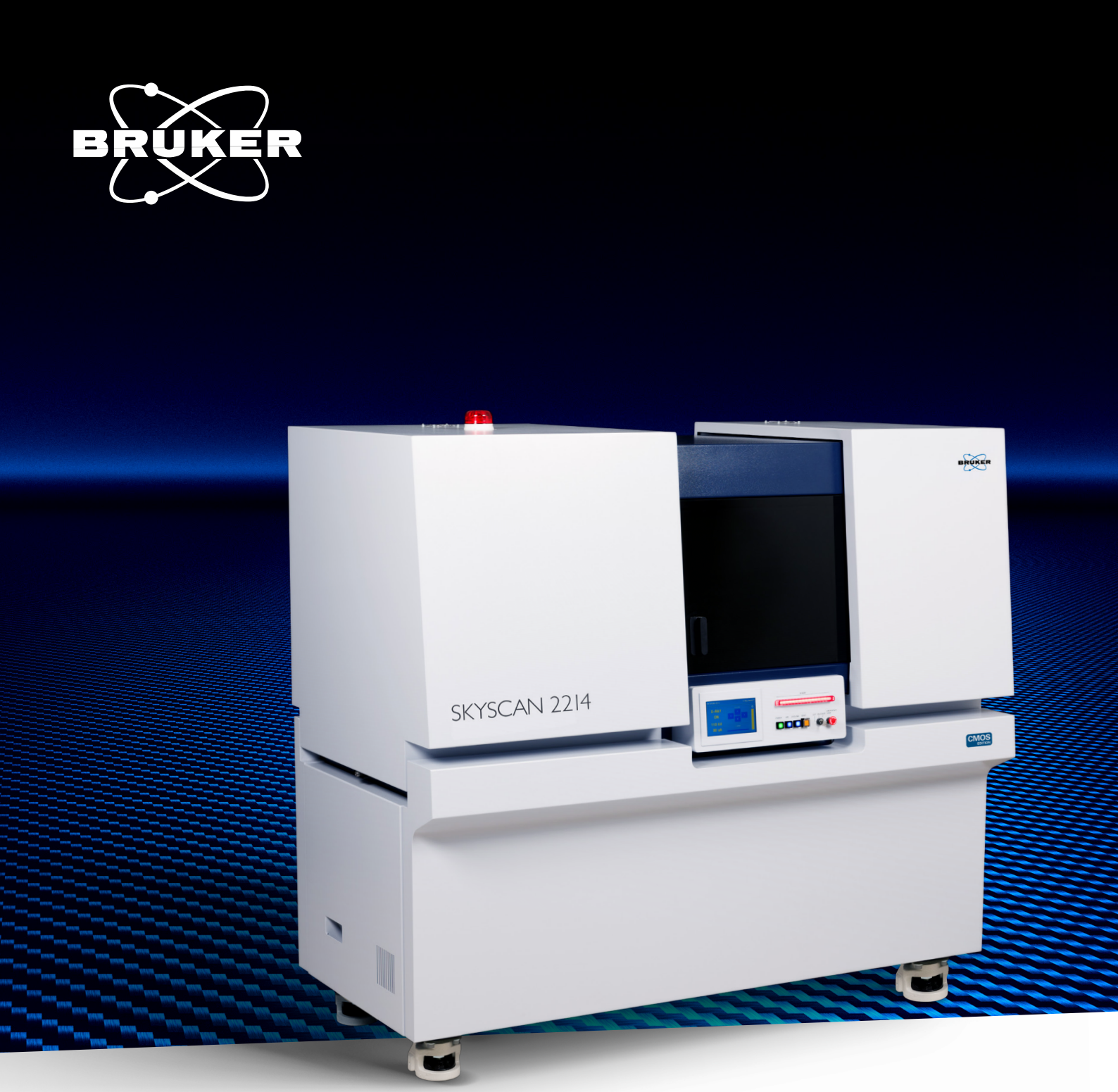



3D X-RAY MICROSCOPY

# SKYSCAN 2214 CMOS Edition

Bigger. Brighter. Bolder.

Innovation with Integrity

# SKYSCAN 2214 CMOS
## Multiscale High-Resolution X-Ray Microscope

3D X-ray Microscopy (3D XRM) is one of the most advanced methods of gaining 3D insights into samples of any material, shape, or size with little to no sample preparation.

SKYSCAN 2214 is the flagship X-ray microscope from Bruker, a pioneer in XRM technology. This XRM solution uniquely pairs top-notch resolution with prime versatility and best-in-class ease-of-use. Designed as a future-proof platform, the CMOS Edition now incorporates the latest X-ray detector technologies to bring XRM to the next level.

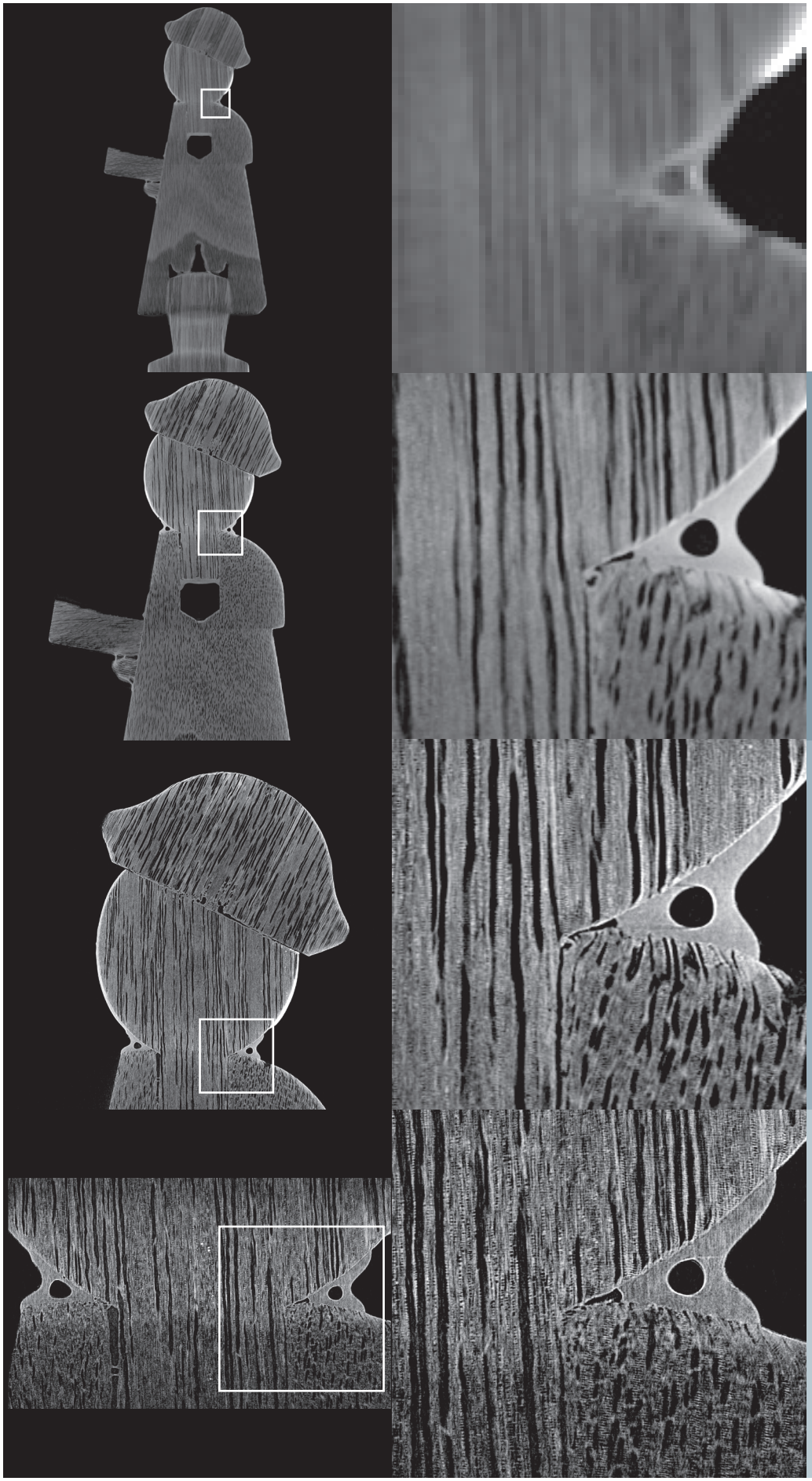
SKYSCAN 2214 CMOS Edition – Bigger. Brighter. Bolder.



