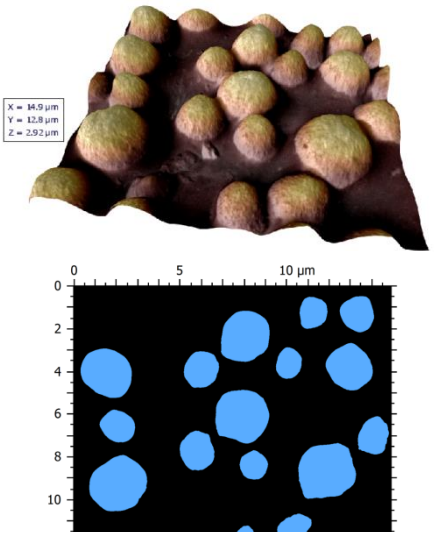
- Automatically detect and count grains, particles, islands, bumps, holes and motifs (texture cells) using multiple methods:

  2D grains and particles on any SEM image (after conversion into an intensity map) – separate grains from the background by binarization at selected intensity level – sort grains into subsets with respect to any parameter.

  3D grains (islands) on 3D surface topography (after reconstruction) with respect to a selected height.

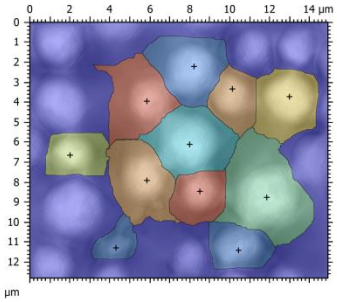
  Motifs on 3D surface topography (after reconstruction) in accordance with a configurable ISO 25178 segmentation by watersheds algorithm and Wolf pruning.

- Calculate morphological parameters for individual grains.
- Generate statistics for all grains and subsets.
- Calculate ISO 25178 features parameters (Spd, Spc, S5p, S5v, S10z, Sha, Sda, Shv, Sdv) for 3D surface topography.



Statistics over all grains			
Global information	**Value**		
Number of grains	16		
Total area occupied by the grains	44.9 µm² (23.5%)		
Density of grains	0.0838 Grains/µm²		
Grain parameters	**Unit**	**Value**	**Std dev**
Area	µm²	2.81	1.57
Perimeter	nm	6260	1751
Equivalent diameter	nm	1816	523
Mean diameter	nm	1810	526
Min diameter	nm	1639	509
Max diameter	nm	1998	560
Form factor		0.827	0.0265
Aspect ratio		1.24	0.132
Roundness		0.824	0.070
Compactness		0.907	0.0396
Orientation	°	88.4	44.1

Statistics on toner particles separated from background by binarization.



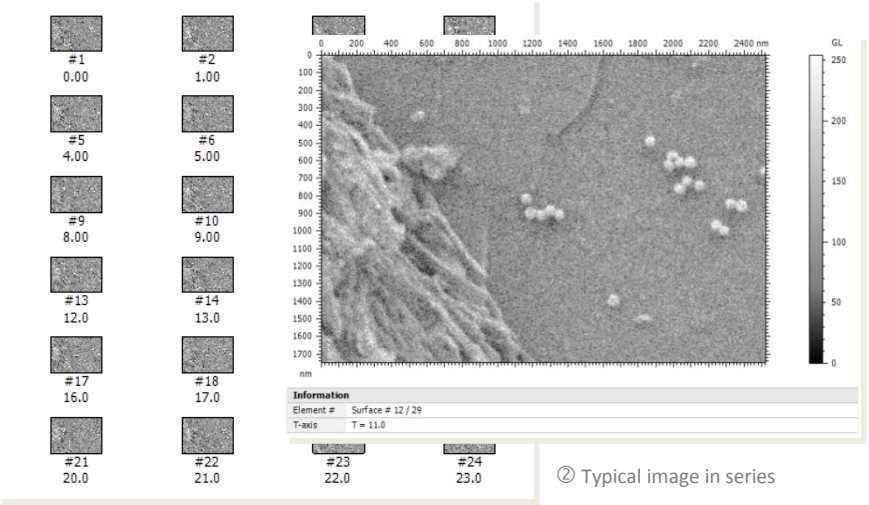
Number of motifs	11		
Parameters	**Stat.**	**Value**	**Unit**
Height	Mean	0.918	µm
Area	Mean	9.03	µm²
Volume	Mean	1.71	µm³

Statistics on motifs (texture cells)

4D series module

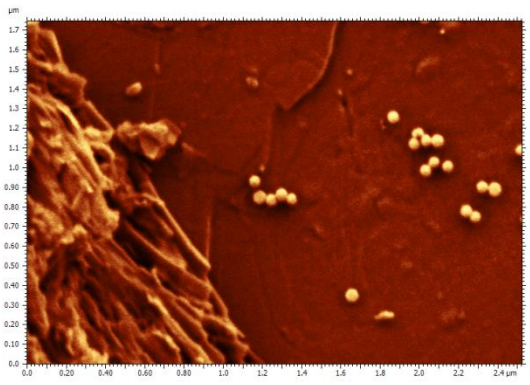
Monitor surface changes over time or under any experimental conditions

