

## Micro-CT for SEM

- Nondestructive Measurement and Volume Visualization of Specimens' Internal Microstructure in SEM

# 3D Microscopy Using Micro-CT for SEM



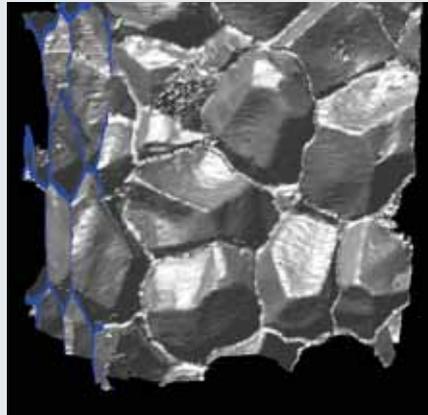
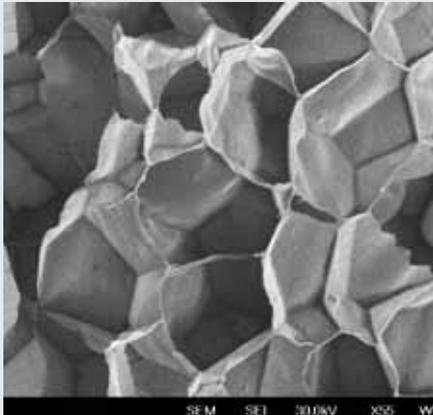
Micro-CT for SEM adds true 3D microscopy to your SEM – regardless of manufacturer and model. Micro-CT for SEM extends the surface information gained with conventional SEM imaging by allowing a unique insight into the specimen's internal microstructures – nondestructively and with ease of use.

## Micro-CT for SEM at a Glance

- Obtain information on a specimen's internal microstructure nondestructively and without any additional sample preparation
- Measure and visualize the internal morphology in 2D and 3D
- Generate realistic models for a virtual travel through a specimen
- Intuitive and easy-to-use software for 3D rendering, visualization as three orthogonal sections or as slice-by-slice movie
- Scanning volume is up to 4 mm in diameter, maximum sample length is 10 mm
- Details are detectable down to a size of 400 nm
- Precision rotation stage for high resolution images
- Direct detection X-ray cameras with 512x512 or 1024x1024 pixels
- Installable on any SEM with a free port of at least 65 mm in diameter

# Analysis with Micro-CT

## Standard SEM image and Micro-CT visualization



Left – The standard SEM image in SE mode displays the 3D surface of the object as a two-dimensional flat picture. Object: plastic foam. Right – The Micro-CT for SEM allows visualization and measurement of the true 3D internal microstructure of the object without any physical cut or additional preparation.

## True 3D microscopy

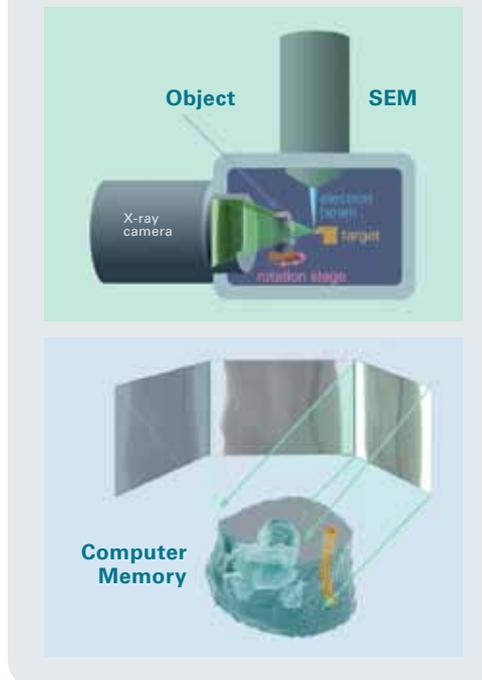
Micro computed tomography or “Micro-CT” is X-ray imaging in 3D, by the same method used in hospital CT (or “CAT”) scanners, but on a small scale with massively increased resolution. It really represents 3D microscopy, where the fine internal structure of objects is imaged nondestructively. The Micro-CT system will add a unique possibility to image and measure 2D/3D morphometry throughout the entire sample volume to your SEM, and to create realistic visual models for virtual travel within the object.

