DicifferX

WAXS Edition

Advanced Polymer Analysis XRD

Pioneering the World of Microstructure

High Brightness, Flexible Sample Environment,
and a Broad Measurement Range – the Next Generation WAXS Solution

Rigaku
POWERING NEW PERSPECTIVES

Advanced X-ray Diffraction System
for Polymer Structure Evaluation

DicifferX
WAXS Edition

Wide-Angle X-ray Scattering (WAXS) Edition for Revealing Polymer Structures

WAXS※ enables non-destructive acquisition of structural information that determines the properties of various materials—such as polymer films, fibers, functional thin films, and lipids—by analyzing atomic and molecular arrangements, crystalline structures, and molecular orientations.

DicifferX WAXS Edition achieves high-precision measurements in a short time, even for small samples, by focusing high-intensity X-rays into a micro-spot using a high-brilliance rotating anode source combined with multilayer-coated X-ray focusing mirrors. Exposure time is reduced to just a few seconds, allowing time-resolved measurements in in-situ experiments involving heating, stretching, humidity control, and more. The wide, goniometer-free stage can directly accommodate large films, sheets, and multi-sample holders without modification.

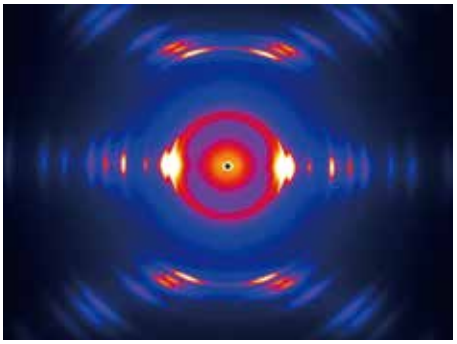
※ While WAXS (Wide-Angle X-ray Scattering) is also referred to as WAXD (Wide-Angle X-ray Diffraction), the term WAXS is used consistently in this catalog.

Micron Scale	Nano Scale	Atomic Scale
		
SAXS (Small Angle X-ray Scattering)	WAXS (Wide Angle X-ray Scattering)	PXRD (Powder X-ray Diffraction)

Structural Analysis of Polymer Films

The arrangement of polymer film materials is controlled by the stretching process, and the structure of the polymer greatly affects its mechanical strength and optical properties. WAXS enables evaluation of crystalline structure and orientation, helping to clarify the relationship between film structure and material properties, and supporting performance improvements in materials.

- Polypropylene
- Polyethylene
- Polyimide
- PET
- Synthetic resin films in general



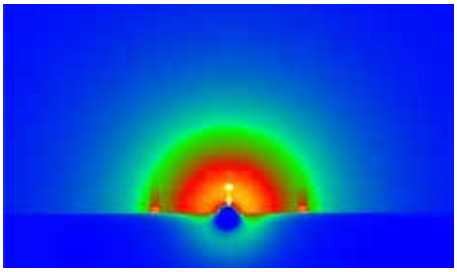
Measurement of Polyethylene Film
Evaluation of Crystallinity and Orientation

Structural Analysis of Functional Thin Films

The structure of a functional thin film greatly affects its electrical and optical properties. GI-WAXS※ allows separate observation of structural information in both the out-of-plane and in-plane directions, helping to reveal crystalline anisotropy and orientation, and supporting performance improvement and functional development in thin films.

- Transparent conductive oxides (ITO and IZO thin films)
- Perovskite solar cells
- Liquid crystalline polymer thin films
- Nanocomposite materials

※ GI-WAXS (Grazing Incidence Wide Angle X-ray Scattering) is a widely used technique in which an X-ray beam is incident on a sample surface at a very shallow angle, enabling efficient detection of weak diffraction signals from thin-film samples.



GI-WAXS Measurement of Organic Thin Films
Evaluation of Periodicity in In-plane/Thickness-direction and Crystal Phase Identification

Structural Analysis of Fibers

WAXS is also used for structural analysis of various fiber materials. WAXS can evaluate the crystal structure, crystallinity and orientation of fibers, revealing factors that contribute to fiber strength and toughness, and contributing to the development of high-performance fibers.