# SKYSCAN 2214 CMOS

## State-of-the-Art X-Ray Microscope with Unrivalled Versatility





**Flat-Panel**

Provides ultimate FoV to image the entire internal 3D structure, e.g. how the head is mounted to the body

**Large format sCMOS**

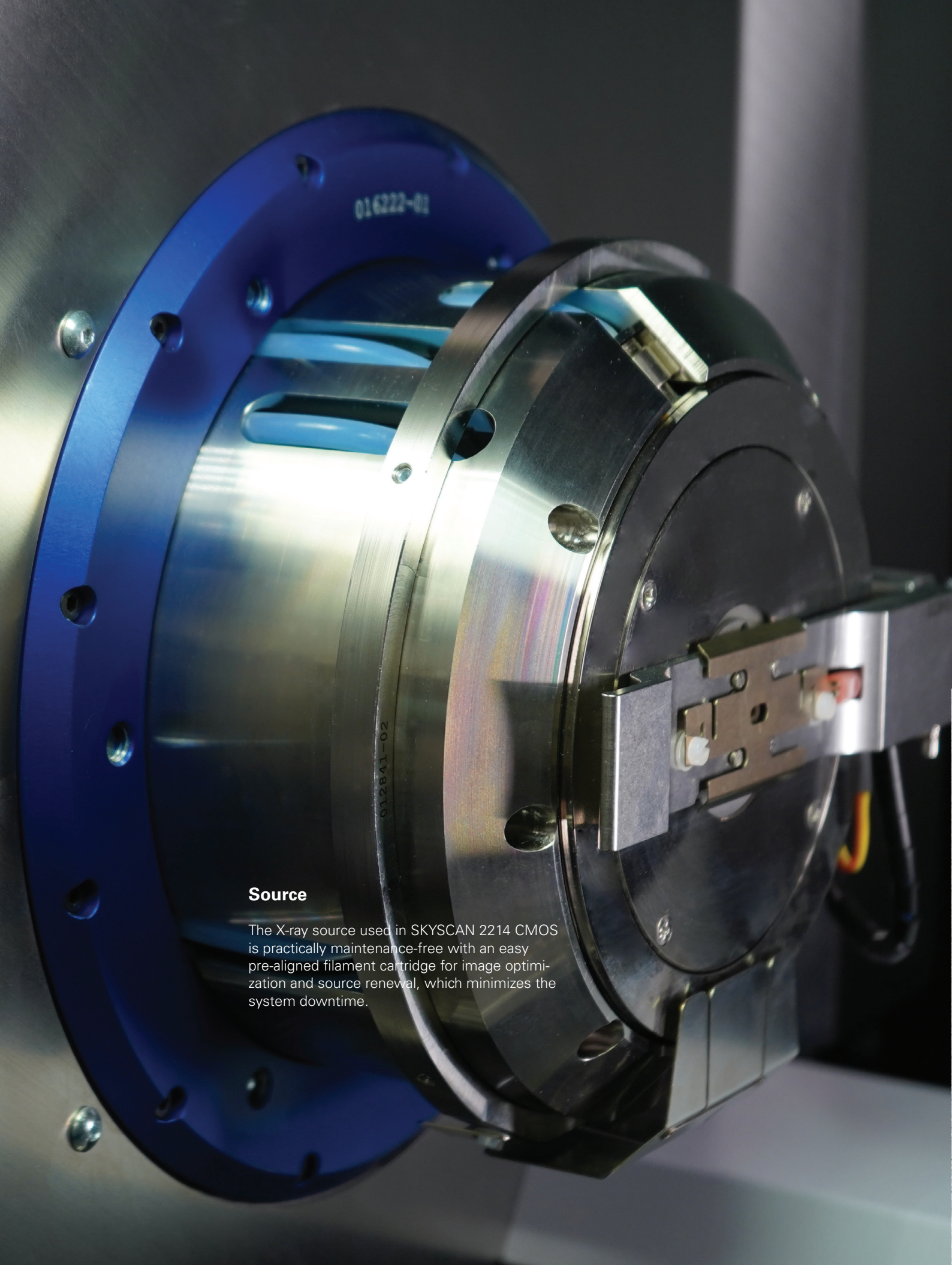
Improves resolution while maintaining a large 3D FoV. E.g. provides more clarity at the statue neck interface and coating on the head

**Standard sCMOS**

Provides a good balance between high resolution and 3D FoV. E.g. structural details of the hat-head interface become visible

**High-Res sCMOS**

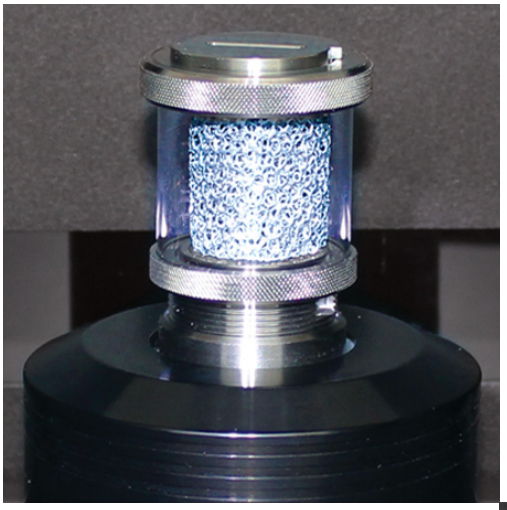
Provides highest resolution resolving the finest fibrous wood structures




## Source

The X-ray source used in SKYSCAN 2214 CMOS is practically maintenance-free with an easy pre-aligned filament cartridge for image optimization and source renewal, which minimizes the system downtime.

