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

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

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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.

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

Measurements on the reconstructed surface correspond to reference standard dimensions.

Metrology
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.

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

3D enhancement in 1 second!

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

The SEM Extension Module 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.
Analyze surface geometry
From basic measurements (distance, angles, volumes, steps) to dimensional analysis

Vertical geometry

The SEM Extension Module 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.

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 MountainsMap® 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 makes it possible to carry out 2D grains and particles analysis on the x,y plane.

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 the SEM Extension Module.

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.

SEM Extension Module for MountainsMap®

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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 using the SEM Extension Module and the BSE particles are colored to obtain the composite image (3).

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

Images courtesy of IEMN, Lille, France.
Example 2: colocalization of SEM image with atomic force microscope (AFM) 3D 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

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.
## SEM Extension Module for MountainsMap®

### 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

### 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