- Combine a series of surfaces (z axis height) or images converted into intensity maps (z axis intensity) for 4D analysis with respect to time, temperature, magnetic field or any other experimental conditions.
- Visualize surface, profile and point evolution, even fly over a surface as it changes and record a movie for presentations.
- Generate statistics on surface texture parameter evolution.
- Filter out noise and highlight areas with different kinetic behavior using the Karhunen-Loève transform (principal component analysis).



① Series of SEM images (in background)

② Typical image in series



③ Mean image after principal component analysis

Noise can be a problem when a series of SEM images is captured at high speed.

Application of the Karhunen-Loève transform (principal component analysis) in Mountains® can help to solve this problem.

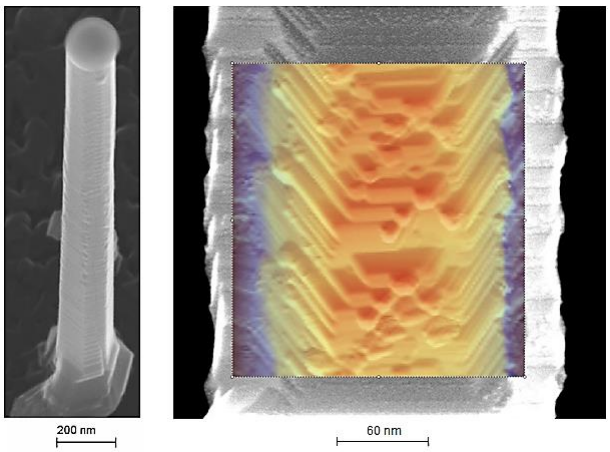
For example a typical image (2) in a series of images (1) is noisy. However, after the application of the Karhunen-Loève transform to the series of images, the resulting image (3) is of significantly higher quality.

Images courtesy of LNE (French National Metrology Institute).

SPM extension module

Work with SPM data

- Load SPM file formats – almost all formats generated by SPM's (scanning probe microscopes) and SPM software packages are supported.
- Correct SPM image acquisition errors – tools include line correction and tip deconvolution.
- Manipulate multiple SPM layers simultaneously – topography, deflection, phase, current, etc.
- Overlay non-topography layers on 3D topography – study correlations between phase, current or another layer and 3D topography.
- Colocalization – use MountainsMap® SEM's colocalization feature to colocalize SEM images with SPM topography and other layers for correlative studies



Colocalization of topography obtained by STM with SEM image of nanowire.

Images courtesy of IEMN, Lille, France

Selected standard and optional features

MountainsMap® SEM

Compatibility	Scanning electron microscope images (including 3D reconstruction from stereo image pairs and image quads) - standard RGB image formats – plus with *optional extensions* scanning probe microscopes (AFM, MFM, CSAFM, STM, SNOM, etc.) , hyperspectral instruments (Raman, FTIR, etc.) – plus with *optional upgrades* 3D optical microscopes and other instruments
Smart desktop publishing user environment	Frame-based desktop publishing environment – logical top-down organization of all functions – contextual-object oriented ribbons – multi-language user interface (EN, FR, DE, ES, IT, PL, JP, CN, KR, BR) – integrated reference manual (EN, FR, DE, JP) - automatic analysis of series of measurements using templates – library of common analysis sequences - single-click in-document navigation via page viewer - analysis workflow for full metrological traceability - tolerances for any parameter with pass/fail traffic lights – frame and page bitmap export (up to 1200 dpi) - Excel-compatible ASCII export of numeric results – PDF and RTF export of multi-page documents – standard and user-defined portrait, landscape and onscreen page formats – master page with common elements (logo, etc.) - auto-save
Image calibration	Assign length units to image axes
3D reconstruction of surface topography	3D reconstruction (z axis in height units) from stereo images pairs taken at different tilt angles (or anaglyphs) using stereophotogrammetric algorithms - 3D reconstruction (z axis in height units) from 4 images captured by quad detectors using photometric stereo methods (shape from shading), optimized for rough surfaces
3D enhancement	3D enhancement of single SEM images obtained using an oblique electron beam.
3D color intensity maps	Conversion of SEM images into 3D color images with z axis in intensity units
3D topography/ intensity map visualization	Real time imaging of 3D surface topography – surface flyovers with video export – contour diagrams - photo-simulations - 2D profile extraction
Image enhancement & data correction	3D image brightness, contrast, gamma and saturation - lighting conditions - renderings and gloss – height (surface topography) or intensity (intensity map) amplification – standard or user-defined color-coded palettes for the vertical scale, optimized to take into account surface data point distribution - resampling to increase image resolution – surface leveling – x,y or z inversion - rotation – thresholding to remove anomalous peaks and pits - filling in missing points - retouching zones – gray level drift correction (using conversion into surface and multi-plane form removal)
Geometric analysis	Distance, angle, area, volume, step heights measurement – extraction of vertical (x,z) and horizontal (x,y) contours (profile) from surfaces – geometric dimensioning
Surface texture analysis	Metrological filters including form removal (surfaces), roughness/waviness filters (Gaussian to ISO 16610), spatial filters (including surface smoothing), morphological filters (surfaces) – MATLAB™ compatibility for custom filters – surface texture analysis including bearing ratio curve and depth histogram, material/void volume and thickness of vertical slices, surface subtraction (wear), sub-surface extraction and analysis, ISO 25178 3D height and functional bearing ratio - ISO 12178 flatness - ISO 4287 2D primary and roughness – ASME B46.1 3D and 2D - EUR 15178 amplitude, volume – national equivalents of ISO parameters DIN (DE), JIS (JP), NF (FR), BSI (UK), UNE (ES), UNI (IT) and GB/T (CN)
Colocalization	Colocalization of surface data (images and/or topography) obtained by different detectors or instrument types – overlay images on 3D surface topography or intensity map for correlative studies