## Working principle

An electron beam in the SEM column hits a metal target and produces X-rays. This radiation is acquired by a sensitive X-ray camera mounted on a flange on the side of the SEM specimen chamber. An object is positioned on the precision rotation stage between the target and camera within the X-ray beam. During scanning, a computer controls the object rotation and acquires a number of angular shadow projections of the objects’ internal microstructure from the X-ray camera.

A special program back-projects all acquired shadow images of the object’s internal microstructure in the computer memory. The combined information from all angular projections

## Generation of internal microstructures



Top – Measurement configuration on a SEM; Bottom – back-projection of an object’s internal microstructure

corresponds to the complete internal 3D structure of the object obtained nondestructively. It can be displayed as virtual slices in any orientation or as a realistic three-dimensional visual model, which includes not only surface information (as in conventional SEM imaging), but also all internal object details.

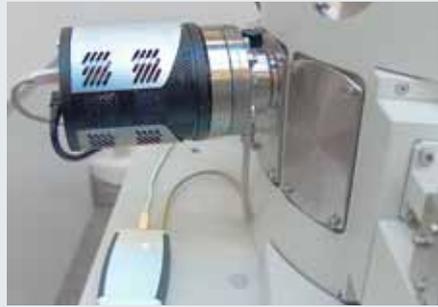
## The Micro-CT system

The Micro-CT system for SEM contains several modules to add a 3D imaging modality to any SEM without compromising standard imaging modes. The Micro-CT system does not require any changes to the standard SEM construction.

A microscanner contains the target to produce X-rays, an object rotation stage, and a motorized linear stage to vary the distance between the X-ray emission point and the object for adjusting the magnification of the X-ray images. The microscanner can be installed inside the specimen chamber in place of standard object holders.

A camera assembly is attached to the flange in the side wall of the specimen chamber. It contains an X-ray camera, a vacuum feed through for connection to the microscanner and a shutter with an alignment pattern. The camera assembly is connected to the microscanner controller, which takes power and receives commands from a USB port and controls all movement of the microscanner parts. The X-ray camera is also connected to the computer through a USB interface.

## Microscanner and X-ray camera



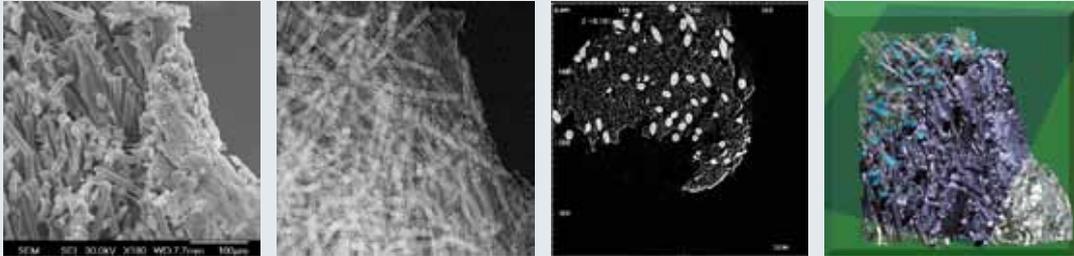
The Micro-CT system can be installed in any new SEM or retrofitted to old instruments. It works with any PC which has two USB 2.0 ports. A PC or laptop can be supplied optionally with preinstalled software.

## Micro-CT for any new or old SEM



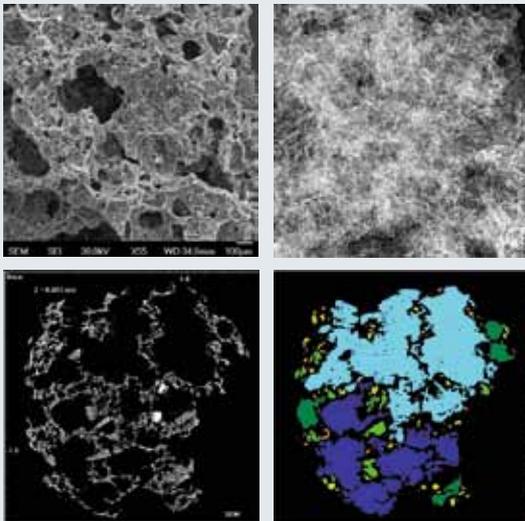
# A Wide Field of Application

## Composite materials



Glass fiber/epoxy composite material containing 10–12 micron fibers in an epoxy matrix. From left to right: 1) SEM image in SE mode; 2) X-ray image through this sample, acquired using the Micro-CT for SEM; 3) a virtual section, obtained nondestructively by Micro-CT for SEM; 4) a 3D model of the internal microstructure built from all reconstructed cross sections with a virtual cut on an inclined plane; all X-ray images have a pixel size of 705 nm

