C251-E043B

SHIMADZU
Excellence in Science

Phase-Contrast X-Ray CT System

# Xctal 5000

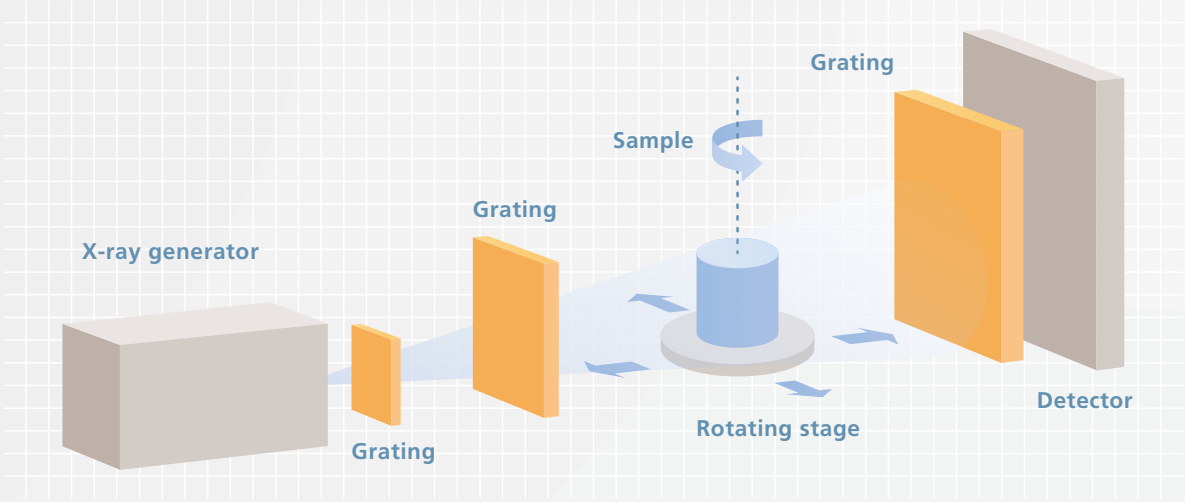
X-Ray Observations Enter a New Phase

# Xctal™ 5000

**The Xctal 5000 is a new X-ray CT system that creates images of X-ray phase shifts.**
**In addition to the X-ray absorption information detected by conventional X-ray CT systems, this system can detect X-ray scattering and refraction information. This enables observations of fine structure across a wide field of view, and high-contrast observations of samples with no absorption differences.**
**This is useful for research and development of fiber reinforced resins, composite materials, and biomaterials, which are advancing through research.**

# A Single Scan Obtains Three Types of Images: Absorption, Dark-field, and Phase Images

A new scanning method has been adopted that can detect phase shifts from X-ray interference using a diffraction grating.




2D projection image
(Absorption)

## Absorption Images

Absorption images visualize X-ray absorption differences, which are also detected by conventional X-ray systems.
This enables detailed observations of shapes within the sample.

2D projection image
(Dark)

New Technology

## Dark-field Image

### Both Wide Field of View and Detailed Structural Observations

Dark-field Images visualize dispersion by fine structure. Fine cracks can be detected with a field of view up to 100 mm in size. In addition, the system is equipped with a fiber orientation analysis function, enabling observations of fiber flow over a wide field of view.

2D projection image
(Phase)

New Technology

## Phase Images

### Dual Observation Method for Absorption and Phase

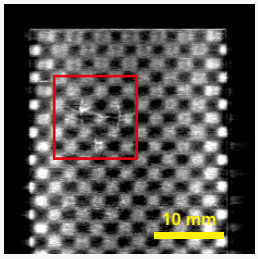
Phase images visualize density differences.
The system is capable of high-contrast observations of samples with no absorption differences, including resin products made of different materials.

# Both Wide Field of View and Detailed Structural Observations

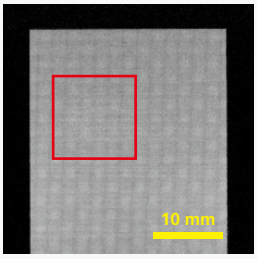
## Detailed Structural Observations

A dark-field image is suited to observations of fine structure, including cracks and the flow of fiber bundles, over a wide field of view.
In contrast, an absorption image is suited to enlarged observations of shapes in detail within samples.
The dark-field image obtained by scanning over a wide field of view makes it possible to ascertain fine structure in the sample as a whole, and to estimate its position.
The absorption image obtained by enlarged scanning makes it possible to observe the shape of fine structure in detail.
When observing fine structure, there is no need to scan repeatedly over a narrow field of view.