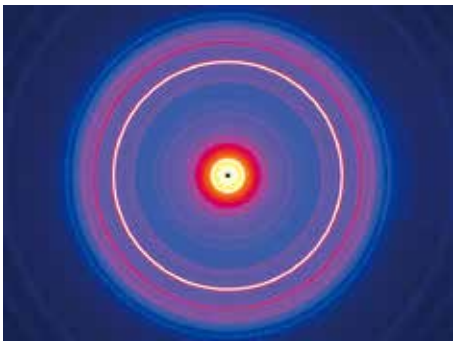
- Carbon fiber
- Cellulose fiber
- Natural fiber (wool, cotton, silk)
- Plastic fibers (nylon, acrylic)
- Metal fibers

Measurement Results of a Single Carbon Fiber
Evaluation of Fiber Orientation and Crystallinity

Structural Analysis of Lipids

The structural organization of lipids critically affects their properties and functionality. WAXS enables precise analysis of lipid crystalline phases and liposomal membranes, providing insights into stability/function relationships and accelerating product development.

- Pharmaceutical and cosmetic materials
- Food lipids
- Emulsions
- Liposomes
- Inks and paints



Evaluation of the Structure and Orientation of Cocoa Butter (Lipid)

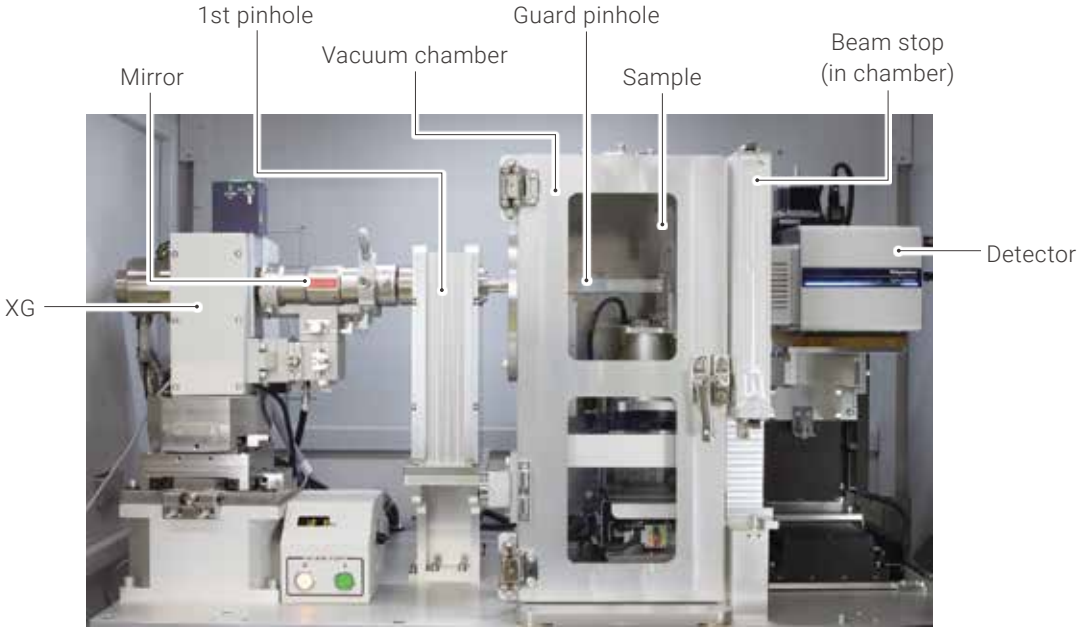
Highly Flexible Sample Space

This system employs a goniometer-less system design, which provides a large space around the sample. For this reason, a variety of sample units are available, including a sample stage for large samples and a dedicated sample cell for liquid samples, which can be easily replaced by the user.

In addition, a variety of temperature and atmosphere controllable attachments as well as third party sample attachments, can be installed, enabling a highly flexible measurement environment.

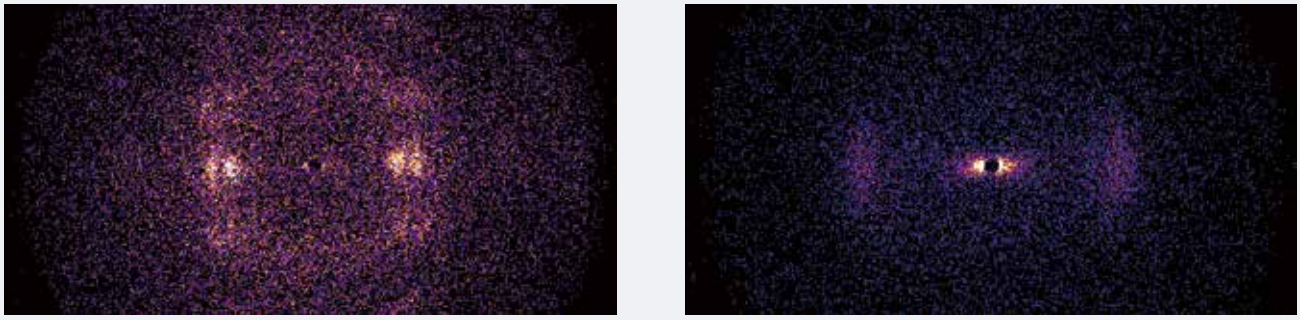
Full Vacuum Chamber (Optional)