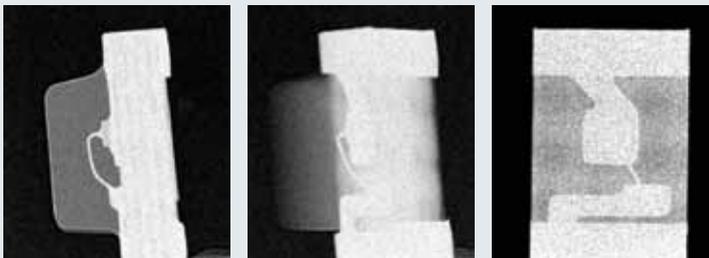
## Heat shielding ceramic



Top left – SEM image in SE mode  
 Top right – X-ray shadow image  
 Bottom left – a virtual slice (notice that true internal porosity is much bigger than seen on the SEM image)  
 Bottom right – 2D and 3D analysis of the internal porous space

Element	Symbol	Value	Unit
Aluminum	Al	0.0000000000	wt%
Barium	Ba	0.0000000000	wt%
Boron	B	0.0000000000	wt%
Calcium	Ca	0.0000000000	wt%
Carbon	C	0.0000000000	wt%
Chlorine	Cl	0.0000000000	wt%
Copper	Cu	0.0000000000	wt%
Fluorine	F	0.0000000000	wt%
Gold	Au	0.0000000000	wt%
Iron	Fe	0.0000000000	wt%
Krypton	Kr	0.0000000000	wt%
Lithium	Li	0.0000000000	wt%
Magnesium	Mg	0.0000000000	wt%
Manganese	Mn	0.0000000000	wt%
Nickel	Ni	0.0000000000	wt%
Oxygen	O	0.0000000000	wt%
Phosphorus	P	0.0000000000	wt%
Potassium	K	0.0000000000	wt%
Silicon	Si	0.0000000000	wt%
Sodium	Na	0.0000000000	wt%
Sulfur	S	0.0000000000	wt%
Titanium	Ti	0.0000000000	wt%
Zinc	Zn	0.0000000000	wt%

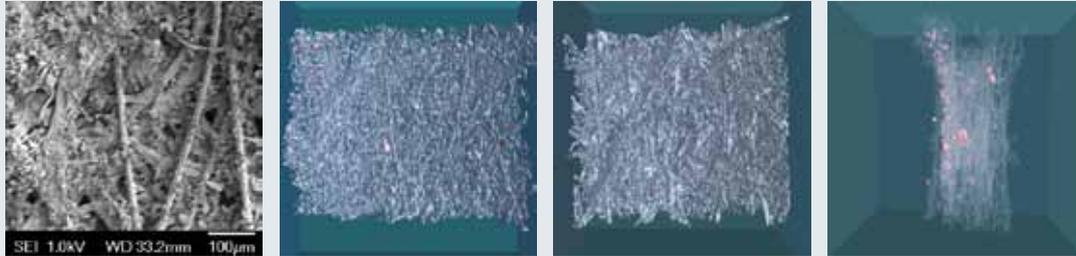
## Electronics



Several X-ray images through a small surface-mounted light emitting diode (LED) with a plastic lens and insulating body. The Micro-CT system for SEM includes a special cap to protect non-conductive objects from electron charge for imaging and slicing without any coating.