MountainsMap® SEM Optional Modules

Grains & Particles Analysis	Automatic detection of grains, particles, islands, bumps, holes and motifs (texture cells) using multiple morphological parameters – statistics – ISO 25178 features parameters – spherical parameters (microlens arrays)
3D Advanced Surface Texture	ISO 25178 volume, hybrid and spatial parameters – graphical study of functional volume parameters - ISO 12178 flatness parameters – isotropy, directionality and periodicity – morphological filters for surfaces – furrows analysis - fractal analysis
3D Fourier & Wavelets Analysis	Frequency spectrum – power spectrum density – surface autocorrelation and intercorrelation – FFT plot editor – discrete wavelet filtering (surfaces and profiles) – continuous wavelet decomposition (profiles)
4D Series	4D visualization, filtering and analysis of series of surfaces and images (z axis: height or intensity) - surface, profile and point evolution – surface flyover movie export – statistics on surface texture parameters – Karhunen-Loève transform (principal component analysis) for noise filtering and highlighting areas with different kinetic behavior
Statistics	Automated data preparation using templates – statistical reports on multiple static and/or dynamic surface data populations - control charts for monitoring metrological and process parameters
Advanced Contour Analysis	Comparison of measured contours with DXF CAD data or user-defined nominal form – tolerance specification – magnified form deviation graphics – table of pass/fail results – Gothic arch bearings analysis
2D Advanced Surface Texture	Form removal - ISO 16610 2D roughness/waviness filters – morphological filters - 2D Fourier analysis including frequency spectrum and power spectrum density - FFT plot editor – profile data correction tools – profile subtraction - profile joining - 2D fractal analysis - series of profiles creation and analysis with statistics
SPM Extension	Load SPM file formats – correct SPM image acquisition errors (tools include line correction and tip deconvolution) – manipulate multiple SPM layers simultaneously – overlay non-topography layers (phase, current, etc.) on 3D surface topography – study correlations between phase, current or another layer and 3D topography
Spectrometry	Extension for hyperspectral instruments (including Raman, EELS, EDX and FT-IR spectrometers) - visualization of spectra and hyperspectral cubes – compositional density maps – 3D intensity maps – colocalization

MountainsMap® SEM Upgrade to MountainsMap® Premium

Premium Upgrade	Upgrade to MountainsMap® Premium - top of the line package compatible with 3D optical profilers, scanning probe microscopes and contact and non-contact 3D/2D surface profilometers - contains all MountainsMap® SEM modules except for Advanced Contour Analysis and Spectrometry

Requirements

PC requirements

Minimum requirements	Operating system	Windows 8 (64-bit or 32-bit) or Windows 7 (64-bit or 32-bit) or Windows Vista (64-bit or 32-bit)
	RAM	4 GB
	Graphics board	Hardware accelerated OpenGL or Direct3D
	Resolution	1280 x 768 in thousands of colors
	HDD free space	800 MB
	Other	1 free USB port
Recommended	Operating system	Windows 8 (64-bit) or Windows 7 (64-bit)
	RAM	8 GB
	Processor	Quadcore
	Resolution	1600 x 1024 in thousands of colors

Digital Surf Head Office & R&D Center
Digital Surf SARL, 16 rue Lavoisier,
25000 Besançon, France
Tel +33 3 81 50 48 00
contact@digitalsurf.fr **www.digitalsurf.com**

MountainsMap® SEM: Version 7.2
Doc Revision: 20150316

© 1996-2015 Digital Surf SARL. All rights reserved. Specifications subject to change without prior notice.