With this specialized chamber, a vacuum can be created around the optics and sample stage, thus minimizing influence of scattering by air. Therefore, single-fiber measurements are possible even for materials with low X-ray scattering intensity, such as silk or carbon fiber.



Example of Application with Full Vacuum Chamber

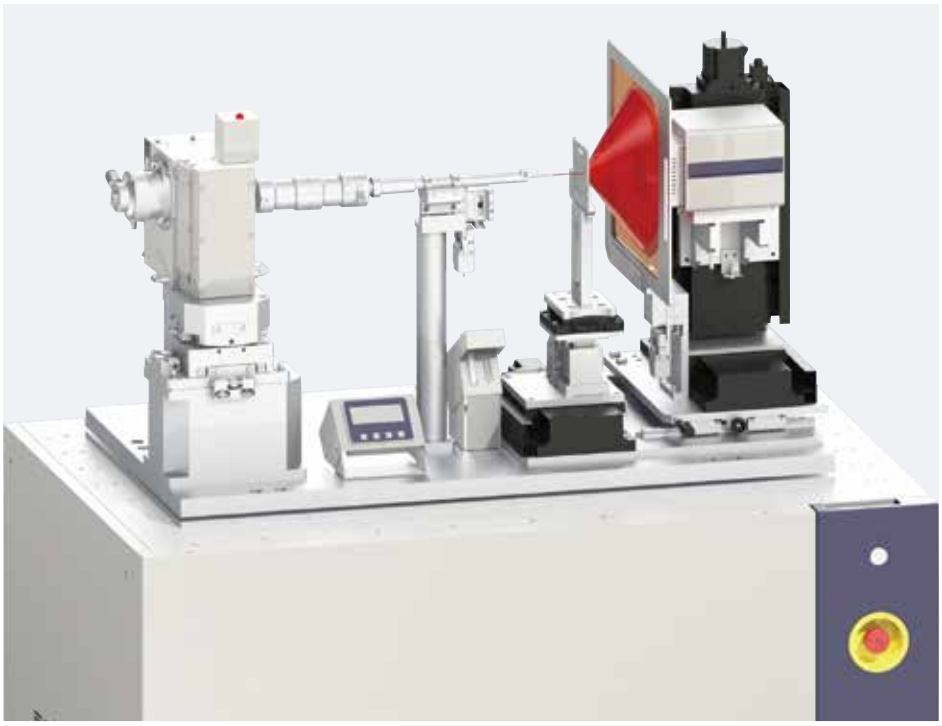
The vacuum chamber enables structural evaluation of a single fiber.

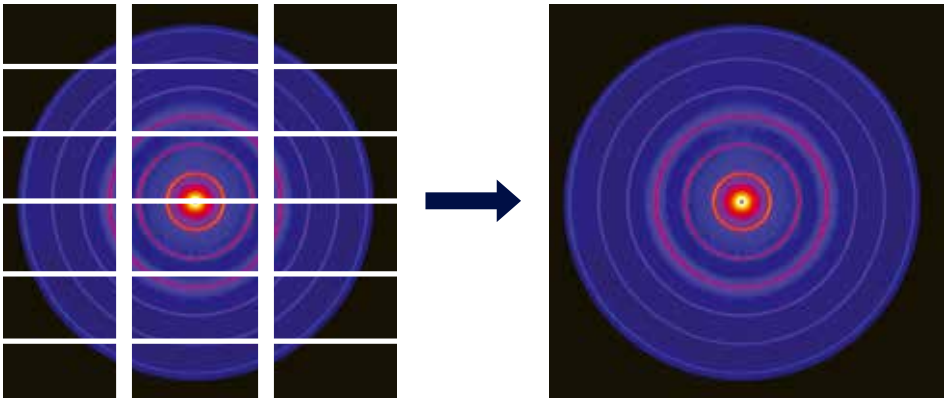


Result of measurements of a silk fiber (left) and a carbon fiber (right) with 10 seconds exposure

Measurement of the Entire Debye Ring Range

The DicifferX WAXS Edition is equipped with a detector mounted on motorized two-axis stages (horizontal and vertical) as standard, featuring a dedicated control software function that stitches multiple measurement images into a single large-area image. This capability enables acquisition of measurement images with an effective detection area of over 200 mm square. When combined with the minimum sample-to-detector distance (camera length) of 40 mm, this allows measurements at scattering angles greater than 65°.