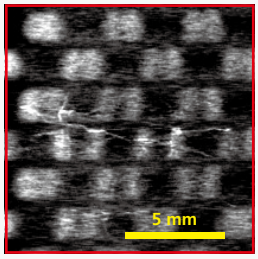
Example: Cross-Sectional Images of a CFRP Cloth Material with Cracks



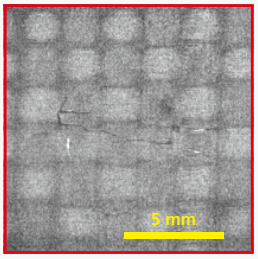

Cross-Sectional Image (Dark) (1)




Cross-Sectional Image (Absorption) (1)

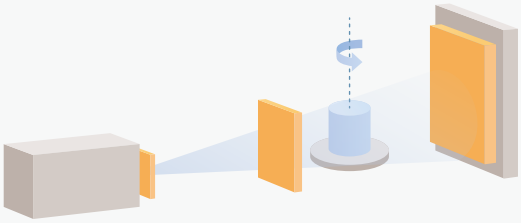


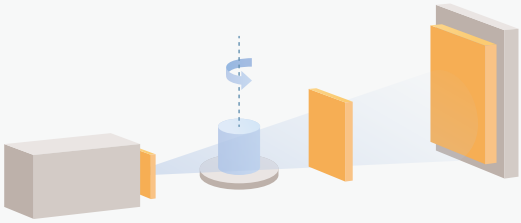

Cross-Sectional Image (Dark) (2)



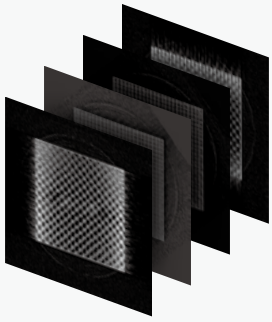

Cross-Sectional Image (Absorption) (2)

**Scanning method: Wide field of view scan** » **Scanning method: Enlarged scan**

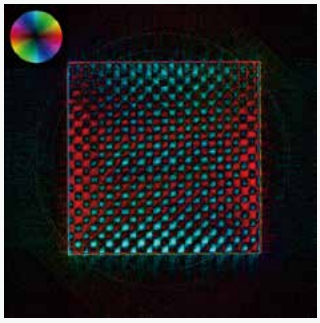




## Observations of Fiber Orientation



Cross-Sectional Image of CFRP Cloth Material (Dark)



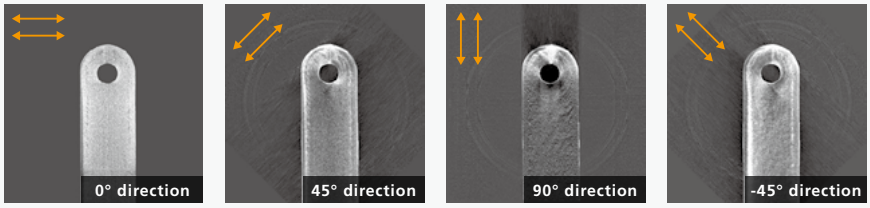
Vector Direction Color Map (CT)

The flow of fiber bundles, derived from multiple dark-field images, can be aligned with the orientation angle and displayed in color (vector direction color maps). The flow of fiber bundles can be understood intuitively by representing it in color.

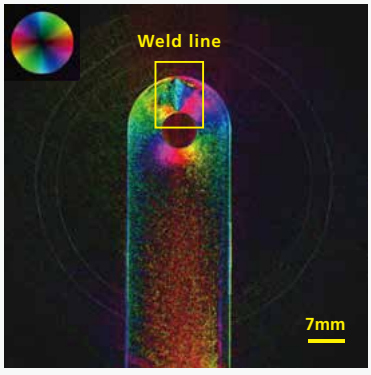
# Applications (Dark-field Images)

## GFRP Injection Molded Items

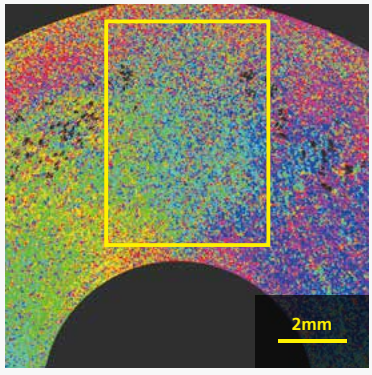
In injection molding, molding defects can occur when a linear mark (weld line) forms where the molten resins meet. With this system, dark-field images can be obtained while changing the angle of the sample, so the fiber flow can be analyzed, enabling the position of weld lines to be specified.