# Large Chamber Accommodating Big Samples and Optional Stages

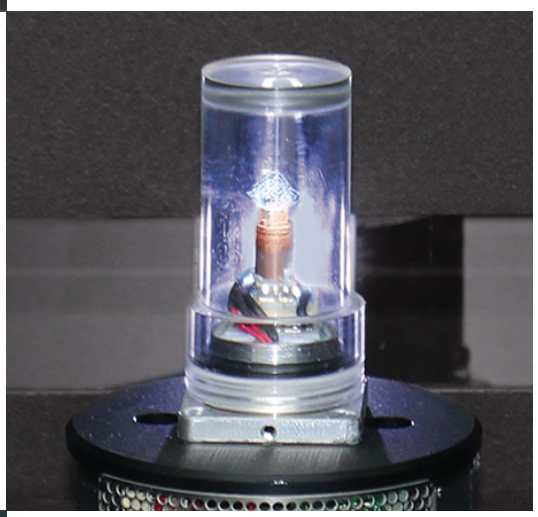


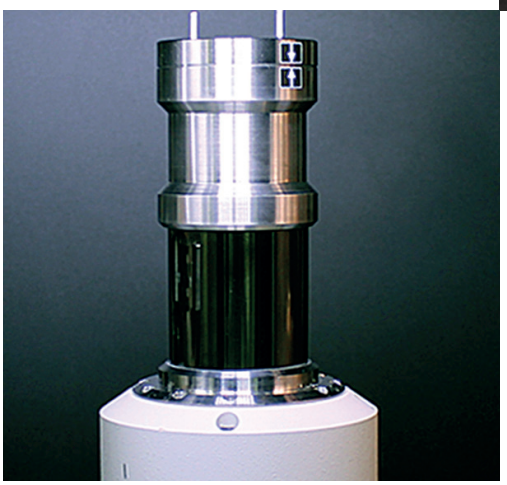
## Material testing stages

The Bruker material testing stages are designed to perform compression experiments up to 4400 N and tensile experiments up to 440 N. All stages automatically communicate through sliprings in the rotation stage, without the need of cable connections. Scheduled scanning experiments can be set up in the acquisition software.

## Cooling / Heating stage

Samples can be examined under non-ambient conditions to evaluate the effect of temperature on the sample's microstructure. Bruker's heating and cooling stages can reach temperatures of up to 80 °C, or 25 °C below ambient temperature. Like the other stages, no extra connections are needed, and the stage is automatically recognized.





## Deben stage

SKYSCAN 2214 CMOS can also accomodate third party solutions as for example supplied by Deben UK Ltd. These stages can be simply mounted on the rotation stage with an included adapter.

In case of the Deben CT5000 RT communication also goes throught the rotation stage without the need of external cables.

# SKYSCAN 2214 CMOS and 3D.SUITE
## an Impressive Powerpack

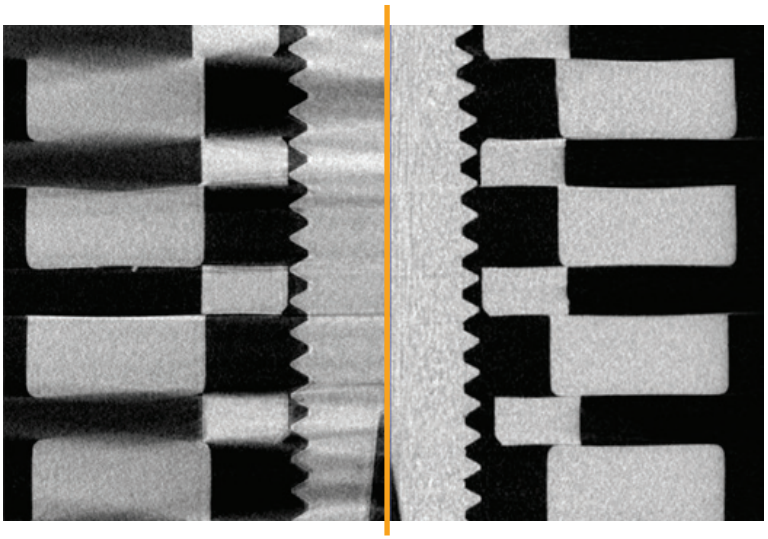
Intuitive, simple, yet powerful – the 3D.SUITE software that comes with every SKYSCAN 2214 CMOS is designed to inspire finding out what's inside. Even a novice user can intuitively start scanning right away. Yet as flagship solution SKYSCAN 2214 CMOS offers many advanced capabilities.

Special scan algorithms are by default included to ensure the best image quality can be obtained in the shortest time. Reconstruction with NRECON readily transforms the 2D projection images into 3D volumes thanks to the supersonic GPU acceleration, no matter how large the image size. Advanced phase retrieval algorithms can reveal features that would remain hidden when using only standard absorption contrast.

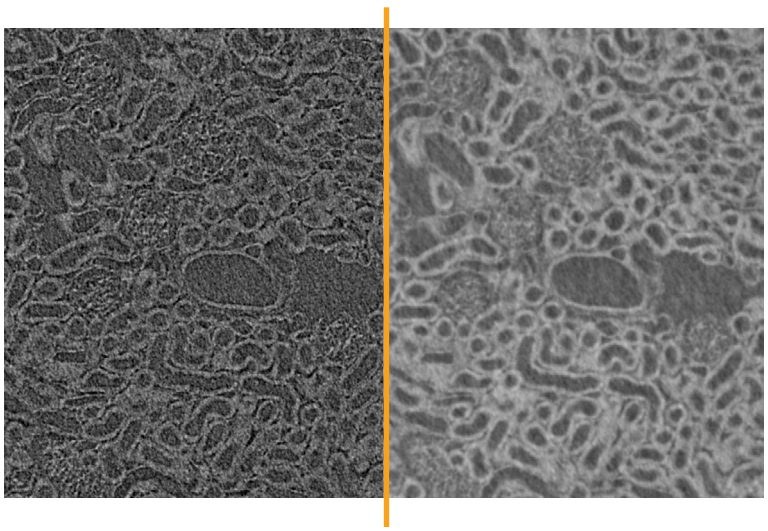
3D.SUITE further includes all advanced software capabilities needed for 3D inspection, visualization, and analysis.