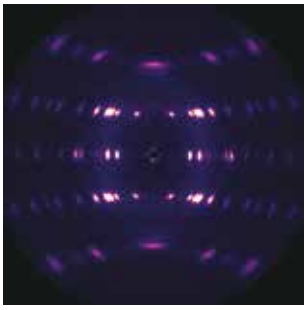


Hybrid Multi-dimensional Pixel Detector

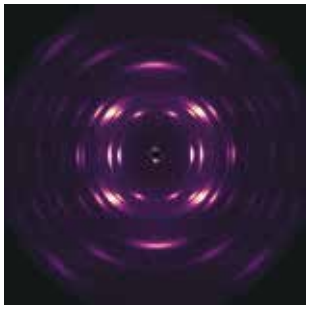
Equipped with Rigaku's proprietary HyPix-6000 detector, noise-free and high-speed measurement is realized. High position resolution and large detection area maximize excellent optics performance.

Evaluation of Crystal Structure, Crystallinity and Orientation Distribution of Polymer Materials

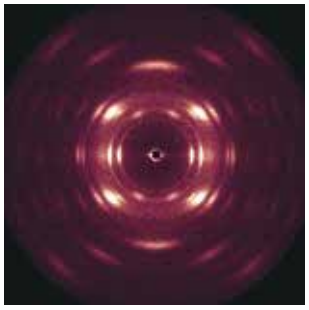
High Stretching



Low Stretching



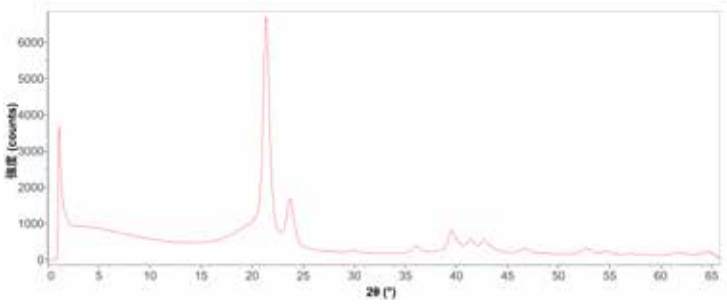
Void Fiber



Measurement Condition

Samples: Highly Stretched Film, Low-Stretched Film, Fiber
Exposure Time: 1 second

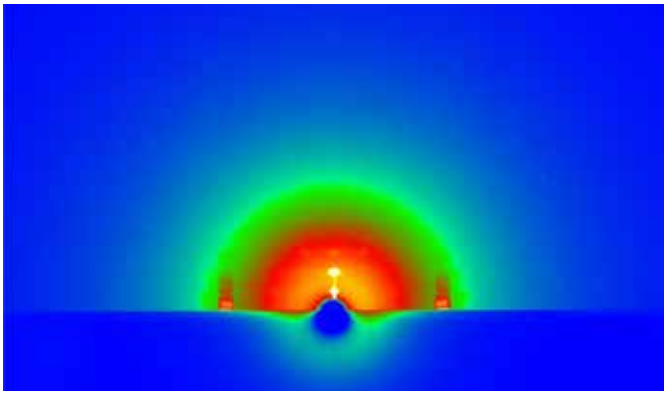
In general, crystalline polymer materials are oriented in a specific direction during processing. The optical system of DicifferX WAXS Edition minimizes the X-ray beam size at the sample position, thereby reducing diffraction peak broadening due to beam footprint. This allows for the precise detection of even subtle structural changes. Moreover, the high intensity of the incident X-rays enables high-speed mapping measurements of film samples and structural evaluation of single fibers.



Measurement Condition

Sample: PE Film
Exposure time: 20 seconds

Structural Evaluation of Thin Film Materials (GI-WAXS)



By using the GI-WAXS stage to irradiate the thin-film sample with X-rays at a very shallow angle, it is possible to evaluate the structural characteristics both in the in-plane direction and along the stacking (normal) direction.

In an actual measurement example, diffraction was observed in both the out-of-plane and in-plane directions of the thin film sample, confirming the presence of distinct periodic structures in each direction.

GI-WAXS Stage

GI-WAXS Stage
with Sample Changer

GI-WAXS Stage
with Gonio-head

A variety of accessories can be mounted, including a T-shaped multi-specimen holder, an adapter for a heating stage, and a dedicated stage for fiber specimens. It provides a flexible measurement environment for a wide range of materials and conditions.

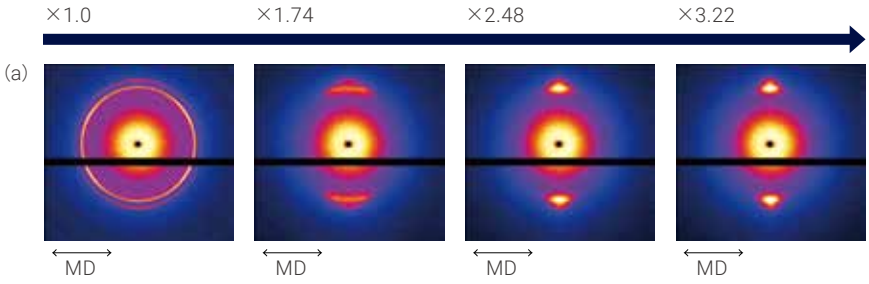
High-speed Time-resolved Measurement

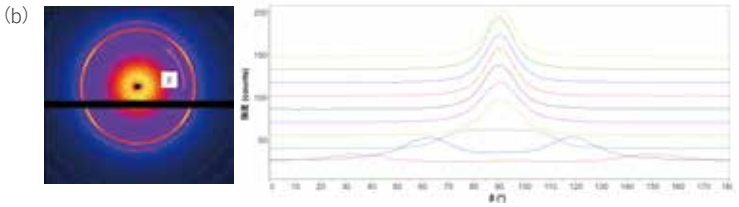
Evaluation of Crystalline Orientation Using a Stretching Stage

This example shows the change in orientation and crystallinity of PE film at different stretch ratios. The 2D-WAXS images show how the orientation state caused by biaxial stretching changes to uniaxial orientation by further uniaxial stretching. The integration of DicifferX WAXS Edition with a stretching stage enables in-situ observation of structural transformation during the stretching process. This enables real-time structural evaluation in a laboratory environment.

Extension Distance (mm)

MD=Machine Direction





Observation of structural changes in PE film during isothermal stretching, captured at one-second intervals using constant-speed time-resolved measurement

(a) 2D data

(b) 1D profiles after azimuthal (β-direction) ring-averaging, displayed with vertical axis offset

Temperature Range: Constant room temperature
Stretching Range: 1 time to 3.22 times
Stretching Speed: 0.1 mm/s
Exposure Time: 1 second

Stretching Stage (manufactured by Linkam)

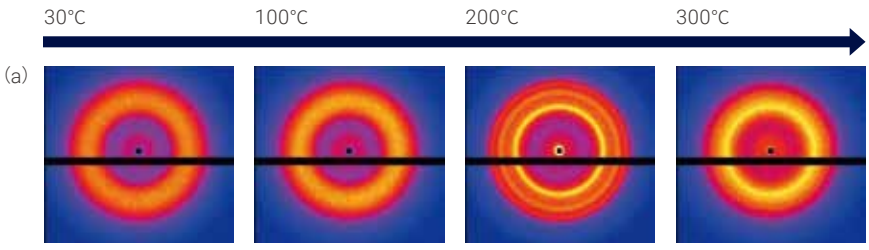
【Stage Specifications】

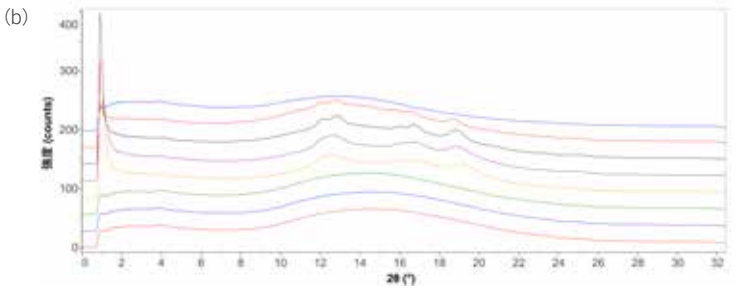
Temperature: Room temperature to 350℃
Cooling option: -195℃※1 to 350℃
Load cell: Selection from 2N, 20N, 200N or 600N

※1 May vary depending on the operating environment.

Evaluation of Crystalline Structure Using a Heating Stage

The combination of high-brilliance X-rays and a high-speed, high-performance detector enables in-situ and operando measurements at the laboratory level, which were previously possible only at synchrotron radiation facilities. While heating polyethylene terephthalate (PET) film from room temperature to 330°C (20℃ /min), 2D-WAXS images are continuously acquired with 1-second exposures. The 1D scattering data obtained allows clear observation of the melting and recrystallization processes. This opens up new possibilities for high-speed, time-resolved measurements in a routine laboratory environment.





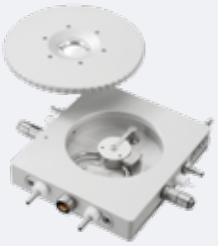
Observation of structural changes in PET film during heating, captured at one-second intervals using high-speed time-resolved measurement

(a) 2D measurement data

(b) 1D profiles after azimuthal ring-averaging, displayed with vertical axis offset

Temperature Range: Room temperature to 330℃
Heating Rate: 20℃ /min
Exposure Time: 1 second

Heating and Cooling Stage (manufactured by Linkam)



【Stage Specifications】

Measurement Method: Transmission or Reflection※2
Temperature: Room Temperature to 350℃
Cooling option: -195℃※3 to 350℃

※2 A GI attachment is required separately for the reflection setup.

※3 May vary depending on the operating environment.

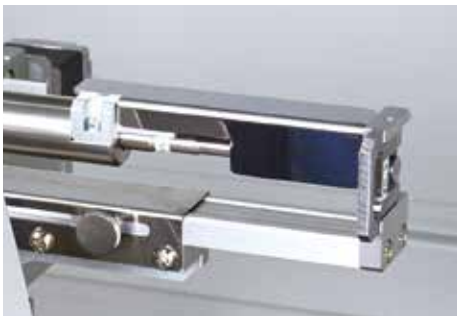
Equipment Features

Beam Unit

MicroMax-007 HF generates X-rays with extremely high brightness by focusing the electron beam onto a rotating anode, producing an effective focal spot of 70 µm in diameter. By combining this high-brightness X-ray source with the VariMax focusing mirror, both high intensity (1.0×10^9 cps) and a micro-beam at the sample position are achieved.

Guard Slit

When X-ray scattering from a sample is very weak, it is greatly affected by air scattering. By installing a guard slit and anti-scattering tube just before the sample, the effect of air scattering upstream from the sample is reduced.

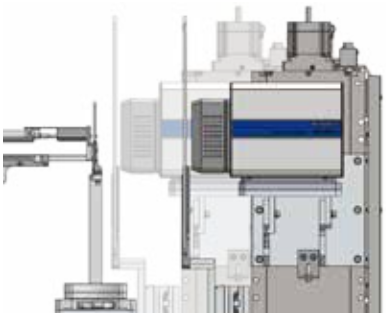


Wide Sample Stage

Equipped with a sample stage with a wide range of motion, it enables measurement of multiple specimens and mapping measurements. A kinematic base is used for mounting sample attachments, allowing easy mounting and dismounting.

Variable Distance Detector

The distance between sample and detector can be manually adjusted in the range of 40 mm to 140 mm. The maximum camera length of 140 mm supports low angle measurements from $2\theta = 0.5°$. The variable camera length allows for flexible adjustment of the sample space and thus also accommodates a wide variety of attachments.