Fiber Orientation Analysis from Four Data Samples




Vector Direction Color Map (CT)

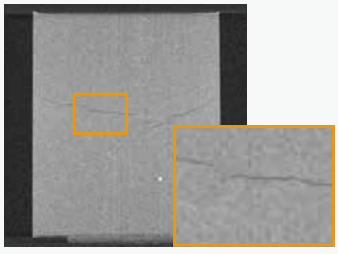



Results of an Absorption Orientation Analysis (Image obtained with the inspeXio SMX-225CT FPD HR Plus)

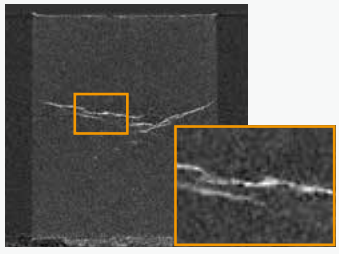
In comparison to conventional X-ray CT systems, the position of the weld line can be specified across a wider field of view.

## Biocoke

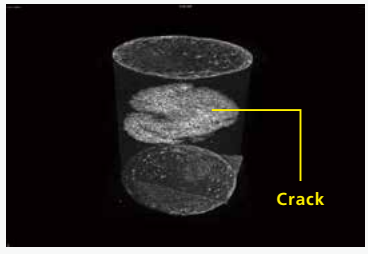
Biocoke is a solid biofuel formed from plants through photosynthesis. In this example, fine cracks produced during formation can be visualized using dark-field images. Fine cracks invisible with conventional X-ray CT can be visualized by detecting the scattering of X-rays at the borderline between the material and the crack (air).



Cross-Sectional Image (Absorption)



Cross-Sectional Image (Dark)




VR Image (Dark)

The quantitative analysis of microscopic cracks using this system has become a standard evaluation to check whether the combustion properties of biocoke are as close as possible to those of coal coke, thus laying the foundations for achieving a carbon neutral society through conversion to renewable energy.
(Samples and comments provided by: Professor Tamio Ida of the Bio-Coke Research Institute, Kindai University)

The affiliation of the providers of the samples and comments is as of July 27, 2022.

# Dual Observation Method for Absorption and Phase

## High-Contrast Observations by Absorption Images and Phase Images

**A phase image is suited to observations of samples with large density differences.
In contrast, an absorption image is suited to observations of samples with large differences in absorption coefficient. The X-ray absorption coefficient makes it possible to visualize samples with no contrast differences, as long as there are density differences. Using these two observation methods widens the scope of observations by enabling high-contrast sample observations.**

### Water and Acrylic

**The density difference is larger than the absorption coefficient difference, enabling high-contrast phase image observations.
High-contrast phase image observations are possible if the density difference is approximately 0.2 g/cm³ or larger.**

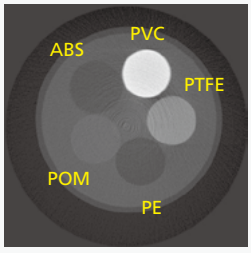
Cross-Sectional Image (Absorption)

Cross-Sectional Image (Phase)

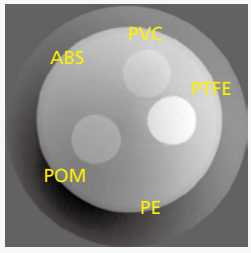
| | Acrylic | Water |
|---|---|---|
| Absorption Coefficient cm⁻¹ | 0.36 | 0.38 |
| Density g/cm³ | 1.19 | 1 |

### Water and Multiple Types of Resins

**The contrast differs for the absorption image and the phase image. As shown in the graphs below, it is evident that the brightness value for the absorption image is proportional to the absorption coefficient, and the brightness value for the phase image is proportional to the density.**

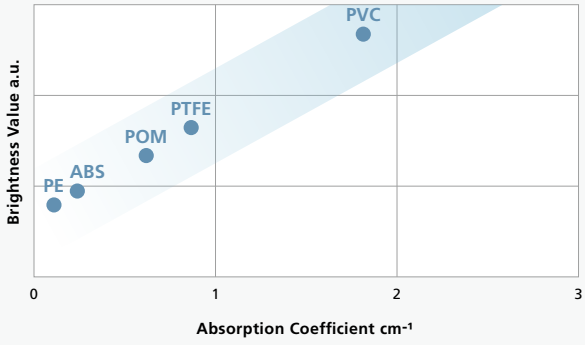


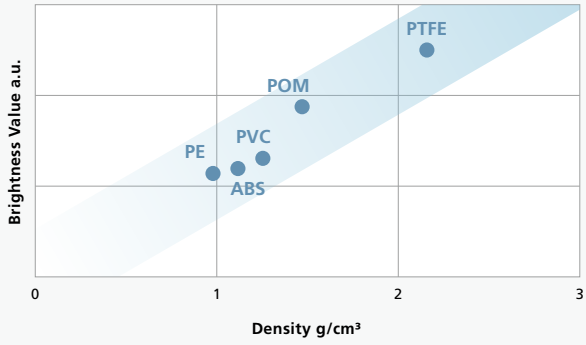

Cross-Sectional Image (Absorption)