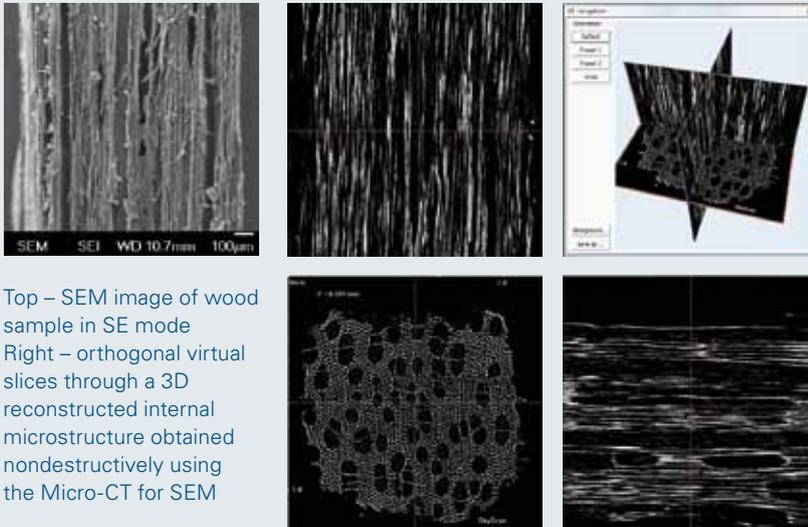


### Filter inspection



Used filter from a vacuum cleaner filled with dust particles. From left to right: 1) SEM image of the filter surface in SE mode. The other three images show the results of Micro-CT reconstruction where the filter material is shown in silver, and dense particles in red; 2) front view; 3) back view; 4) side view with semitransparent filter material; notice that most particles are absorbed within the front surface of the filter (figures 2 and 4) and cannot pass through the filter material

### Wood and plants



Top – SEM image of wood sample in SE mode  
Right – orthogonal virtual slices through a 3D reconstructed internal microstructure obtained nondestructively using the Micro-CT for SEM

### Dragonfly



Clasper-organs at the tip of the abdomen of an *Ischnura elegans* sample prepared with critical point drying, analyzed using a SEM with Schottky FE source. Top – X-ray projection image of the abdomen; Middle – Coronal virtual slice; Bottom – Volume rendered 3D model of the dragonfly created from reconstructed slices

### Paper

Left – SEM image of paper sample in SE mode  
Right – 3D model based on results obtained by the Micro-CT for SEM with a virtual cut by a plane in the top front of the sample.



# Easy-to-Use Software

The Micro-CT for SEM is supplied with a software package for Windows 7, Vista or XP, which includes a control program, 3D reconstruction, morphological analysis and realistic visualization tools.

Using a simple intuitive user interface, the control program for the Micro-CT for SEM acquires images from the X-ray camera, adjusts magnification and angular position of the object for X-ray imaging, collects a set of angular shadow projections through the object for 3D reconstruction and supports calibration of the camera and microscanner.

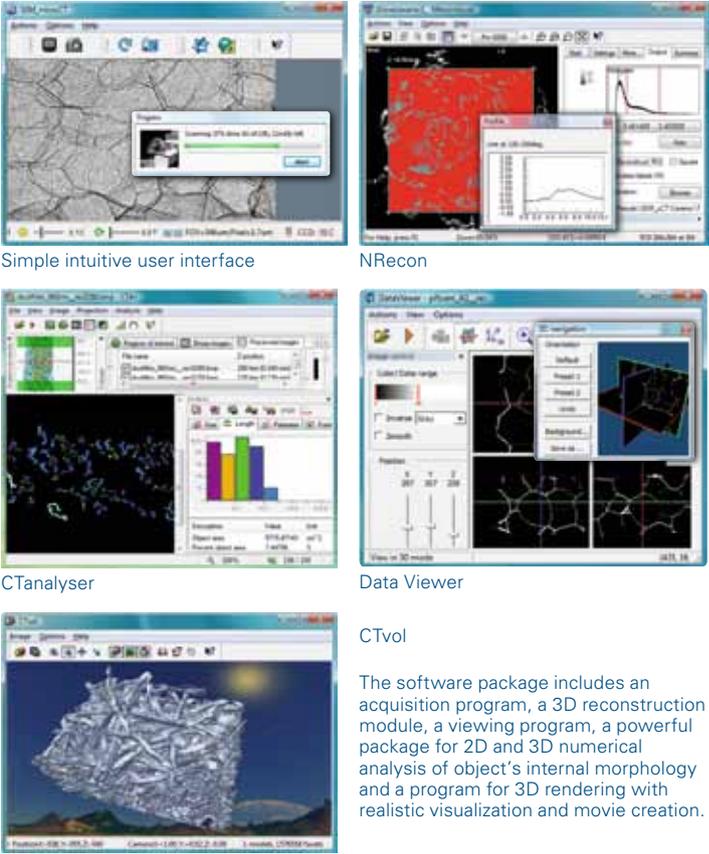
Volumetric reconstruction “NRCon” converts acquired angular projections into slices through the object. It provides misalignment correction, ring artifact suppression, volume of interest selection, reconstruction of objects larger than the field of view and density window adjustment.