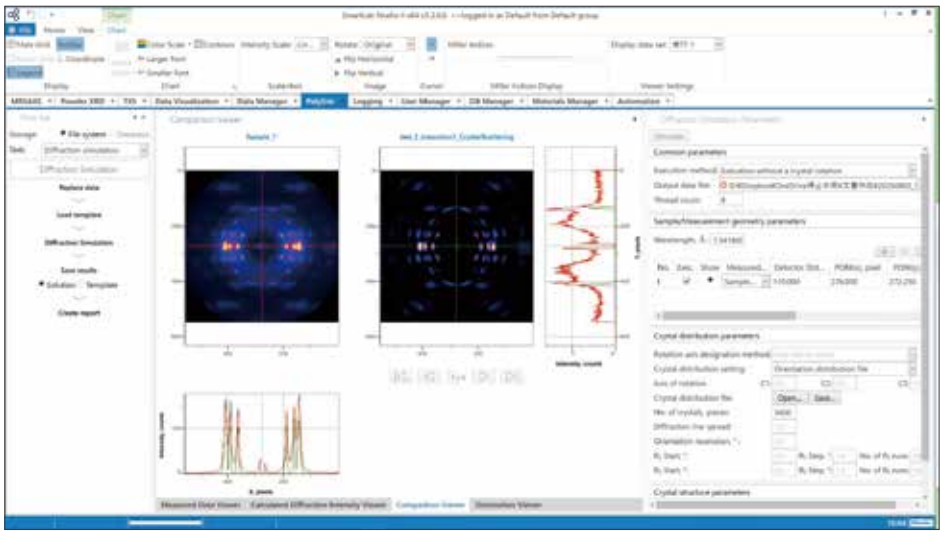


PolyOrientX

Analytical Software Specialized for Structural Analysis of Polymer Materials

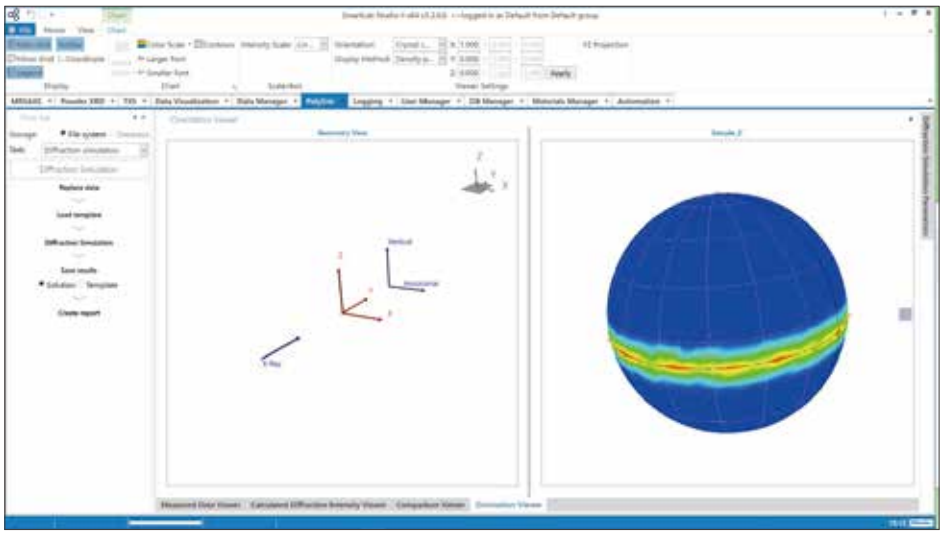
PolyOrientX quantitatively and visually analyzes and displays key information related to the physical properties of polymers. It evaluates the crystalline structure and orientation distribution of polymer materials based on two-dimensional diffraction patterns.

Comparison Viewer (Comparison between Experimental Data and Simulation)



The software includes analysis parameters such as orientation distribution and crystallite size, enabling side-by-side comparison between experimental data and simulation results. Not only two-dimensional diffraction patterns, but also one-dimensional intensity profiles extracted from arbitrary positions can be compared with simulation results, allowing for detailed examination of differences between experimental and theoretical data.

Orientation Distribution Visualization Feature



The software is equipped with a visualization function that displays the orientation distribution of the crystalline structure. This feature allows intuitive understanding of the direction in which the crystals are oriented relative to the X-ray incidence, as well as the strength of the orientation. It proves highly effective in assessing orientation behavior during structural analysis of polymer films and fiber-based materials.

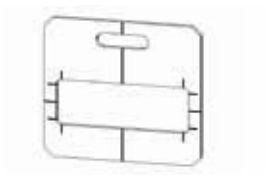
A Variety of Accessories

Sample Cells

Film / Thin Sample / Solid Sample

Standard Cell
5 slots
(Hole diameter: φ 2 mm)

Multi-Cell
35 slots
(Hole diameter: φ 3 mm)



Mapping Cell 26× 76
Hole diameter: 26× 76 mm

Film

Film thickness direction Cell
2 slots
Film specimens can be mounted in either portrait or landscape orientation

Solution

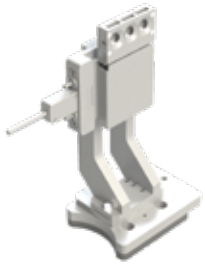
Solution Cell
Flat-Type Solution Cell for Peltier Attachment
Sample Volume: 30–40 mL

Capillary Cell
6 slots
Compatible with φ1.0, φ1.5, and φ2.0 mm glass capillaries

Powder-Gel-Solid

Powder/Individual Cells
15 slots
5 specimens can be set in one container

Attachment



Peltier Attachment
Heating and cooling by Peltier temperature control system.
Temperature range: -10～ 120°C, 0.01～ 20 °C/min

Sample Observation Camera
A camera for sample observation that observes samples from the direction coaxial to X-rays.

Temperature and Humidity Controlled Stage
A sample stage designed for measurements under controlled temperature and humidity conditions. Enables stable measurement without condensation at high temperature and high humidity.

Diamond Anvil Cell (DAC) Attachment
An attachment designed for mounting a commercially available diamond anvil cell for measurement.
The four-axis motorized stage allows precise adjustment of the X-ray incident angle during measurement.

Transmission DSC Attachment
This attachment enables simultaneous measurement of DSC and WAXS.
A dedicated sample pan holds the sample, enabling measurement in the transmission configuration.

Sample Pan for Transmission

Specifications

X-ray Generator：MicroMax-007 HF

Rotating cathode material	Cu	Mo
Effective focus size	φ70 μm	150 μm×100 μm
Current, voltage	40 kV、30 mA	50 kV、24 mA
Output power	1.2 kW	

Optics

	Standard Specifications	Vacuum Chamber Specifications
Mirror	VariMax HF	
Collimation	Beam shaping by collimator	2-pinhole optics
Camera length	40～140 mm	110 mm

Detector

Rotating cathode material	HyPix-6000C (For Cu)	HyPix-6000HE (For Mo)
Detection element	Pixel type silicon semiconductor device	
Pixel size	100 μm×100 μm	
Pixels	775×770 pixels	

Sample Environment - Attachment

Standard Attachment Cell-Stage

- Multiple Cells
- Capillary Cells
- Solution Cells
- Gel Cells
- Polymer Cross Section Cells
- Powder Cells
- Mapping Cells
- Flow Cells
- Manual Stretch Stage

GI-WAXS Attachment (4 axis)

WAXS-DSC Attachment

Temperature and Humidity Control Attachment

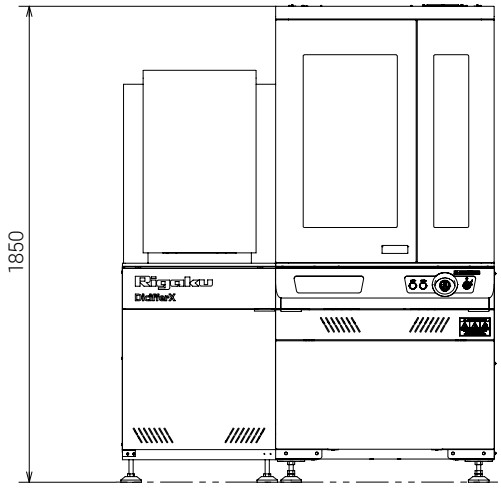
Universal Attachment for Linkam Products

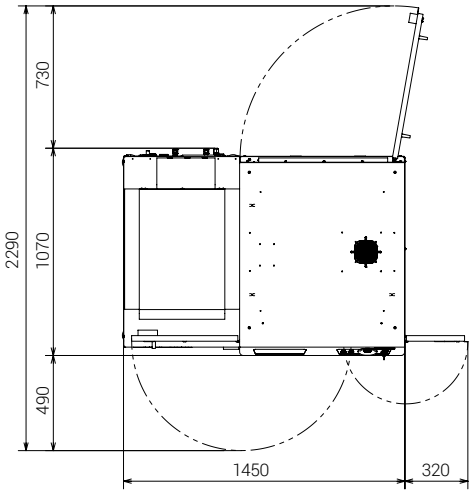
Peltier Attachment

Diamond Anvil Cell (DAC)

Sample Observation Camera

Dimensions (Unit：mm)





	Width	Depth	Height	Weight
Main body	1,450 mm	1,100 mm	1,850 mm	About 750 kg
Rotary pump	170 mm	490 mm	340 mm	25 kg

DicifferX

WAXS Edition

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