Cross-Sectional Image (Phase)

| | ABS | PVC | PTFE | PE | POM | Water |
|---|---|---|---|---|---|---|
| Absorption Coefficient cm⁻¹ | 0.29 | 1.87 | 0.87 | 0.26 | 0.47 | 0.38 |
| Density g/cm³ | 1.07 | 1.26 | 2.17 | 0.96 | 1.42 | 1 |

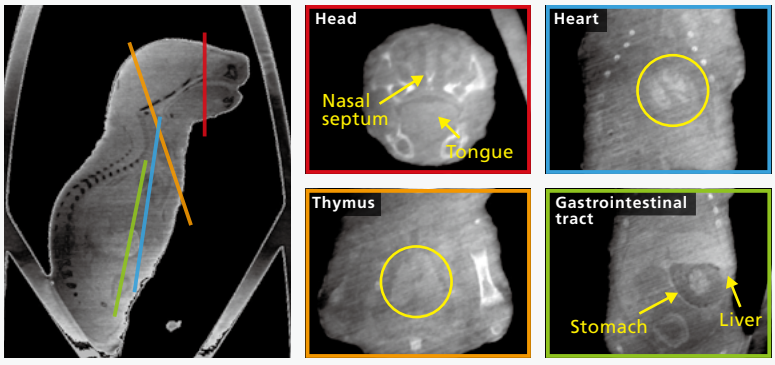


# Applications (Phase Images)

## Mouse (Neonate)

**This is a sample scan of a mouse (neonate). The internal organs can be observed without a contrast medium by, just using formalin fixation.**




Cross-Sectional Images (Phase)

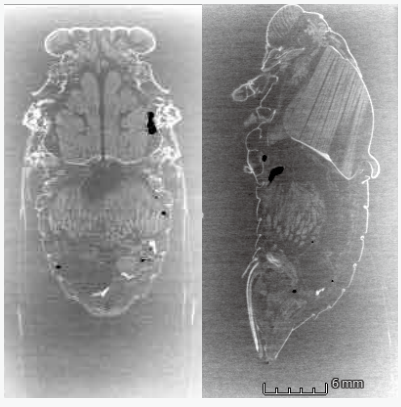
VR Image (Phase)

**A single scan with Xctal 5000 provides the internal feature of soft tissues such as tongue, heart, thymus, liver, stomach, as well as the clear image of hard tissues equivalent to that scanned by a conventional micro CT system. The sample remains intact without using contrast enhancing media, enabling users to carry out further histological analyses immediately.**
**(Samples and comments provided by: Professor Sachiko Iseki and Shigeru Okuhara, Section of Molecular Craniofacial Embryology and Oral Histology, Tokyo Medical and Dental University)**

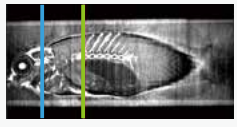
**The affiliation of the providers of the samples and comments is as of November 11, 2022.**

## Insects and Fish

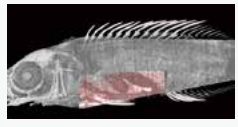
**These are sample scans of a robust cicada and twospot hogfish.**



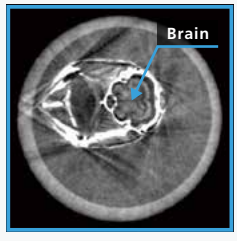

Cross-Sectional Image (Phase)



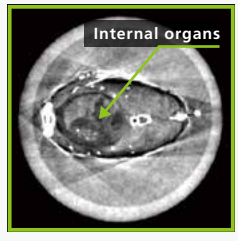
Cross-Sectional Image (Phase)



VR Image (Phase)




Cross-Sectional Image (Phase)




Cross-Sectional Image (Phase)

**Insects have conventionally been too small for high-resolution CT scans to be performed. In these cross-sectional images, however, the flight muscle bundles running across the thorax of a female robust cicada and individual eggs packed into the abdomen are clearly visible.**
**(Samples and comments provided by: Dr. Shuhei Nomura, Division of Terrestrial Invertebrates, National Museum of Nature and Science)**

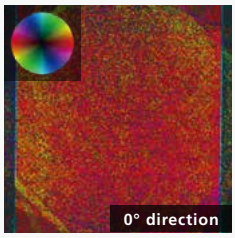
**This system is capable of observing the viscera and brains of small vertebrates, such as fishes, morphologically. As a result, it is expected to advance progress in the difficult surveys of soft parts. The new observative method does not require staining, which is important for maintaining precious biological specimens and materials.**
**(Samples and comments provided by: Dr. Gento Shinohara, Division of Vertebrates, National Museum of Nature and Science)**

