SkyScan 1275

- Fast, Automated, Desk-Top
  X-Ray Microtomograph

MICROTOMOGRAPHY

Innovation with Integrity

SkyScan1275 Fast, Automated, Desk-top X-Ray Microtomograph

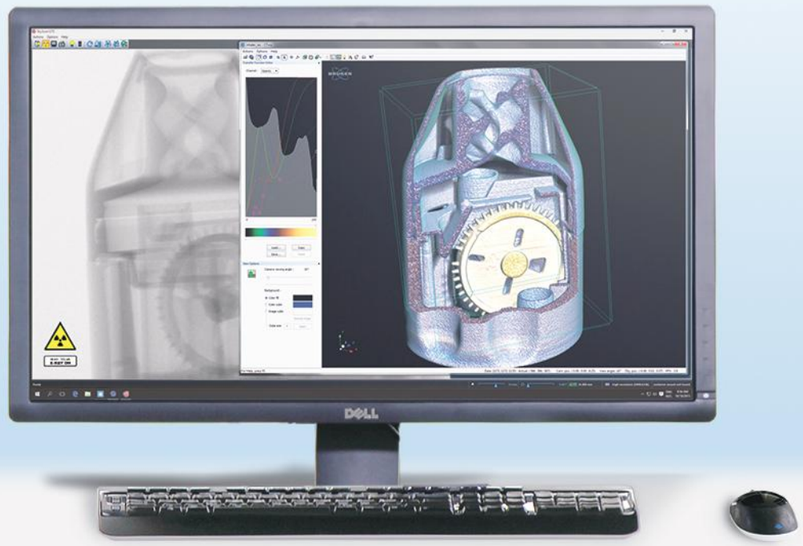
The SkyScan1275 is specially designed for fast scanning using new advances in the technology of X-ray sources and efficient flat-panel detectors. Shortening the distance between source and detector, and quick camera readout reduce scan time down to a few minutes without compromising image quality. Current developments in high-speed reconstruction accelerated by graphics cards give an additional gain in performance and speed. Realistic visualization of results by volume rendering enables fabulous imaging of internal object's microstructure with power to reveal all internal details by virtual cut or virtual flight around and inside the objects.

Fast scanning with high quality results is crucial for scientific research and industrial applications such as quality control or production process monitoring. The SkyScan1275 provides a high level of automation. Simple push of a button starts an auto-sequence of a fast scan followed by reconstruction and volume rendering executed during scanning of the next sample.

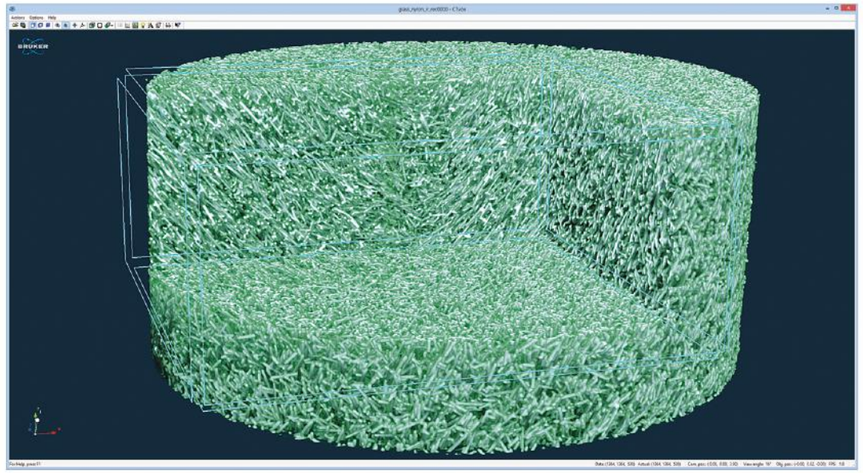
High Quality Results the Easy Way

- This highly automated micro-CT system allows pushbutton operation with a preselected sequence of actions including scanning, reconstruction and volume rendering.
- A wide range of X-ray energies 20-100kV, small spot size in the X-ray source and multiple filter options provide optimal scanning conditions for any particular application.
- This scanner accommodates a generous object size range up to 96mm in diameter and 120 mm in length to scan large samples including industrial parts and assemblies.
- The distortion-free flat-panel active pixel 3Mp detector includes a fiber-optic plate to ensure long lifetime and the highest reconstruction quality and accuracy.
- Shortest scanning takes only 80 seconds.
- GPU-accelerated 3D reconstruction supports all image formats with speed-up 5-10 times compare to conventional CPU-based reconstruction.
- The supplied software package includes programs for 2D/3D image analysis and realistic 3D visualization by surface and volume rendering, data export and volume rendering on mobiles.
- Optional stages for micropositioning and material testing support scanning of a sample under compression, tension, heating or cooling.
- The 16-position automatic sample changer (optional) accepts a mix of the samples with different sizes. The scanner can automatically select magnification according to a sample's size and shape. Scanned samples can be replaced at any time without interrupting an ongoing scanning process.

on the screen: 3D reconstruction of the interior of an inhaler obtained non-destructively by the SkyScan1275 system



Variaty of Applications

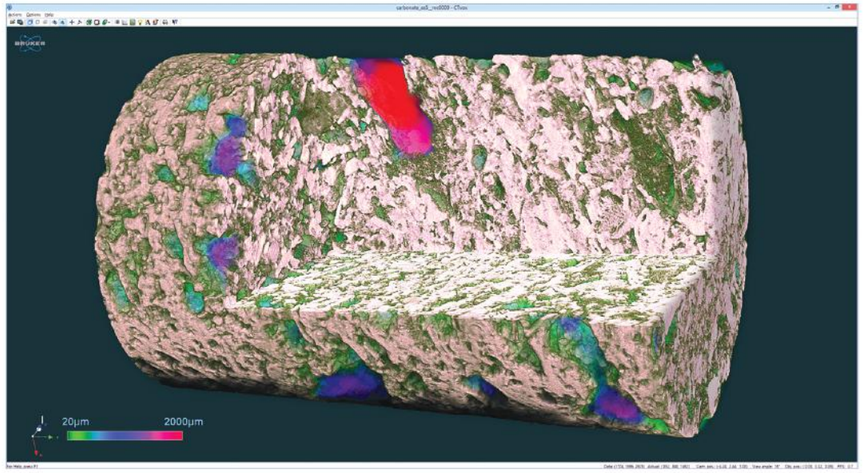


COMPOSITES

Volume rendering of
a rod of glass fiber
reinforced nylon.

The front top corner
is virtually removed.

3.8µm isotropic resolution,
1944x1944x538 pixels



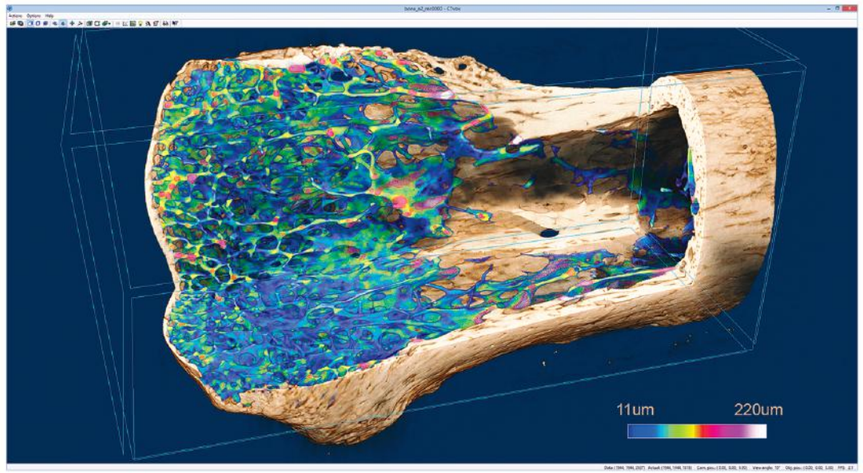
GEOLOGY
OIL/GAS EXPLORATION

Volume rendering
of the internal structure
in a carbonate.

The front right corner
is virtually removed.

Color coding of
local pore sizes.

20 µm isotropic resolution
1944 x1944x2925 pixels



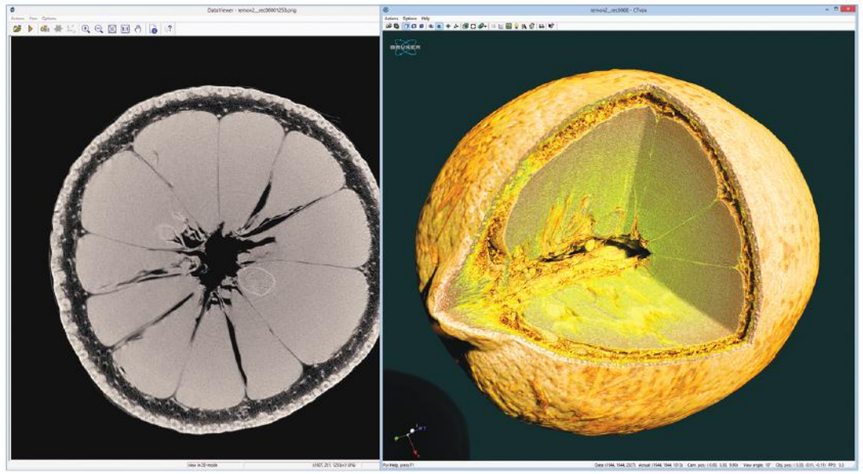
BONE

Volume rendering of the
structure inside a bone.

The left top corner is
virtually removed.

Color coding of local
trabecular thickness.

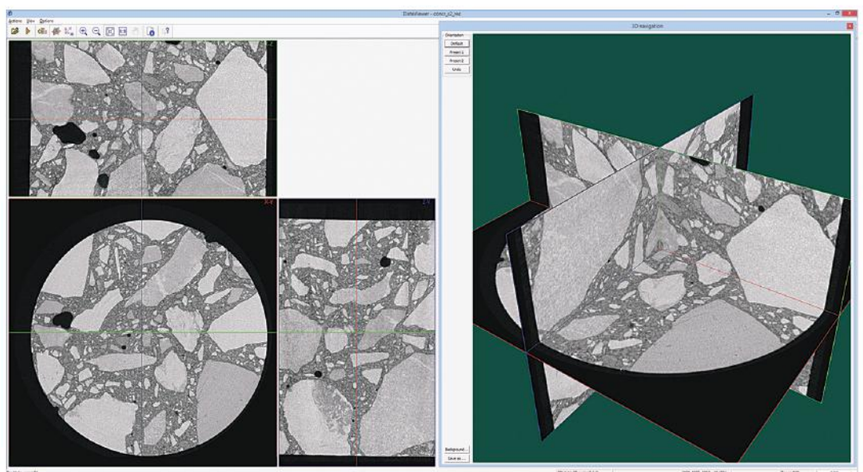
11µm isotropic resolution,
1944 x 1944 x 2637 pixels



FOOD

Reconstructed slice (left)
and volume rendering (right)
of the structure
inside a lemon.

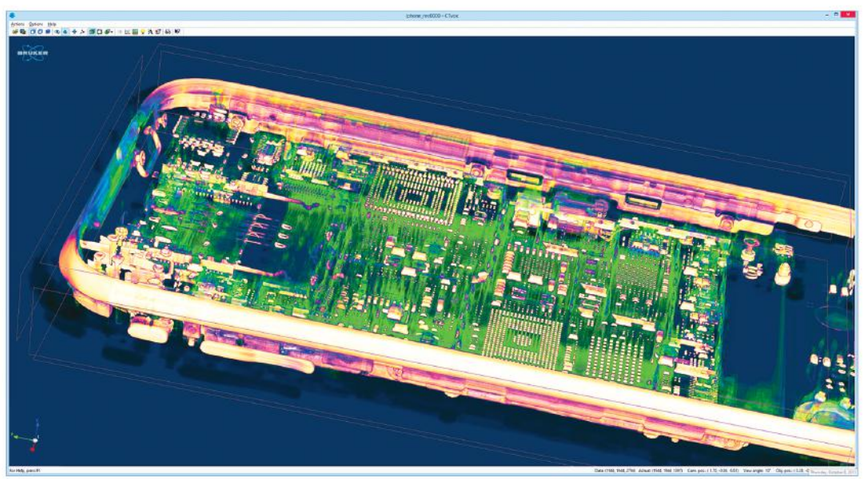
29µm isotropic resolution,
1944x1944x2650 pixels



BUILDING MATERIALS

Three orthogonal
virtual slices through
sample of concrete.

16µm isotropic resolution,
1944 x 1944 x 1135 pixels



ELECTRONICS

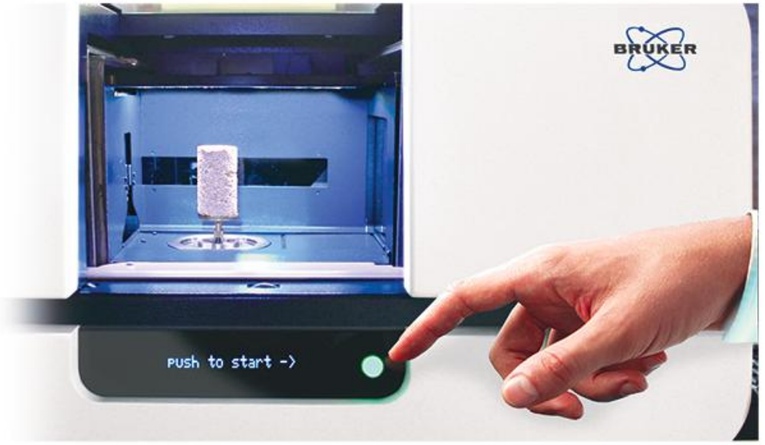
Volume rendering
of the internal structure
of a mobile phone.

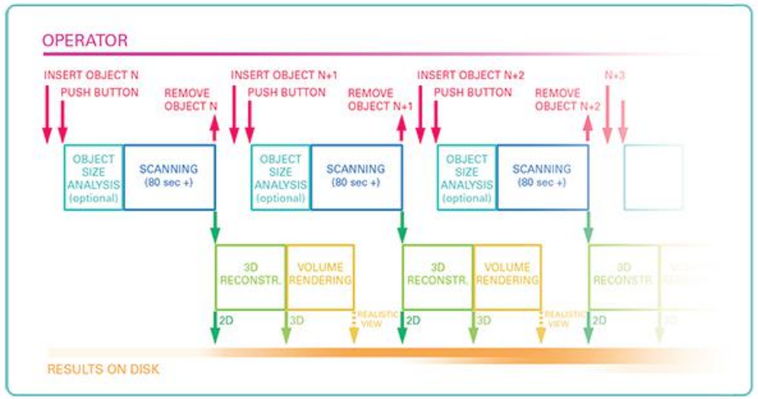
30µm isotropic resolution,
1944 x 1944 x 2794 pixels

Automated Scanning

PUSHBUTTON OPERATION SEQUENCE

The SkyScan 1275 can work either as a conventional micro-CT instrument with full flexibility available from the on-screen user interface or according to a preselected sequence of operations. The sequence can be initialized by simple touch of a pushbutton on the front of the system. The typical sequence includes automatic analysis of object size, corresponding selection of optimal magnification, a scanning cycle with distribution of results to incrementally indexed subfolders, 3D reconstruction with following displaying of results as three orthogonal slices intersecting at any point of the reconstructed volume or as a realistic 3D object created by volume rendering.



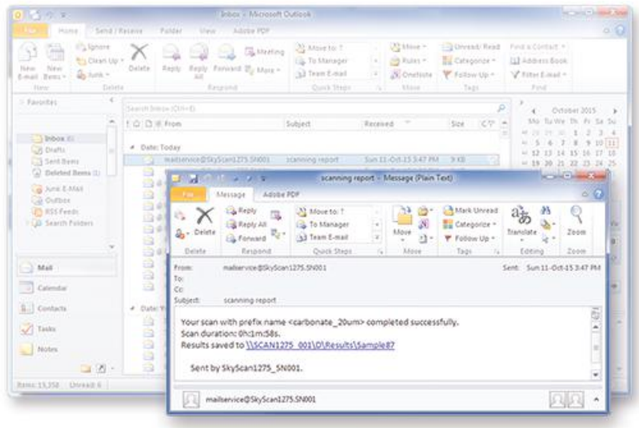


The pushbutton operating sequence doesn't require from the operator any interaction with keyboard or mouse and can be repeated multiple times. The reconstruction and visualization parts of the cycle run during scanning of the next sample. The sequence can be flexibly configured in advance for reconstruction and visualization parameters based on a predefined protocol or by repeating the reconstruction with the last selected settings.

AUTOMATIC E-MAIL REPORTING

The SkyScan 1275 control software can send you an e-mail at the end of a scan. The e-mail includes a direct link to the data folder containing the scan results. By a simply click on this link you can open the dataset directly. If the scanning process has been interrupted, the software will also e-mail you a report of the details.

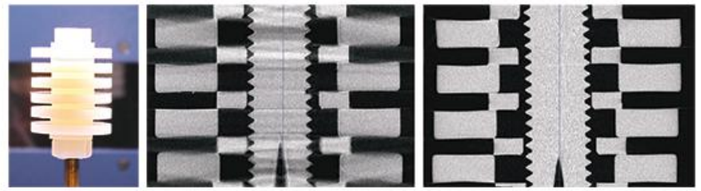
The e-mail notification can be flexibly configured according to local security rules for your IT infrastructure.



Helical (Spiral) and Circular Scanning Trajectories

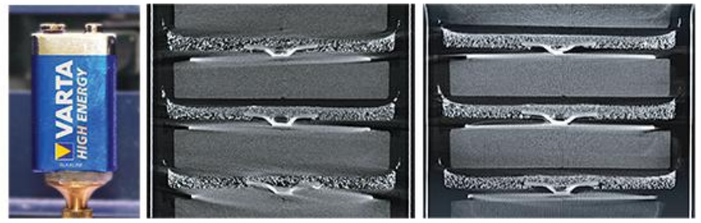
SCANNING AND RECONSTRUCTION WITH SPIRAL TRAJECTORY

The SkyScan 1275 can perform scanning of objects using circular trajectory when the object rotates during scanning to obtain different angular views and by spiral (helical) trajectory when the object simultaneously rotates and moves along the rotation axis during scanning. The supplied reconstruction program supports both scanning approaches and performs highly accurate 3D reconstruction from spiral (helical) scans. Using spiral trajectory allows coverage of long objects by a continuous scan and eliminates artifacts in reconstruction around flat surfaces perpendicular to the rotation axis. Such artifacts can be demonstrated in scanning and reconstruction of a special object, which contains a number of disks or washers perpendicular to the rotation axis (the so called "Defrise phantom"):



Central vertical slice through a Defrise phantom with a number of washers scanned and reconstructed using circular (left) and spiral (right) scanning trajectories

In practical cases when an object contains a number of flat parts perpendicular to the rotation axis, the above-mentioned artifacts in standard cone-beam reconstruction after scanning by a circular trajectory may fill the gaps between object parts and distort the shape of flat elements in the reconstructed images. Spiral scanning with highly accurate reconstruction avoids such distortion:



Central vertical slice through a 9V battery with multiple internal cells scanned and reconstructed using circular (left) and spiral (right) scanning trajectories

EXACT MATCH OF MULTIPLE PARTIAL SCANS

If an object doesn't contain big flat surfaces perpendicular to the rotation axis, standard scanning and reconstruction using circular trajectory produces high-quality results with shorter scanning time compared to spiral (helical) scanning. To cover long objects, SkyScan 1275 can perform multiple scans with round trajectories, which will be automatically connected during reconstruction to one continuous set of results. The reconstruction program supplied with the SkyScan 1275 contains a unique procedure for exact matching of any number of partial scans using positional and rotational fits, which makes junctions between partial scans practically invisible and artifact-free.

Result of reconstruction (central vertical slice) of a Vosges sandstone sample scanned using four partial scans automatically combined during reconstruction to a single continuous set of results.

Automatic Sample Changer

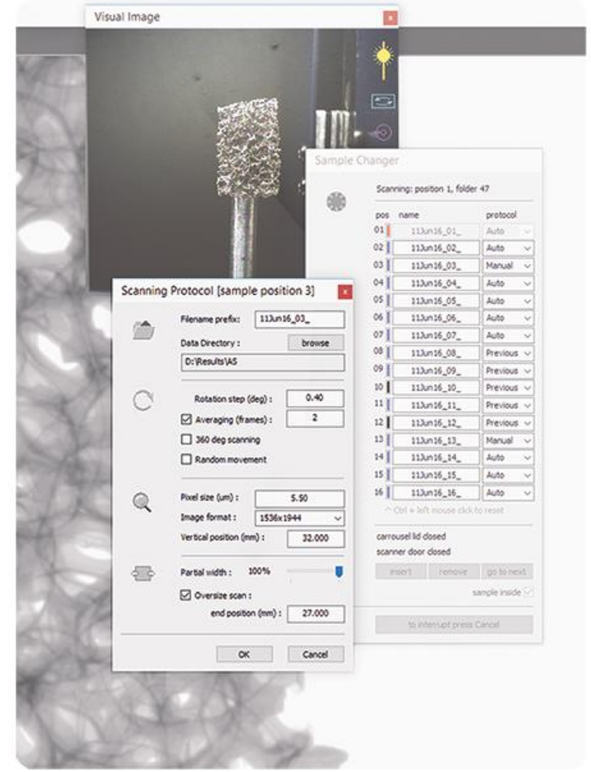
The optional automatic sample changer has 16 positions, which can be populated by samples with different sizes and shapes. It can accept 16 samples up to 50mm in diameter or 8 samples up to 96mm in diameter or any mixture of large and small samples. Maximum length of the samples is 80mm. The changer is located on top of the scanner, outside the shielded area. All scanned samples can be removed or replaced at any time without interrupting an ongoing scanning.

SAMPLE CHANGER CONTROL

The sample changer contains a motorized object carrousel, a robotic arm with multiple precision drives and a microprocessor controller for monitoring the object's presence and the scanning process. At every position on the object's carrousel, the scan status of the sample is indicated by a color illuminated bar: for newly installed objects waiting for scanning the bar has blue illumination, for already scanned objects the bar is green and for the position reserved for returning an object from the scanner the bar is red. An operator can replace scanned objects at any time without interrupting the scanning process. After scanning one object, the carrousel will turn to the position occupied by the next object waiting for scanning and the robotic arm will install the object into the scanner. A special sensor inside the sample changer identifies sample mounts with objects larger than 50mm in diameter to prevent collision with neighbors during return to the carrousel and to inform the control software of the possible range of magnifications.

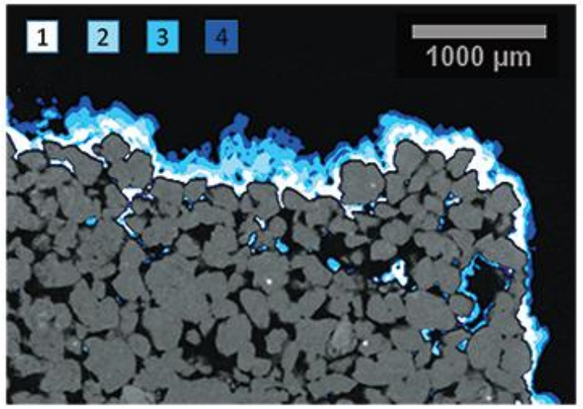
SCANNING PROTOCOL SELECTION

The scanning protocol for every sample can be adjusted individually. There are three possible selections of scanning protocols: manual selection, automatic selection and repeating scan parameters from the previous sample. In the case of manual selection, the operator can adjust all scan settings, filename prefix and data directory as in the shown screenshot. In the case of automatic selection of scanning protocol, the control software will firstly measure the size of a sample using the X-ray image at the lowest magnification in multiple angular positions. Afterwards it will adjust the optimal magnification for that sample where it will be fully inside field of view. Then it will start scanning and repeat the automatic adjustment process for the next object in the case of selection of automatic protocol adjustments. The automatic adjustment can be overwritten by the operator. Selection of the scanning protocol and filename prefix can be done at any time for any non-scanned object without interrupting the scan sequence. After installing the next object by the sample changer, the visual camera inside the scanner may take a "photo" of the object under scanning, which will be saved to the disk in the folder with all X-ray images. The control software can automatically distribute acquired datasets into folders with incremented names and update filename prefixes by automatically incremented indexes to avoid the necessity of individual selection of filenames and folders by the operator.



Time-Lapse Scanning, Metrological Calibration

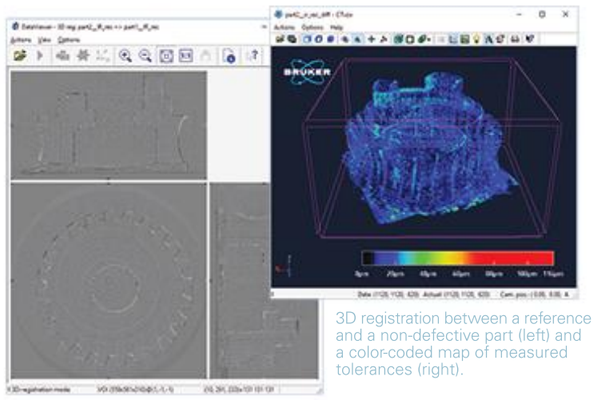
TIME-RESOLVED 4D-MICROROMOGRAPHY



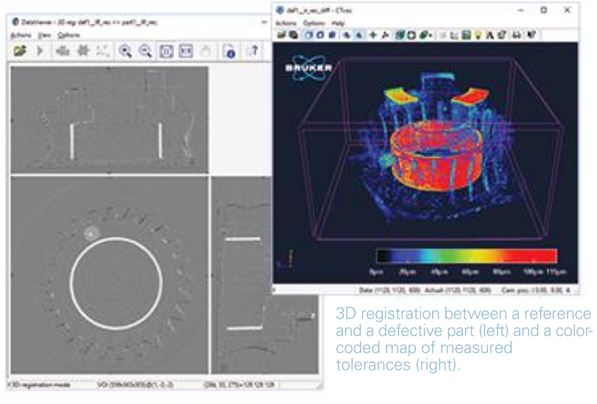
Evolution of salt crust formation during 16 minutes (4 scans with 4 minutes interval) in a sample of Bentheim sandstone.

Short scanning time in SkyScan 1275 allows the investigation of dynamic processes inside a wide variety of samples. With typical scanning time of a few minutes, multiple scans can be done during relatively short time interval. In some cases, such as drying or filling of porosity by fluids, the dynamic process can be done *in-situ* without removing the sample from the scanner. In other cases, the sample has to be removed to perform certain modification steps. After placing the sample back into the scanner, its position and orientation may be different from the previous scans, but results of the scanning can be automatically co-registered in 3D by supplied DataViewer program. After co-registration, the differential dataset can be extracted. It reflects differences in the sample structure happened in between of two consecutive scans. Multiple sets of reconstructed results can be displayed as a time-lapse sequence to reveal the dynamics of modifications in an object's internal microstructure

METROLOGICAL CALIBRATION, 3D MEASUREMENTS OF DIMENSIONS AND TOLERANCES



3D registration between a reference and a non-defective part (left) and a color-coded map of measured tolerances (right).



3D registration between a reference and a defective part (left) and a color-coded map of measured tolerances (right).

In the case of purchasing the SkyScan 1275 system for metrological purposes, the scanner can be factory calibrated to achieve high measurement accuracy. The calibration process includes scanning of several special phantoms previously certified in dimensions by independent measurements with subsequent exact adjustments of scanner calibration parameters. The first rectification of scanner settings is been done by scanning a 3-ball phantom and processing the results by special analysis software to calculate the exact settings for key calibration parameters of a particular scanner. Subsequent verification using a 9-ball phantom fine-tunes the scanner measurement accuracy.

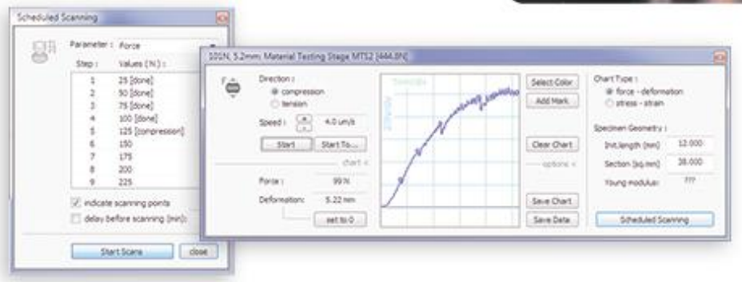
The properly calibrated scanner can now be used for measuring any dimensions of the scanned parts. In contrast to standard measuring techniques by optical or tactile methods, micro-CT allows measurement of not only external, but also internal dimensions of objects non-destructively. It helps to verify internal dimensions of 3D-printed parts with closed cavities, and to measure internal cracks or voids in a metal cast.

Dimensional measurement opens the possibility of quantifying sizes of internal defects and dimensional tolerances in manufactured parts. Once a reference object is scanned, other similar objects can be compared by automatic extraction of differences from the reference object. All external and internal differences can be quantified in size and correspondingly color-coded during visualization.

Stages for *In-Situ* Investigations

MATERIAL TESTING STAGES

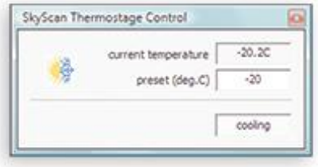
The material testing stage (MTS) applies controlled tension or compression symmetrically to both ends of an object. It keeps the central part in a static position allowing tomographic scanning under force. The loading curve is displayed on-screen in real time. An internal microprocessor controls the loading mechanics and the readout of displacement as well as applied force. An object can be held under specific load(s) during one or several micro-CT scans. The material testing stage is supplied with several sample chambers for objects up to 24mm in diameter and 24mm in length for compression or 20mm wide and 17 mm long for tension. Travel range is 11mm. The stage can be equipped with different load cells for maximum compression or tension force of 42N, 210N or 440N. The software for the material testing stage works in handshake with the main control software of the scanner to perform multiple scans with selected forces applied or at predefined deformations. A special version of the stage (MTS3) can apply 2200N or 4400N force with asymmetrical load (compression only, 5.5mm travel).



HEATING AND COOLING STAGES

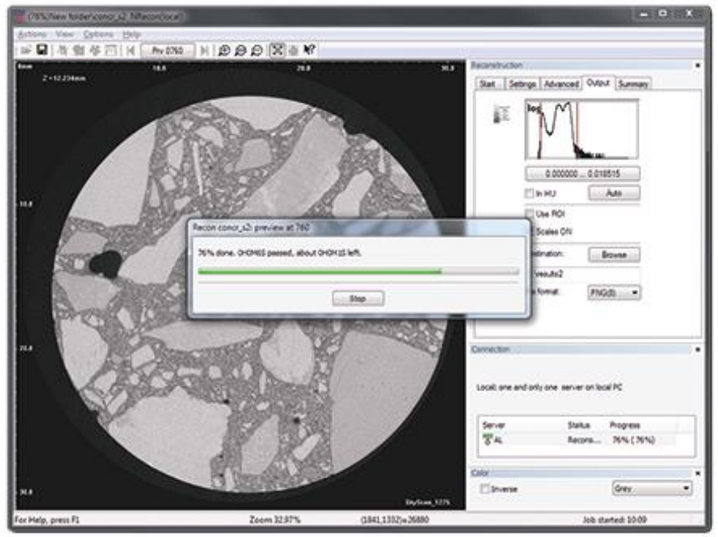
The heating and cooling stages provide environments for micro-CT scanning under controlled object temperature above or below ambient. The heating stage keeps an object at a temperature up to +85°C. The cooling stage keeps an object at sub-zero temperatures down to 30-40°C below ambient. An internal microprocessor controls a solid-state cooling or heating system and measures the object temperature with <1°C accuracy.

Like other stages for *in-situ* examination, cooling or heating stages are powered and controlled through a small connector at the top of the object stage. The power and control signals are connected to the static part of the scanner through special gold contact slip rings with low friction and high reliability in continuous rotation.



Software Suite for Reconstruction, Visualization and Analysis

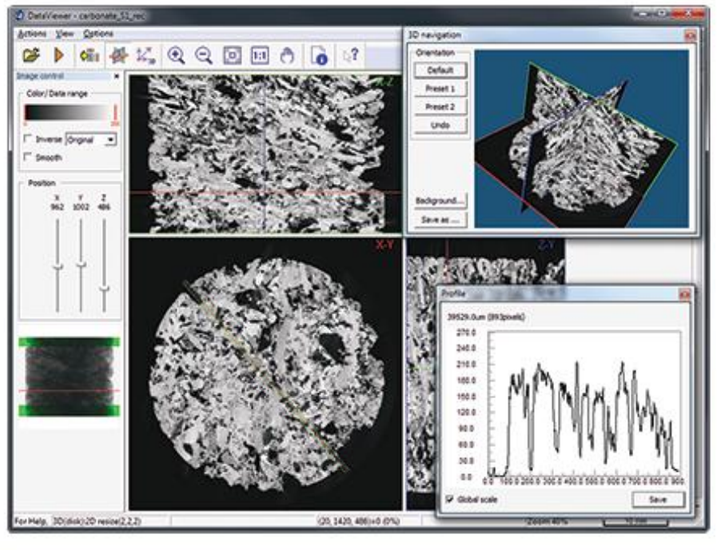
NRECON: GPU-ACCELERATED 3D RECONSTRUCTION



The supplied reconstruction program **NRecon** can run reconstruction for circular and spiral (helical) scans, supports beam-hardening correction, misalignment correction, ring artifact elimination, reconstruction of objects larger than field of view, automatic merging of partial scans, volume of interest reconstruction, drift compensation and many other options. The results can be saved in conventional formats, such as 16-bit TIFF, 8-bit BMP, 24-bit JPG, lossless compressed PNG as well as in DICOM format (compliant with the DICOM 3 convention). Additional **NRecon** features provide batch reconstruction of multiple datasets with individually adjusted settings, fine tuning of reconstruction parameters for best possible results, fifth order polynomial beam-hardening correction, and many other options.

The reconstruction engines supplied with **NRecon** utilize a filtered back-projection algorithm and can use computer processors (CPU) running on all available cores or employ graphics card processors (GPU) to accelerate reconstruction. The GPU-accelerated reconstruction uses a unique parallelization algorithm to support execution on multiple GPUs or several graphics cards in parallel.

DATA VIEWER: SLICE-BY-SLICE MOVIE, ORTHOGONAL VIRTUAL SLICES CROSSING AT ANY POINT



DataViewer shows reconstructed results as a slice-by-slice movie or as three orthogonal sections, intersecting at any selected point in the reconstructed space. One can rotate / resample the reconstructed volume in any direction. Additional features include the 4th dimension for time-resolved tomography, compression / tension and cooling / heating *in-situ* examination with the possibility to scroll over time, force or temperature changes inside the object. It also includes variable smoothing options, measuring distances in 3D with saving a table of results, and measuring intensity profiles.

DataViewer includes automatic co-registration of several datasets in position and spatial orientation and output of differential image data.

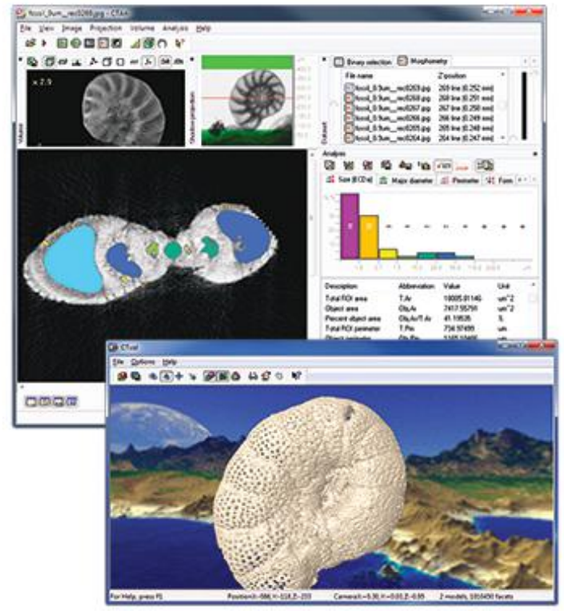
CTAN: 2D / 3D IMAGE ANALYSIS AND PROCESSING
CTVOL: REALISTIC VISUALIZATION BY SURFACE RENDERING

CT-Analyser or **CTAn** performs accurate and detailed study of micro-CT results for morphometry and densitometry. Powerful, flexible and programmable image processing tools deliver a wide range of segmentation, enhancement and measuring functions for analysis ranging from porosity to contact surface around high-density insertions in complex architectures. Versatile volume of interest selection tools are included. "CT-Volume" or **CTVol** uses surface triangulated models from **CTAn** and provides a virtual 3D viewing environment, flexible and rich in features, to give you a wide range of options for 3D presentation of micro-CT results.

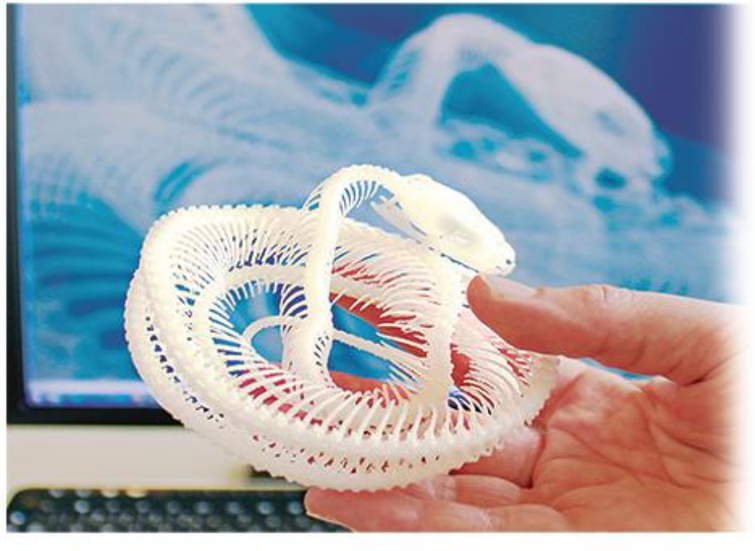
Main features of **CTAn** are:

- Import of dataset in tiff, bmp, jpg, png, DICOM, etc.
- Global, Otsu, multi-level and adaptive segmentation
- Advanced region/volume of interest selection tools
- Maximum and minimum intensity projections
- Measures 3D distances and angles
- Smooth, sharpen, despeckle, Boolean operations
- Analysis of all objects within VOI in 2D, 3D
- Parameters measured (in 2D and 3D):
  - Object (pore, particle, etc.) volume
  - Object surface
  - Structure thickness
  - Structure separation
  - Fragmentation index (trabecular pattern factor)
  - Euler number, eccentricity
  - Degree of anisotropy, eigenvalues, eigenvectors
  - Fractal dimension (Kolmogorov)
  - Moments of inertia (x, y, polar, product)
  - Detailed analysis of porosity
- Automated batch analysis
- Connection to user-created plug-ins
- Creating 3D models by several rendering algorithms
- Export triangulated models in STL and PLY formats

Full list of functions can be found at
bruker-microct.com/next/CTan_UserManual.pdf
bruker-microct.com/next/CTvol_UserManual.pdf



STL FILE EXPORT FOR 3D PRINTERS, FINITE ELEMENT ANALYSIS AND 3D CAD



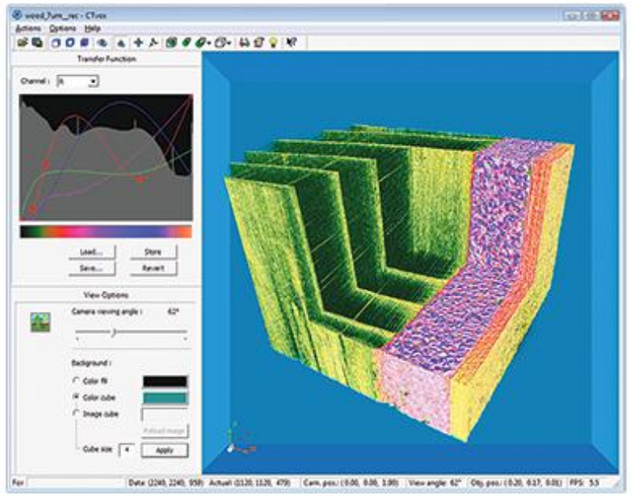
The **CTAn** / **CTVol** programs can create and visualize triangulated models of object surfaces. Such models can be saved in STL-file format. The STL-files can be sent to a 3D printer to build a magnified physical copy of the scanned objects using different materials.
By selecting of volume of interest in **CTAn**, the physical model may be partially opened to get access to internal object details.