### Special scan and reconstruction algorithms

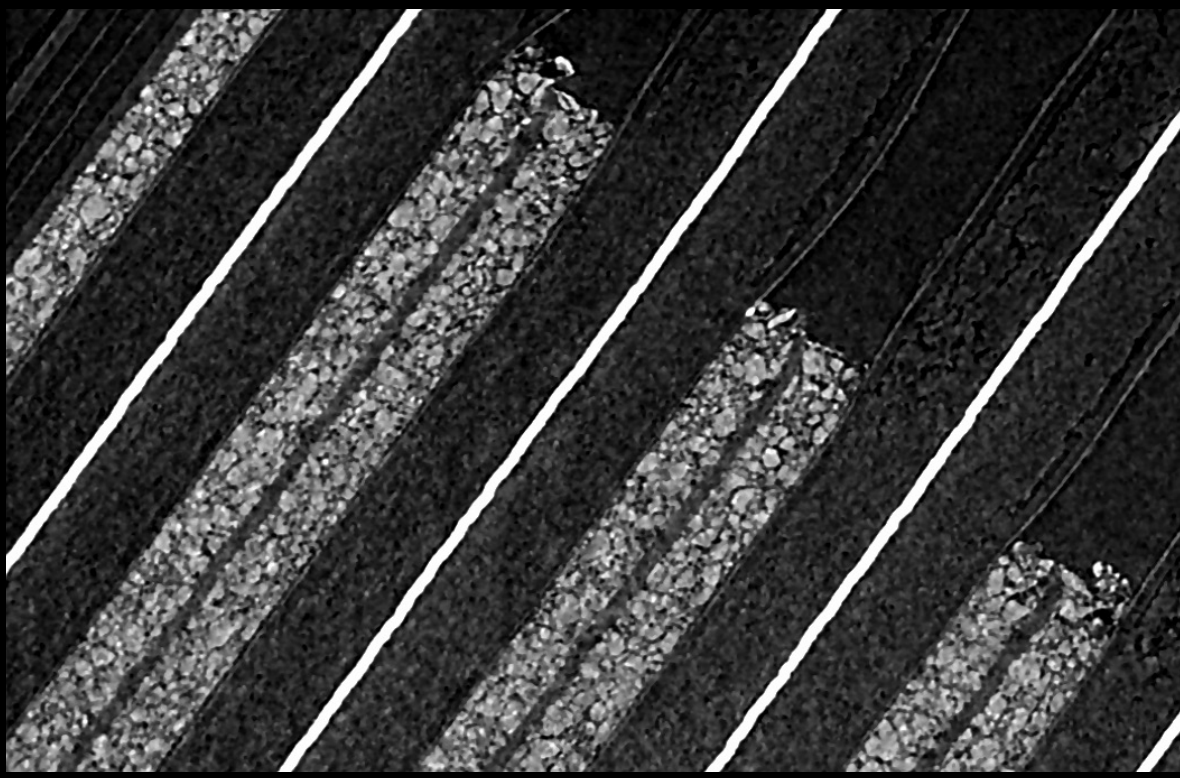
- Helical scanning for objects with planar structures perpendicular to the rotation axis
- Oversized and offset scanning for objects exceeding the detector FoV
- HART Plus scanning for high aspect ratio objects
- Time-resolved, in-situ scanning to follow dynamic processes (4D XRM)
- Advanced phase retrieval algorithms reveal features that remain hidden when using only absorption contrast



Reconstructed slice image of a Defrise phantom
(left) standard scan with FDK reconstruction
(right) helical scan with exact reconstruction



Reconstructed slice image of a kidney, scanned at 700 nm
(left) absorption contrast
(right) phase retrieved contrast

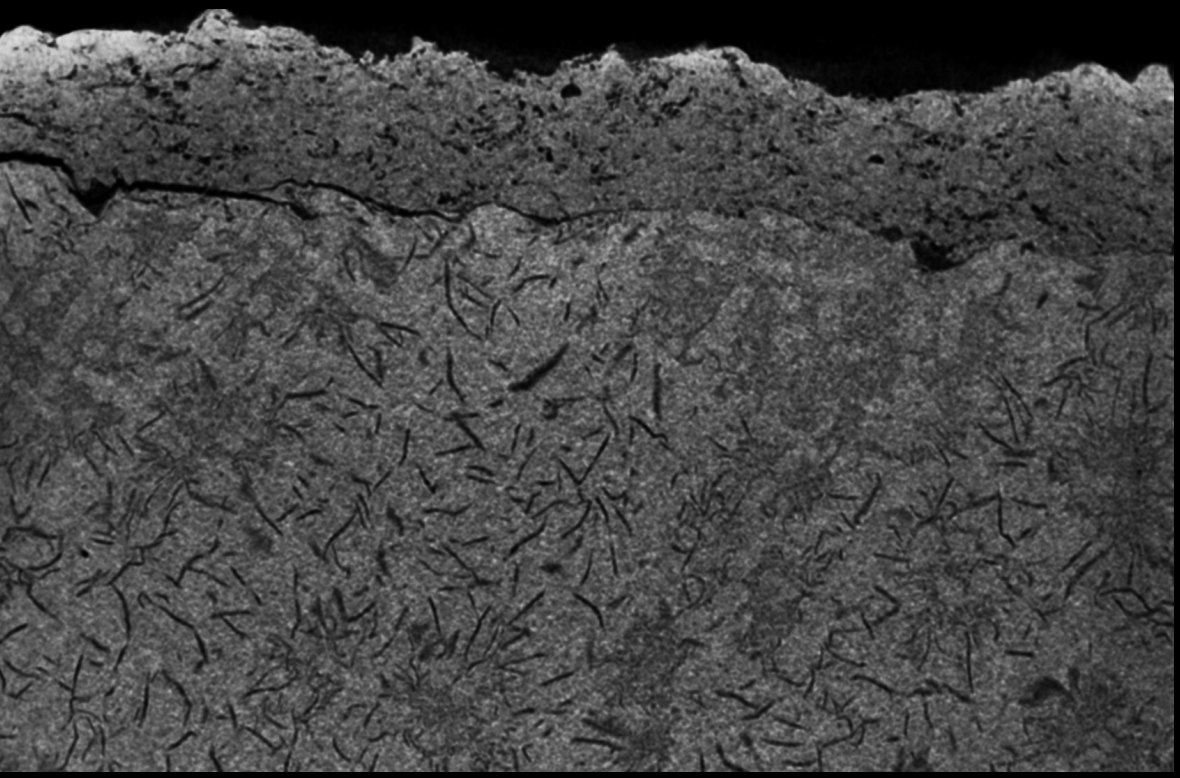


Prismatic Li-ion pouch cell scanned at 1 micron voxel size.



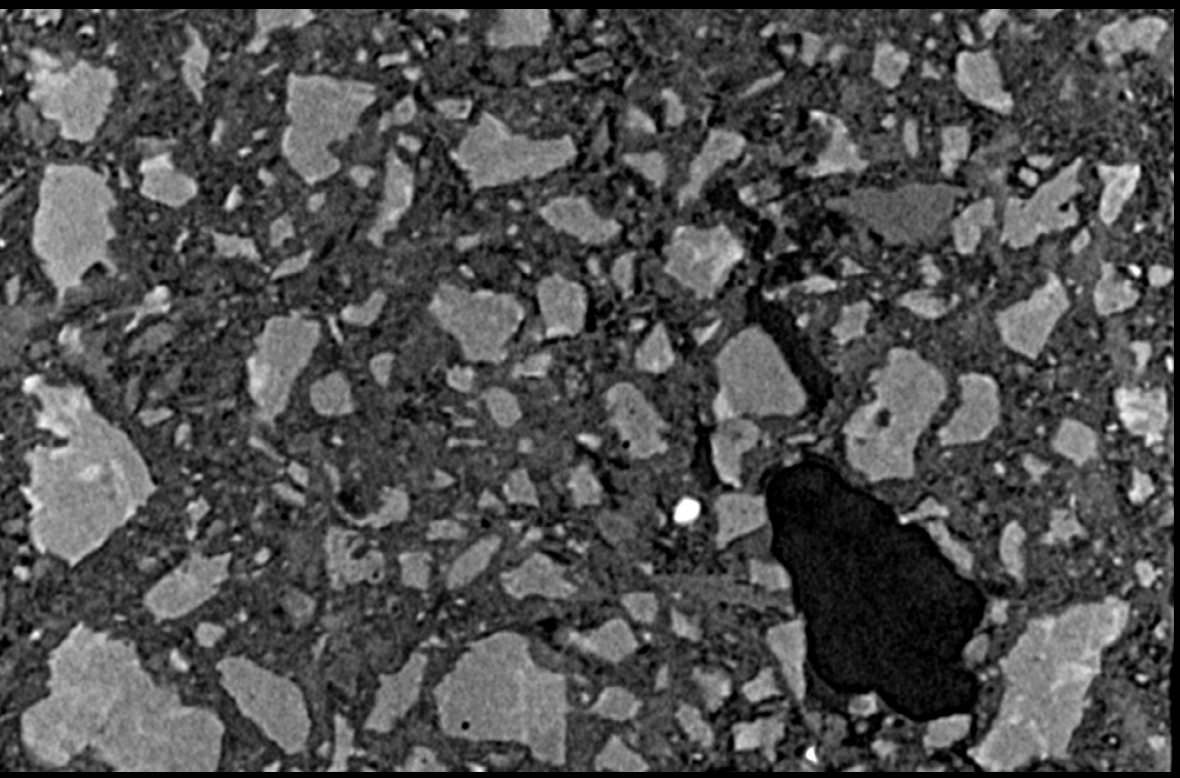
Drosophila abdomen (Fruit fly abdomen), osmium tetroxide stained and imbedded in resin, 420 nm voxel size.

# SKYSCAN 2214 CMOS
## Image Quality That Speaks For Itself



Lamellar cast iron with thermally sprayed coating scanned at 650 nm. The martensitic fine structure can be well distinguished in the bulk.

*Sample courtesy of Dr. H. Hoche, Technical University Darmstadt.*



Hydrated cement in capillary scanned at 220 nm.

*Sample courtesy of Prof. M. Aranda, Malaga University.*

## Polymers & Composites

- Resolve fine structures with <500 nm true 3D resolution
- Assess microstructural architecture and porosity
- Quantify defects, local fiber orientation, and thickness

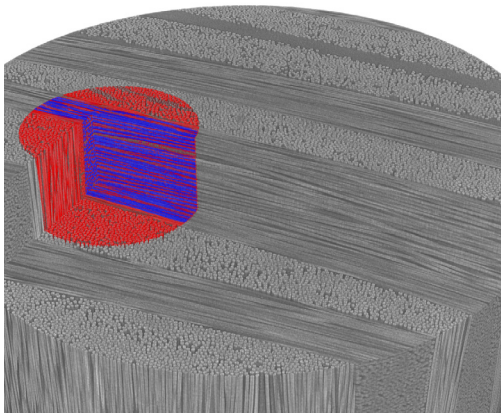


**Figure 1**
CFRP scanned at 300 nm voxel size. Volume rendered 3D model with color coded local fiber orientation.

## Energy Storage

- Non-destructive 3D imaging of batteries and fuel cells
- Quantify defects
- Operando experiments monitoring structural changes over time

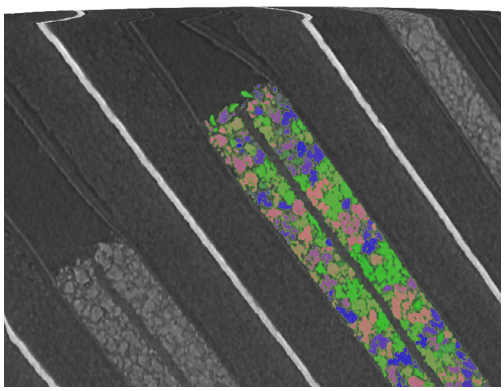


**Figure 2**
Lithium-ion pouch cell scanned at 500 nm voxel size. Volume rendered 3D model with segmentation of the individual cathode particles.

## Foam

- Quantify porosity, pore network, and local thickness in 3D
- Apply in-situ analysis of mechanical properties and dynamic processes
- Detect inhomogeneities and deviations in the printing process

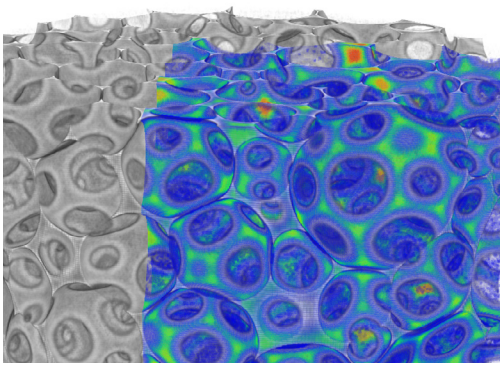


**Figure 3**
Foam scanned at 500 nm voxel size. Volume rendered 3D model with color coded struth thickness.

## Life Science

- Resolve structures with true submicron resolution, e.g. soft tissues, bone osteocytes, and dentinal tubules
- Artifact-free imaging of osteointegration of biomaterials and high density implants
- High-resolution characterization of biological samples, e.g. plants and insects

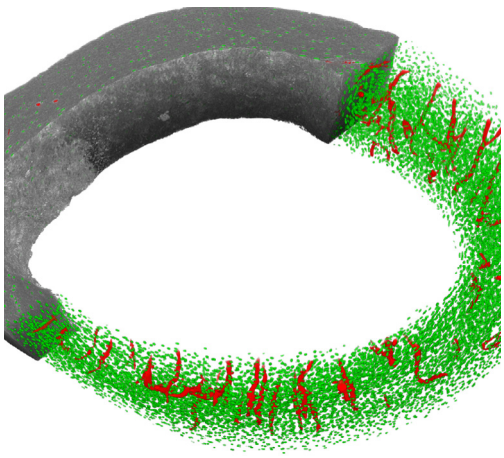


**Figure 4**
Mouse proximal femoral cortical bone scanned at 600 nm voxel size. Osteocyte lacunae (cell spaces) are colored in green and blood vessel canals in red.

*Courtesy of Dr Sam Stephen, Rensselaer Polytechnic Institute, USA.*



## High-Precision Object Stage

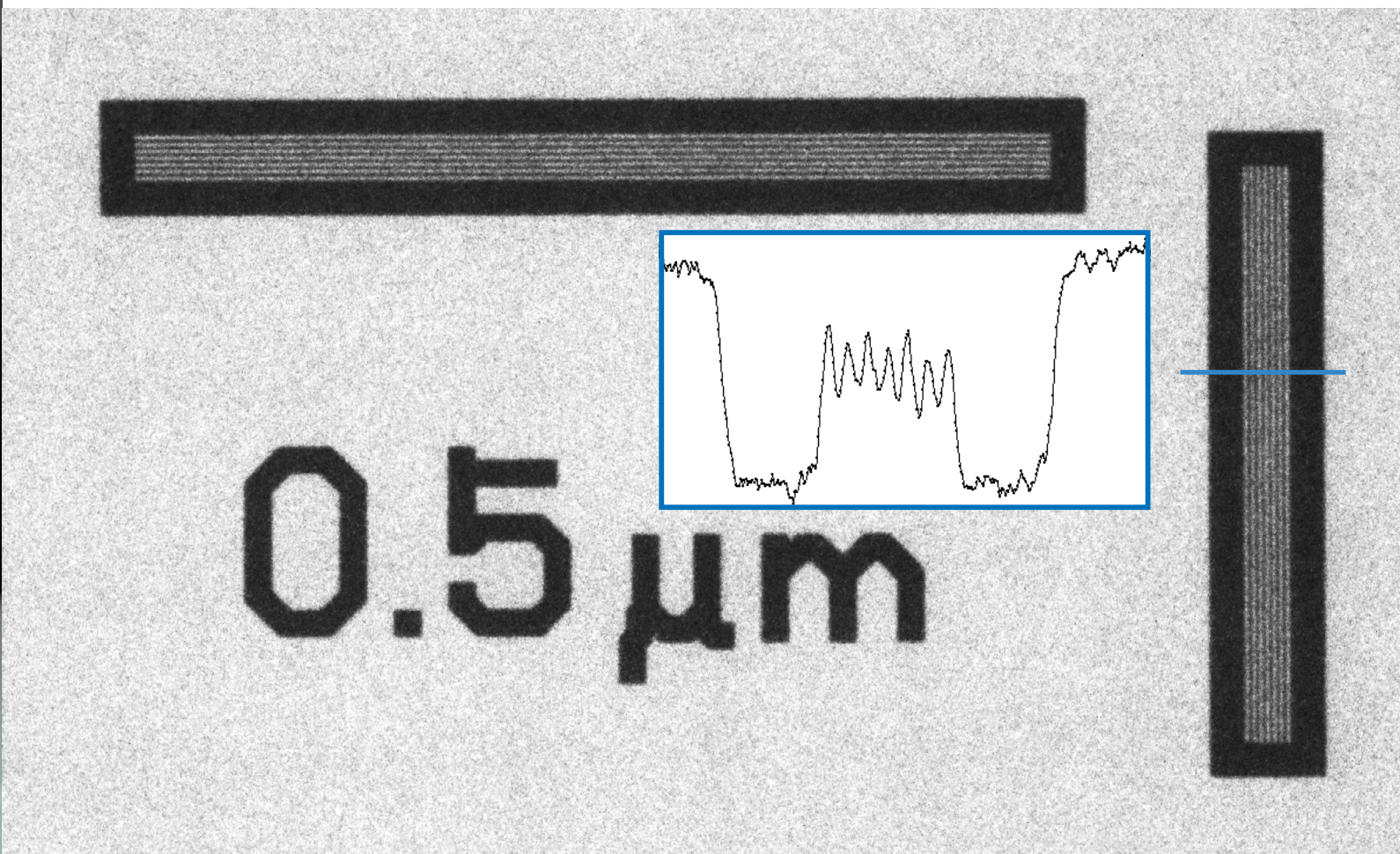
SKYSCAN 2214 CMOS supports objects up to 300 mm diameter and 20 kg in weight. An air-bearing rotation motor provides rotation with both high accuracy and precision. The integrated micro-positioning stage guarantees a perfect sample alignment.

# High-Performance X-Ray Source

SKYSCAN 2214 CMOS utilizes a latest generation nanofocus X-ray source with diamond window, which produces an X-ray beam with a cut off energy from 20 keV to 160 keV. This high-tech X-ray source is easy to operate thanks to pre-aligned, user-exchangeable cathodes. Tungsten (W) cathodes operate in the full range of accelerating voltages up to 160 kV and provide a spot size down to 800 nm.

Lanthanum hexaboride ($LaB_6$) cathodes can be used for accelerating voltages from 20 kV to 100 kV and provide a spot size of the X-ray beam smaller than 500 nm to achieve outstanding 3D resolution in X-ray imaging. The JIMA resolution pattern indicates that 500 nm structures can be easily resolved according to objective criteria.

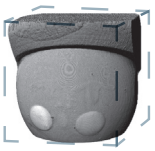
The X-ray source is equipped with an internal liquid cooling system to keep the temperature constant. This ensures the focal spot size and position of the emission point remain long-term stable.



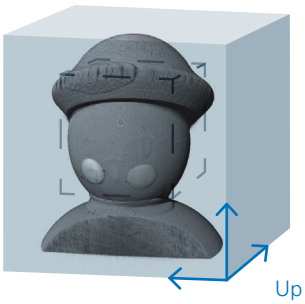
# Geometric Magnification Plus
## Always the Perfect Balance

Traditional CT systems use Geometric Magnification (GEM) to visualize the internal 3D structure of an object at a typical resolution between 10 and 100 micron.
This resolution can be improved by increasing the source to detector distance or by combining geometric magnification with additional lens magnification.
In either case, the improved resolution is achieved at the expense of a substantially reduced 3D field-of-view (FoV).

SKYSCAN 2214 CMOS squares the circle with **Geometric Magnification Plus** (GEM Plus). Thanks to the implementation of fine-pitched large-frame scientific CMOS (sCMOS) detectors the **3D FoV is up to 8 times larger** at the same resolution compared to traditional CT solutions, which provides a statistically more relevant view of the region of interest.



Traditional CT provides only reduced 3D FoV



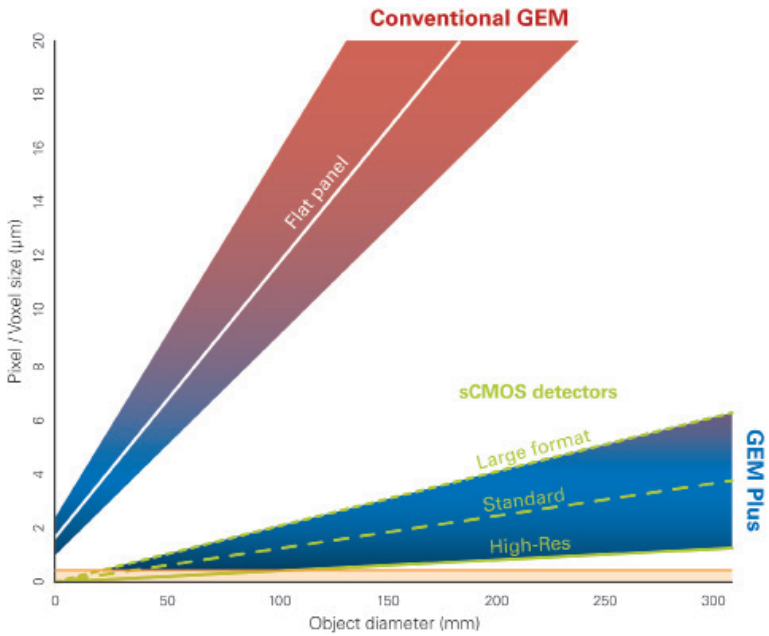
Up to **8x** larger 3D FoV with GEM Plus provides the full context at once



### High magnification for small and large objects

Using sCMOS detectors with small pixel sizes allows extension of high-resolution imaging and 3D reconstruction to large objects. The built-in detector flexibility enables adjusting the field of view and spatial resolution according to the object size and density.

An advanced reconstruction from a volume of interest enables visualizing a selected part of a large object with high resolution without compromising image quality. Additionally, the field of view can be increased horizontally and vertically by using offset camera positions and vertical object movement.



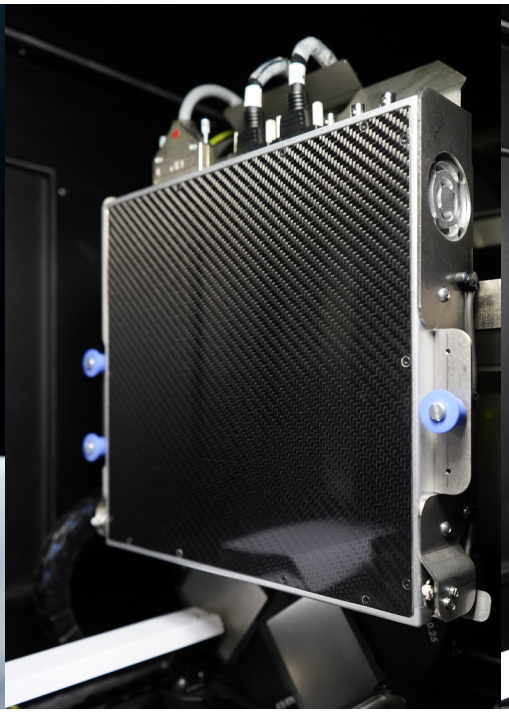

### Detectors

The SKYSCAN 2214 CMOS can be equipped with up to four X-ray cameras for ultimate flexibility: three large-format sCMOS cameras with different resolution and FoV balance, and one large-area flat panel detector. All cameras can be selected with just a single mouse click, without the need for any recalibration.

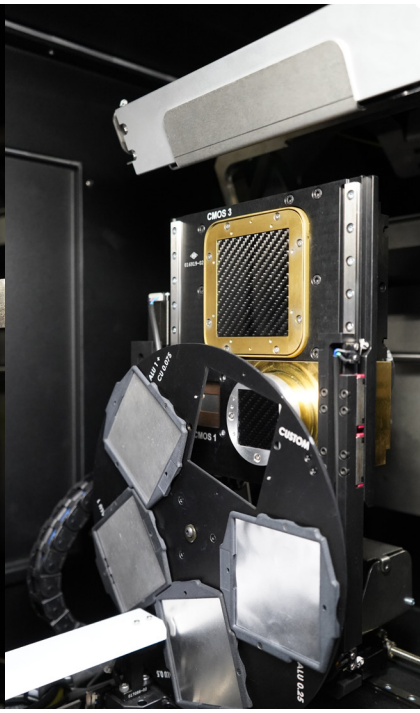
The sCMOS cameras can be positioned at different source to detector distances to optimize resolution versus FoV.
In addition, the sCMOS cameras can be placed in offset position to further extend their large FoV at a given resolution.
The acquired images are automatically stitched together with compensation of the shifts and possible intensity differences.



Large chamber for mounting big samples and optional stages



Flat-panel CMOS detector for ultimate field-of-view



Up to three different sCMOS detectors balancing resolution and field-of-view

## Multiscale X-ray microscope

SKYSCAN 2214 CMOS is a multiscale X-ray microscope with a unique X-ray source and detector geometry that generates sharp images with outstanding precision. SKYSCAN 2214 CMOS offers unprecedented nano-scale resolution and ultimate field-of-view (FoV) for imaging fine details in large objects.

## Ultimate flexibility

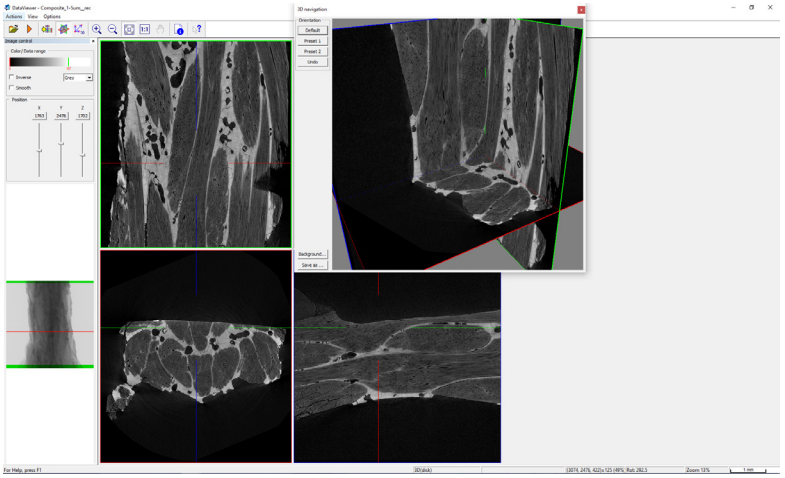
SKYSCAN 2214 CMOS features an innovative, modular design guaranteeing the best image quality, for every sample and application. This supreme flexibility offers the scanning of a wide variety of sample types and sizes in one instrument, eliminating the need for multiple CT systems. SKYSCAN 2214 CMOS can be configured with up to four detectors. All detectors are field-upgradeable, which ensures the future-proof SKYSCAN 2214 CMOS can accomodate changing analytical requirements.

## Ultra-high submicron resolution

SKYSCAN 2214 CMOS pushes the boundaries for measuring larger objects at ultra-high resolution. Its unique large FoV allows for the analysis of objects up to 300 mm in size. For objects up to 12 mm in diameter, it provides better than 500 nanometer true 3D resolution with an achievable voxel size better than 60 nanometer.

## 3D Inspection with DATAVIEWER

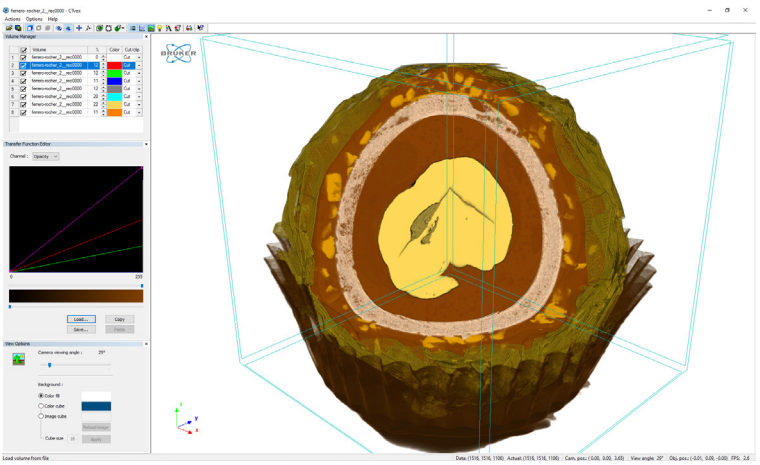
- Display reconstructed results as slice-by-slice movies or three orthogonal projections
- Smoothing, linear and non-linear grey scale transformations, color coding
- Differential image analysis between samples
- Exactly align multiple scans through image registration



3 orthogonal projections through a CFRP composite

## 3D Visualization with CTVOX and CTVOL

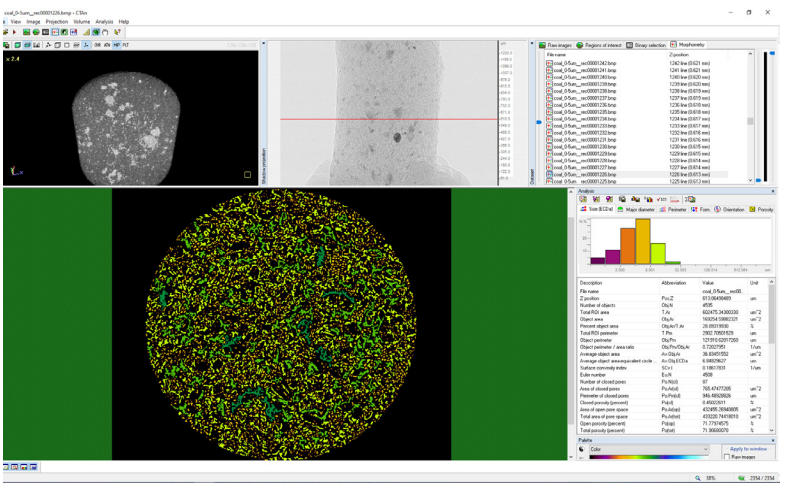
- Volume rendering to display reconstructed results as a realistic 3D object
- Create animated movies flying around or through the object
- Produce cut-away views
- Adjust coloring and transparency
- Export surface rendered models in STL format to 3D printers or to 3D CAD software



3D rendered volume of a hazelnut chocolate bonbon

## 3D Image analysis with CTAN

- Handles large data sets with ease
- Open/closed porosity
- Thickness and separation
- Fiber orientation
- Density analysis
- 3D distances and angles
- Extensive tool set for region-of-interest selection
- Various thresholding methods, morphological operations, and filtering algorithms
- Color coding of local orientation, thickness and separation
- Automated batch analysis



Morphometry analysis of a coal sample

## Technical specifications

| | |
|---|---|
| **X-ray Source** | Open (pumped) type with diamond window 20-160 kV, 16 W max. |
| **X-ray Detector(s)** | 6 Mp active pixel flat-panel<br>16 Mp large format sCMOS<br>16 Mp standard sCMOS<br>15 Mp high-resolution sCMOS |
| **Spatial Resolution** | 60 nm smallest pixel size, <500 nm low-contrast resolution ( Modulation transfer function at 10% ) |
| **Positioning Accuracy** | <50 nm for rotation, anti-vibration granite platform with pneumatic leveling |
| **Maximum Object Size** | 300 mm in diameter, 400 mm in height, maximum object weight 20 kg |
| **Radiation Safety** | <1 µSv/h at any place of the instrument surface |

**System Dimensions**




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