The reconstructed set of slices can be flexibly viewed in the “Data Viewer” program. Images are displayed as a slice-by-slice movie or as three orthogonal sections, centered at any point inside the reconstructed space. You can add smoothing, save sagittal or coronal slices, measure distances and intensity profiles, turn the reconstructed object in any direction and save as alternatively oriented dataset.

“CTanalyser” analyses results for morphology and densitometry. The software features include:

- Loading datasets as .tif, .bmp and .jpg; angular resampling
- Advanced volume of interest (VOI) selection tool
- 2D/3D distances and angles measurements
- Image processing: e.g. smoothing and despeckling
- Morphological measurements in 2D and 3D, such as sizes, areas, perimeters, volumes, shapes, orientations, moments of inertia
- Automated batch analysis, adding user plug-ins

**Software components**



Simple intuitive user interface

NRCon

CTanalyser

Data Viewer

CTvol

The software package includes an acquisition program, a 3D reconstruction module, a viewing program, a powerful package for 2D and 3D numerical analysis of object's internal morphology and a program for 3D rendering with realistic visualization and movie creation.

“CTvol” (surface rendering) and “CTvox” (volume rendering) provide virtual 3D viewing environment, flexible and rich in features, to give you a wide range of options for 3D presentation of Micro-CT results.

- Movement and rotation of the object model(s)
- Selection of background including scenery
- Selection of viewing angle, light direction and color
- Control of object texture, color, transparency
- Cut models along a selected plane
- Semi-automated creation of animated “movies”

# Technical Specifications



<b>Nominal resolution</b>	400 nm – 8 µm pixel size (depends on magnification)
<b>Low-contrast resolution</b>	typically 800 nm
<b>Object size</b>	0.18–4 mm scanning diameter, 10 mm maximum object length
<b>Object manipulator</b>	precision rotation 0.45 deg min. step size; motorized zoom with feedback
<b>Manipulator controller</b>	microprocessor controller powered (with manipulator) from USB 2.0
<b>X-ray camera</b>	direct detection cooled CCD, 512x512 pixels or 1024x1024 pixels, 16-bit
<b>Integration time</b>	typical exposure time: 2–4 s, possible range: 0.5 to >100 s
<b>Required space on flange</b>	65 mm in diameter on any flange of the SEM specimen chamber
<b>Camera power supply</b>	100–240 VAC, 47–63 Hz, 1.9 A max. (power supply included)
<b>X-ray target material</b>	standard: Brass (8–9.6 keV), fixation for user-selected targets
<b>Required e-beam current</b>	typically more than 100 nA
<b>Connections to PC</b>	two USB 2.0 ports (two 5 m cables included); PC not included
<b>Environmental conditions</b>	15–30 °C (5–45 °C storage), <85 % humidity, no condensation

## The Micro-CT system includes the following standard parts:

- Microscanner for object manipulation within the vacuum of the SEM specimen chamber, with precision rotation stage and motorized zoom adjustment with sensor to measure magnification
- Camera assembly including X-ray CCD camera with Beryllium front window, connection flange with vacuum feed through for electrical connections to microscanner, alignment target, shutter, flanges and all necessary sealing components for mounting on the SEM specimen chamber
- Power supply unit for X-ray CCD camera with power cables
- Microprocessor controller for microscanner manipulation from computer through USB 2.0 port
- Two targets for microscanner to emit X-rays: short arm for high magnification imaging and long arm for scanning large objects
- Special cap with X-ray windows for imaging and scanning non-conductive objects without coating
- Two specimen stages, which allows mounting of a new sample whilst scanning the current one
- CD with control, reconstruction, analysis and visualization programs, all necessary drivers and electronic version of documentation and manuals

● **Bruker Nano GmbH**  
 Berlin · Germany  
 Phone +49 (30) 670990-0  
 Fax +49 (30) 670990-30  
 info@bruker-nano.de

[www.bruker.com/micro-ct-for-sem](http://www.bruker.com/micro-ct-for-sem)

**Bruker Nano**  
 Ewing, NJ · USA  
 Phone +1 (609) 771 4400  
 Fax +1 (609) 771 4411  
 info@bruker-nano.com

Sales representative:

