We make it visible.

3DSM

3D Surface Modelling

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What is 3DSM?

Scanning electron microscopes are great tools for 2D inspection and metrology of a wide variety of samples. However, their 3D capabilities are still very limited, especially when it comes to qualitative surface characterization. This is the main problem tackled by 3DSM. 3DSM is a PC-based application capable of providing topographical information for samples examined with Carl Zeiss Microscopy electron microscopes equipped with an AsB® or 4QBSD detector. The application can perform a 3D surface reconstruction based on the individual AsB®/4QBSD segment signals and visualize the resulting 3D model in several different ways. 3DSM can work together with SmartSEM® in live mode, for real-time 3D imaging. It may also operate in stand-alone mode for visualizing archived project files.

3DSM takes advantage of the possibility of using a single point of view, scanned using four detector segment signals. This method, called the multi-detector method, utilizes the principle of „shape from shading". Using four input images, the gradation of grey-levels on topographical objects provides a basis for calculating local surface geometry. This leads to a continuous surface model for visualization purposes. The algorithm underlying 3DSM has several advantages over classical 3D surface reconstruction methods based on 2 viewpoints:

- Real-time operation (Live mode)
- Fast reconstruction time (< 1 second)
- Full automation
- No additional hardware necessary (e.g. stage)

- High resolution performance
- Compatibility with any type of 4-quadrant diode or 4-detector system
- Works for smooth surfaces lacking distinguishable details

Applications

3DSM has a vast scope of applications. Almost everything examined so far in a SEM now gains a third dimension, creating endless possibilities in fields ranging from biology to machining quality control. The main application fields are listed below.

Life sciences
- Cellular & tissue biology
- Particle surface analysis

Electronics
- Defect & failure analysis
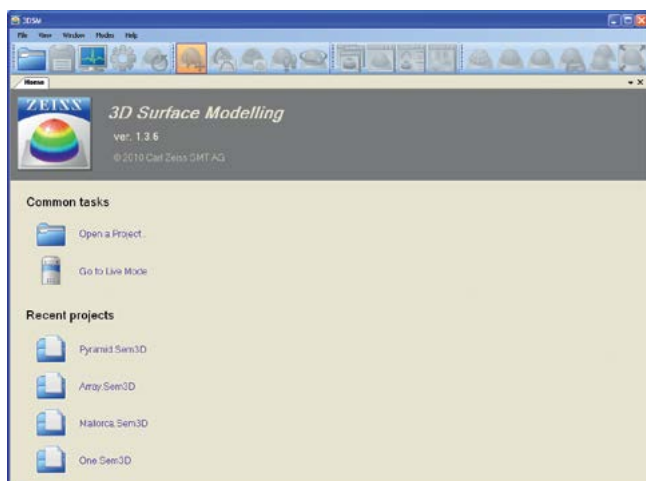- Nano-imprint analysis & recognition

Forensics
- Bullet & firearm investigations
- Evidence characterisation at the nano-scale

Industry
- Roughness measurements
- Wear analysis
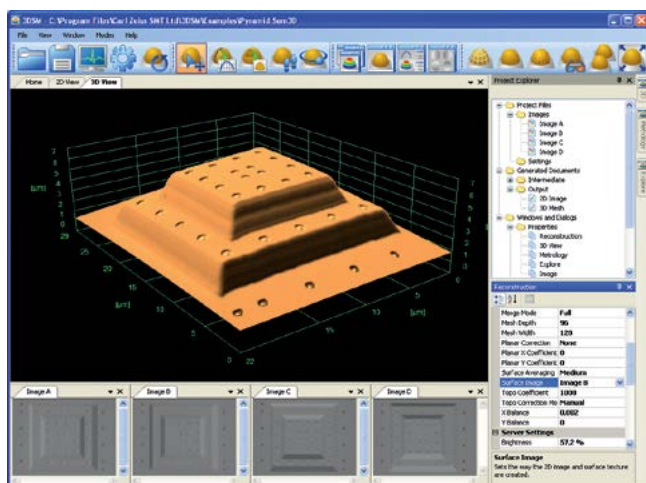- Quality control in machining

Quick Start

When launched for the first time, 3DSM displays the Home screen with a list of example project files.

3DSM Home screen.

A single-click on the recent projects list file will open the project. The following screenshots use the *Pyramid* sample project to explain the basic features of the interface.



View of 3DSM after loading a project.

By default, 3DSM displays the main 3D View of the object along with the four input images (bottom) and basic reconstruction parameters grouped in tabs (right). Use the mouse to navigate around the application and explore the resulting images. The mouse will allow rotating, zooming and panning of the surface mesh and 2D images.
A context menu is always available with a right-click, showing the most common options.

Using 3DSM

The appearance of the 3DSM interface is designed using very flexible docking-window technology. This feature allows the user to construct virtually any application layout. Each window may be docked within any of the other document windows or to any of the four side panels. The most commonly used layouts are available at a single mouse click from the toolbar, as shown on the images below.
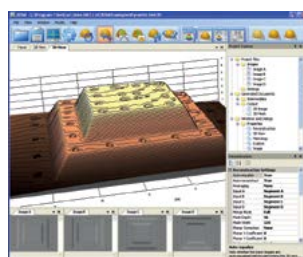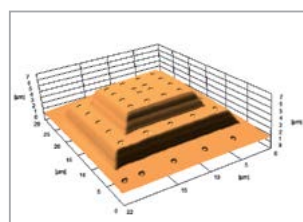

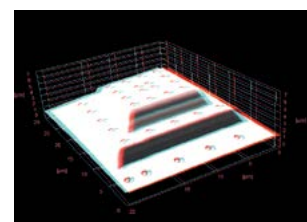*Standard view.*
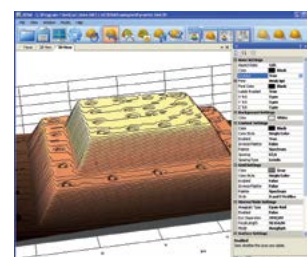
3D view layout.
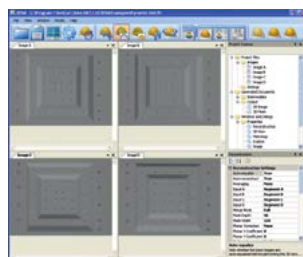
Input image layout.