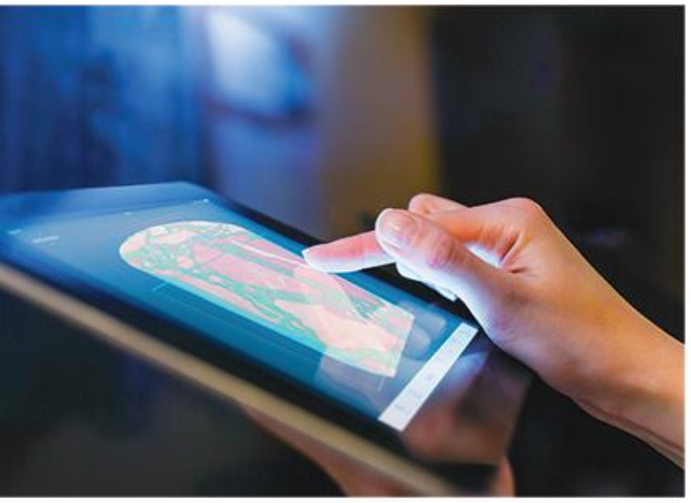
The STL-file format is also used as input information for FEA (Finite Element Analysis) software packages which analyze the impact of mechanical load on internal microstructure of objects. It is also a common file format for data import to 3D CAD software packages. Importing the scanned results to CAD packages opens possibility for direct comparison of a scanned object with a CAD model used to create the object.

Volume Rendering for Desk-Tops and Mobiles

CTVOX: REALISTIC VISUALIZATION BY VOLUME RENDERING

The volume rendering program **CTVox** displays reconstructed results as a realistic 3D object with intuitive navigation and manipulation of both object and camera, a flexible clipping tool to produce cut-away views, and an interactive transfer function control to adjust transparency and color. The lighting and shadowing with selection of material properties produces fully realistic visualization. A "flight recorder" function allows fast creation of "fly around" and "fly through" animations based on simple selection of several key frames with interpolation in between. Imaging possibilities include displaying multiple datasets obtained from the same or different objects or from the series of *in-situ* scanning during applying force or temperature variations.





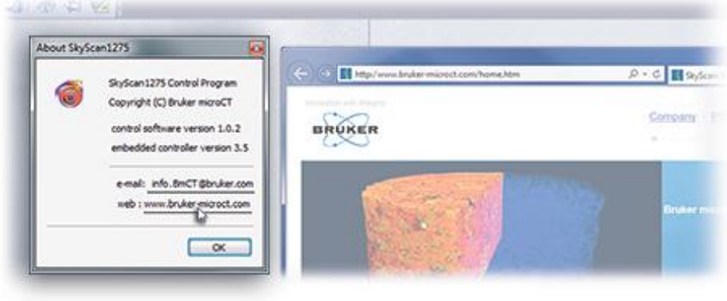
VOLUME RENDERING FOR MOBILES

The volume rendering program supplied with the system, **CTVox**, also has its mobile versions, which can be downloaded for free from the AppStore for iPhone and iPad or from GooglePlay for Android devices. Any 3D results obtained by the system can be sent to a mobile device for realistic visualization by real-time volume rendering with 3D object manipulation, adjustments of opacity and colors, virtual cut, etc.

The results can be sent through a cable connection or wireless network. The exported rendered data and color schemes are stored in the local memory of the mobile device and do not require any connection or downloading during manipulation. A large number of datasets can be loaded to the memory of a mobile device, allowing you to study reconstructed results while travelling, share them with colleagues and demonstrate them at meetings.

SOFTWARE UPDATES

All users of Bruker microCT instruments have unlimited free access to all software updates. New versions of control and application software can be downloaded from the bruker-microct.com website. To go to the Bruker microCT website, just click on the link in the "About" box in the control program. Using the other link in the same "About" box, the operator can send an e-mail with questions or requests to info.BmCT@bruker.com.



Comprehensive Training and Support

TRAINING COURSES

Bruker microCT offers a combination of both system and software training that covers three major topics: image acquisition, image reconstruction and data analysis/visualization. These 5-day courses are held several times a year at **Bruker microCT** headquarters in Belgium. The goal is to combine the basic theoretical background of microCT and hands-on experience. After installation of every system, new customers receive first initial training, and later advanced training either on-site or by course attendance, at the user's choice.

MICRO-CT ANNUAL MEETINGS

Bruker microCT also organizes the annual MicroCT Meetings in the form of a 3-day scientific conference with oral and poster presentations and best picture / best movie competition. The meetings include training workshops. Intensive exchange of knowledge and experience helps new and skilled users to find the way to get the best results from their microCT instruments.

Invitation to the next MicroCT annual meeting and abstracts from presentations in the previous MicroCT meetings can be found at www.bruker-microct.com

'BRUKER MICRO-CT ACADEMY'

The "Bruker microCT Academy" is an efficient educational network for the hundreds of groups who are using SkyScan instruments. It includes a monthly newsletter with application and technical tips and keeps users updated on new methods, developments and company news.

Through participation in the Academy our users gain access to a database with detailed application and technical notes and provide feedback with questions and suggestions for improvements of our instruments and software.

TECHNICAL SPECIFICATIONS

X-ray source	20-100 kV, 10 W, <5 µm spot size	
X-ray detector	3Mp (1944x1536) active pixel CMOS flat panel	
Nominal resolution (pixel size at maximum magnification)	<4 µm	
Reconstructed volume (after a single scan)	up to 1944 x 1944 x 1160 pixels	
Scanning space	96 mm in diameter, 120 mm in length	
Radiation safety	<1µSv/h at any point on the instrument surface	
Dimensions	1040W x 665 D x 400 H mm (590 H with sample changer)	
Weight	170 kg	
Power supply	100-240V AC, 50-60Hz, 3A	
Control workstation	Standard	Powerful
Processors	Dual 8-core Intel XEON	Dual 10-core Intel XEON
Memory (RAM)	64GB / 2133 MHz	128GB / 2133 MHz
Disk space (HDD)	8TB (RAID0)+512GB SSD	12TB (RAID0)+512GB SSD
Graphics	4GB NVIDIA Quadro	4GB NVIDIA Quadro
Monitor	24"LED LCD (1920x1200)	24"LED LCD (1920x1200)

Bruker microCT is continually improving its products and reserves the right to change specifications without notice.

www.bruker.com ● **Bruker microCT**

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