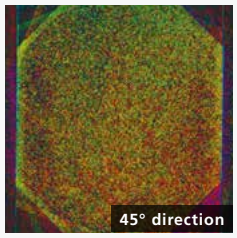
**The affiliation of the providers of the samples and comments is as of July 27, 2022.**

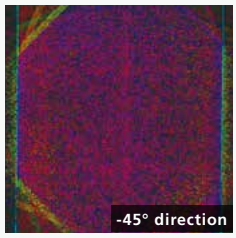
# Applications
# (Absorption, Dark-field, and Phase Images)

## CFRP Laminate Layers

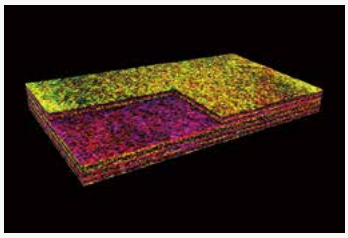
This is a sample scan of a material in which the angle of a prepreg of fibers aligned along one direction is changed to build up the laminate layers. It is evident from the cross-sectional images that there are three orientation directions, and from the VR image, these have evidently been used by turns in the laminate.



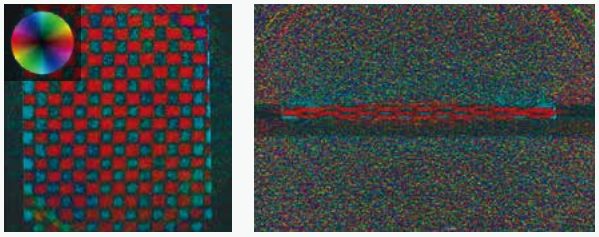

Vector Direction Color Maps (CT)



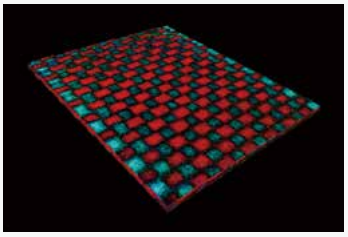
VR Image (Vector Direction Color Map)

## CFRP Cloth Material

This is an example of the analysis of fiber orientations in a laminate material, woven with carbon fibers.



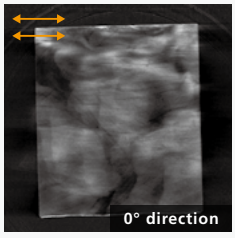
Vector Direction Color Maps (CT)

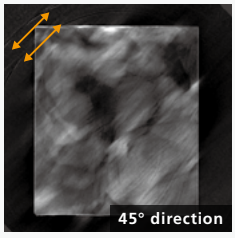


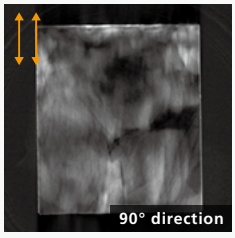
VR Image (Vector Direction Color Map)

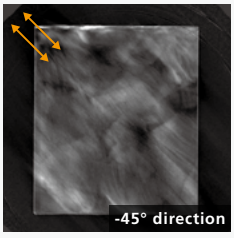
## CFRP Random Laminate

This is a sample scan of a material in which pieces of carbon tape with random orientations are used to build up the laminate layers. X-rays scattered along the orientation of the grating are detected, enabling the fibers oriented along these directions to be detected.



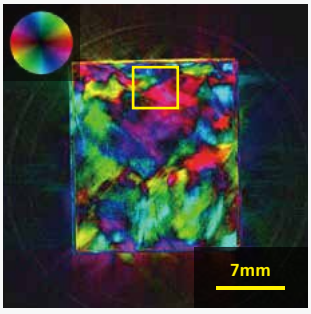



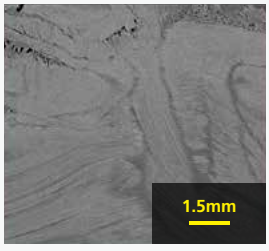



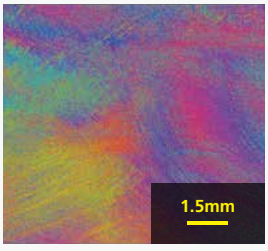

Cross-Sectional Images (Dark)

Fiber orientation analysis




Vector Direction Color Map (CT)
FOV : 40 mm



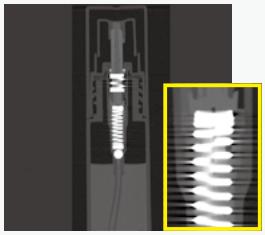

Cross-Sectional Image of the Enlarged Absorption Image of the Area in the Yellow Frame, and the Results of an Orientation Analysis (Image obtained with the inspeXio SMX-225CT FPD HR Plus)

With the random sheet of chopped tape, variation of the fiber orientation changes the mechanical properties and moldability, thereby changing the quality of the molded product. The fiber orientation analysis makes it possible to predict the quality nondestructively, and further, enables research into the design of laminates with a slight variation and stable quality.

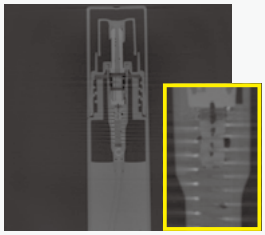
(Samples and comments provided by: ICC, Kanazawa Institute of Technology)

## Plastic Bottles

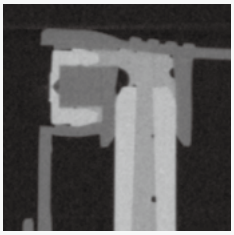
This is a sample scan of a plastic spray bottle. With a phase image, it is possible to observe the voids in the plastic, without the impact of artifacts due to a spring. In addition, the internal structure of the sample where different types of plastic are joined can be observed using absorption and phase images due to the difference in the absorption coefficients and densities.



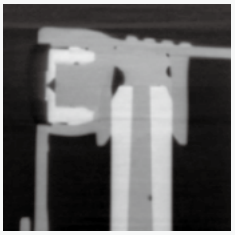
Cross-Sectional Image (Absorption)



Cross-Sectional Image (Phase)



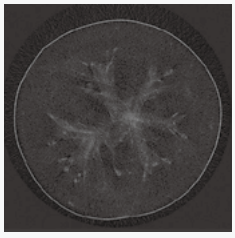
Cross-Sectional Image (Absorption)



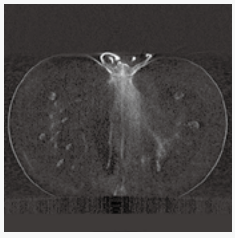
Cross-Sectional Image (Phase)

## Tomatoes

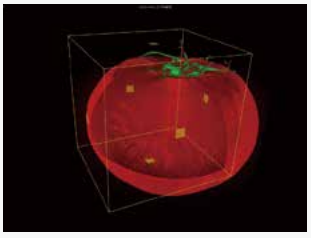
This is a sample scan of a tomato. The internal structure of the vegetable can be observed even if there is a high moisture content.



Cross-Sectional Image (Dark)



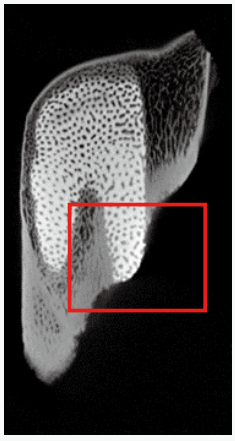
Cross-Sectional Image (Dark)



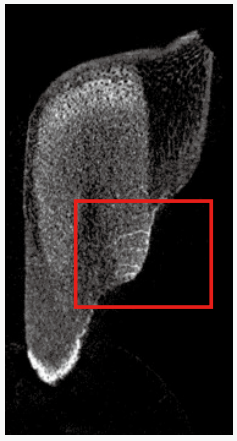
VR Image (Dark)

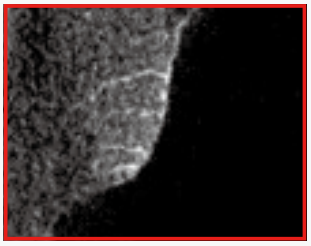
## Upper Jaw Tooth Plate of an Elephant Shark

This is a sample scan of an upper jaw tooth plate of an elephant shark.



Cross-Sectional Images (Absorption)





Cross-Sectional Images (Dark)

A number of cracks, probably caused by occlusion, are visualized in the red squared area in the dark-field image (right) of the upper jaw tooth plate of the elephant shark. Whereas cracks are not visible in the absorption image (left). Technique to detect such an internal structural defects nondestructively should be highly useful in development of biomaterial which is subjected to mechanical stress.

(Samples and comments provided by: Dr. Mayumi Iijima, Graduate School of Agricultural and Life Sciences/Faculty of Agriculture, The University of Tokyo)

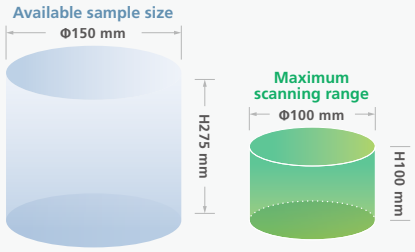
The affiliation of the providers of the samples and comments is as of July 27, 2022.

# Anyone Can Easily Perform New Observations

## Three-Step Scan

### 01 Placement of the Sample

Place the applicable sample on the stage.




### 02 Scanning condition setting

Configure the grating and image quality settings. The settings are configured just with pull-down menus and checkboxes, enabling scanning to start easily.

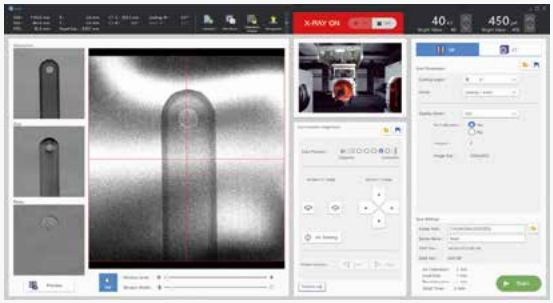
### 03 Scanning

Calibration before scanning is not required, so CT scanning can start immediately. After scanning is finished, software (Viewer or MPR) for observations and analysis corresponding to the scanning method starts up automatically.

## Standard Software

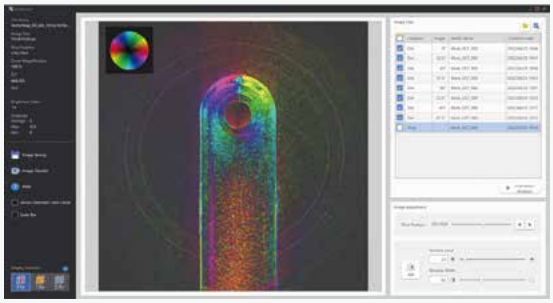
### Xctal Control Software

Functions include system control, fluoroscopy, CT scan, and reconstruction.



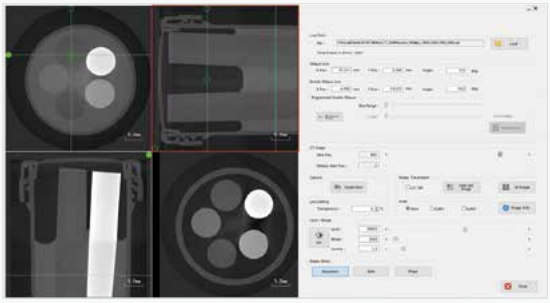
### XctalViewer Viewer Software

This software displays the X-ray 2D projection images and cross-sectional images from scans with Xctal 5000. In addition to displaying images, it can output vector direction color maps created from multiple dark-field images.



### MPR(Xctal)

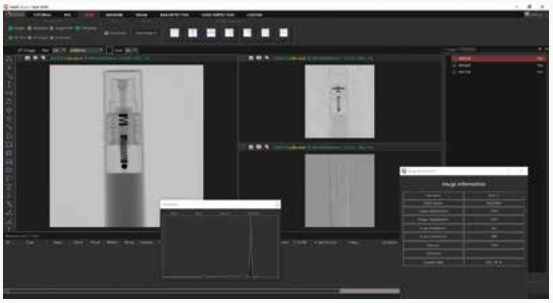
This software displays cross-sectional images obtained with the Xctal 5000. Four cross-sectional images at any angle can be displayed simultaneously.



# Optional Software

## HADI-S
## 2D Image Processing Software

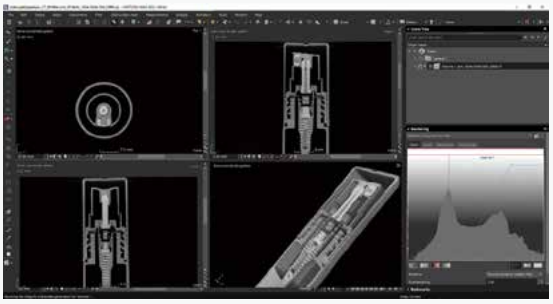
**This can perform a variety of image processing on 2D projection images and cross-sectional images, including size measurements and filter processing.**



**(Smart Vision Corporation)**

## VGSTUDIO MAX
## 3D Image Processing Software

**This is high functional volume rendering (VR) software. Multiple functions are available including the creation of animations, various measurements, extirpation of the center region, image filtering, and positional alignment of 3D images.**

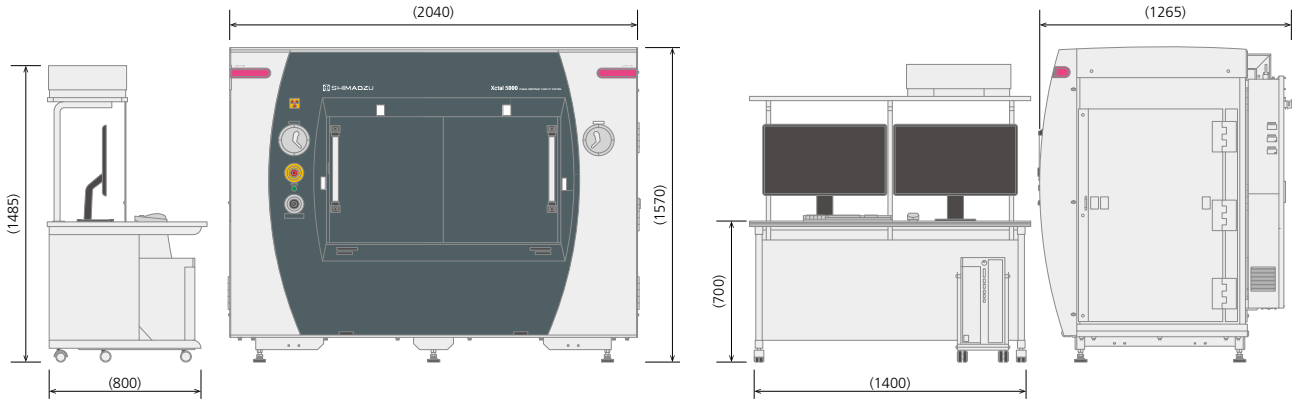


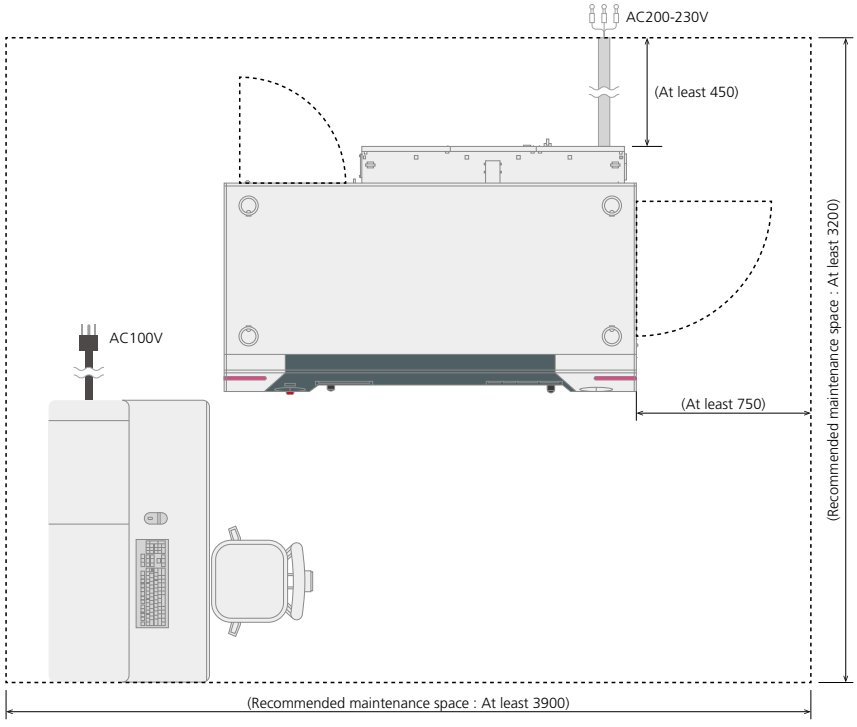
**(Volume Graphics)**

# Main Specifications

| Model | | Xctal 5000 |
|---|---|---|
| X-Ray Generator Output | | Max. tube voltage 90 kV Max. tube current 800 µA Rated Output 50 W |
| X-Ray Detector | | Flat panel detector |
| Available Sample Size | CT Stage | Φ150 mm × H275 mm Max. 5 kg |
| | Orientation Analysis Unit | Φ100 mm × H10 mm Max. 300 g |
| Max. Scanning Range | Fluoroscopy | 100 mm × 100 mm |
| | Fiber Orientation Fluoroscopy | Φ100 mm |
| | CT Scan | Φ100 mm × H100 mm |
| | Fiber Orientation CT Scan | Φ85 mm × H85 mm |
| CT Data Acquisition Time | | Min. 30 minutes |
| Rated Power | Main Unit | Single phase 200 to 230 VAC ± 10 % 50/60 Hz, 1.0 kVA |
| | Control Computer | Single phase 100 to 230 VAC ± 10 % 50/60 Hz, 1.5 kVA |
| | Grounding | Grounding resistance of 100 Ω max. |
| Weight | | 1700 kg |
| Operating Conditions (when running) | | Ambient temperature 20 to 30 °C<br>Ambient humidity 40 to 80 % max. (no condensation) |
| External Leakage Dose | | 1 µSv/h or less |

# Layout and Size Schematic (Units: mm)






SHIMADZU

Shimadzu Corporation

**www.shimadzu.com/an/**