Predefined application layouts available from the toolbar.

The 3D surface may be explored in several ways, ranging from false-color LUTs and texture overlays, to surface-walk and fly-around modes. Some common examples of 3D surface investigation are shown below.
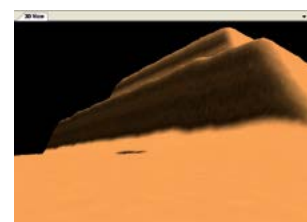

Texture overlay view.

Anaglyph view.

Contour overlay.

Surface walk mode.

Examples of surface visualization available in 3DSM.

Live mode

Live mode is a special mode in which 3DSM connects directly with SmartSEM®, the primary control software for Carl Zeiss Microscopy SEM microscopes. 3DSM will acquire frames from all four detector quadrants directly and perform a 3D reconstruction on-the-fly each time a frame set is completed. It is advised to operate 3DSM and SmartSEM® in parallel using two monitors or a widescreen monitor. This is because both applications should be visible at once in order to ensure maximum ease of use. An optimal arrangement is to use monitor one for SmartSEM® and monitor two for 3DSM.

Two monitors are recommended for operating 3DSM in live mode.

Before switching to live mode, the SEM should be adjusted to display a valid image using backscattered electrons. This requires the use of working distances in the range of 3-15 mm and EHTs ensuring backscattered electron detection (depending on detector diode type). Switching to live mode is done by a single mouse-click. 3DSM will adjust the remaining parameters automatically and update the 3D surface reconstruction after every frameset. Simply lean back and enjoy the show!

Limitations

The surface reconstruction method underlying 3DSM is the multi-detector method, utilizing the „shape from shading" principle. 3DSM uses gradation of grey-levels on the four input images to derive local surface geometry. This leads to a qualitative surface model under the following conditions:

■ The input images are free from artefacts such as charging or tunnelling effects
■ The input images do not show the shadowing effect
■ The sample is a continuous surface without overlapping objects

From the requirements listed above, the shadowing effect may cause problems on some classes of samples, displaying particularly steep slopes or vertical features. This means that the detector segments may not be screened from the flow of electrons by local surface topography.

To avoid the shadowing error, large working distances can be chosen, resulting in a larger backscattered electron acceptance angle. However, some structures with dominating vertical features may not be feasible to reconstruct to an accurate manner.

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Accuracy

3DSM allows SEM specimen surface reconstruction with a high resolution and accuracy, but only on condition that the input signals contain an undisturbed signal fulfilling backscattered electron distribution. The parameters for the system can be specified as follows:

- Maximum reconstruction angle is dependent on working distance and diode diameter. For working distance 6 mm and diode diameter 10 mm, the maximum angle is around 60°. If the slope exceeds this limit, then detector shadowing occurs.
- Lateral resolution and maximal lateral reconstruction error are limited only by SEM resolution and lateral image error.
- Reconstruction time is estimated to be below 1000 ms for acquisition size 1024x768 with surface texture.

Input images from the detector quadrants are the main condition for successful surface reconstruction. Most artefacts (such as charging) are easy to compensate for through proper sample preparation and using optimal SEM working conditions. The only unavoidable image error is shadowing, occurring for steep specimen slopes. In such cases surface reconstruction and visualization are still possible, however 3DSM cannot be considered as a metrology tool.

3DSM in forensics

One of many applications of 3DSM is analyzing firing-pin imprints left on bullets. The goal is to match the characteristic markings on bullets to conclude whether they were fired by the same gun or to pair a gun with a bullet. Until now, this type of research has been performed primarily in 2D. Carl Zeiss Microscopy scanning electron microscopes together with 3DSM add a whole new dimension to this area. The certainty level of bullet analysis is significantly increased owing to the possibility to image the 3D qualitative imprint rather than only the 2D outline.
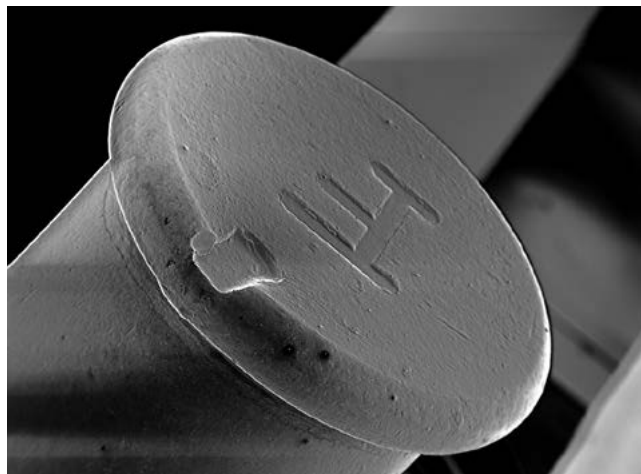
An imprint of the firing-pin left on a bullet.

Summary

3DSM adds a whole new level to scanning electron microscopy by allowing samples to be examined in three dimensions almost in real time. There is no further need for complicated stage tilting procedures. Simply find an object of interest, switch to Live mode and enjoy the show!

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